ECONOMIC ANALYSIS OF FARMERS' PREFERENCES FOR CASSAVA VARIETY TRAITS: IMPLICATIONS FOR BREEDING AND TECHNOLOGY ADOPTION IN GHANA

by

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DECLARATION

I do hereby declare that this work has not been submitted in substance for any degree elsewhere other than the PhD pursued at the Kwame Nkrumah University of Science and Technology. I also declare that this work is the result of my own investigations and it contains no materials previously published by any other person except for references which have been duly acknowledged.

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ABSTRACT

Cassava, the most widely used food crop in Ghana, has received increased research attention mainly in the aspects of development of improved varieties. Since 1993, the National Agricultural Research System has officially released 18 improved cassava varieties which are high yielding, disease and pest resistant and early maturing. However, adoption of these varieties by mainly smallholder farmers is very low leading to low outputs and low incomes. Adoption could be improved with greater understanding of farmers' cassava variety attributes preferences. The purpose of this study was therefore to contribute to the development and adoption of improved cassava varieties by assessing the preferences of farmers for cassava variety traits. The study explored Ghanaian cassava producers' decision-making behaviour towards variety selection and the values they place on different cassava traits. The study applied the choice experiment technique to estimate the utility farmers derive from five cassava traits including purchase price, productivity, disease resistance, in-soil storage (matured root longevity in the soil) and multiple usage (ability to be used for different food preparations).

The empirical analysis of farmers' preferences for these traits was based on primary data collected from 450 cassava growing farmers in the Atwima Nwabiagya District of the Ashanti Region, Techiman Municipal Area in the Brong Ahafo Region and Fanteakwa District of the Eastern Region. Conditional, mixed logit and latent class models were employed to model preference behaviour for cassava traits from the choice experiment data with a focus on heterogeneity among cassava producers. The conditional logit model was employed to assess cassava traits preferences while the mixed logit model and latent class models were employed to investigate existence of preference heterogeneity and sources of heterogeneity respectively amongst cassava producers. Further analyses of farmers' perceptions of variety traits and adoption of cassava varieties were carried out using logit and multinomial logit models in order to identify the role of trait perception on adoption of improved cassava varieties.

Conditional logit and mixed logit estimates of farmers' preferences for cassava variety traits revealed a higher preference for the in-soil storage and disease resistance traits of cassava. The willingness to pay estimates from the mixed logit also showed high willingness to pay for the in-soil storage trait in all the Districts. Farmers were willing to

pay ₵127.68, ₵69.83 and ₵35.50 for a year or more increase in the in-soil storage trait at Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District respectively. Farmers were willing to pay ₵12.85, ₵37.49 and ₵33.70 for an increase in resistance to cassava mosaic virus disease (CMVD) trait respectively at Atwima Nwabiagya District, Techiman Municipal Area and Fanteakwa District. The findings are particularly interesting because traditional cassava breeding programs often focus on high yielding and disease resistance traits, with little or no emphasis on the non-income production trait like in-soil storage. Socio-demographic factors that influenced farmers' preferences were gender, age, experience, farm size and household size. There were significant differences between males and females, as well as between the aged and the young concerning the choice of cassava traits. The latent class model results revealed that farmer preferences were clustered around the socioeconomic parameters. Males and younger farmers mostly preferred in-soil storage and multiple usage traits. Also those with smaller land sizes preferred productivity and disease resistant traits.

The logit and the multinomial logit estimates of factors that influence adoption of improved cassava varieties revealed that trait perception plays a role in the probability of adoption of improved varieties. The logit estimates results showed that hired labour, farm size, awareness, participation in cassava field day/demonstration and trait perceptions such as high resistance to diseases and pest and high in-soil storage are positive and statistically significant. The multinomial logit estimation results showed joint effect of disease resistance and in-soil storage on adoption of two improved varieties, *Abasafitaa* and *Afisiafi*. These results make a convincing case for increased field schools and demonstrations to reduce information asymmetry and to increase adoption. Higher yield, a major focus of recent research, has no effect on farmers' adoption decisions. Farmers would not see the need to adopt more productive cassava varieties when constraints to marketing are not alleviated. Government and private sector intervention should therefore emphasize improving markets and value chains. The need for the national agricultural research systems to focus on other traits in addition to high yielding and disease resistance in order to boost adoption and increase cassava production is imperative.

DEDICATION

I dedicate this work to Emmanuel, Ama, Edward and Kwabena

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ACRONYMS

AIC	Akaike Information Criterion
AgSSIP	Agricultural Services Sub-Sector Investment Programme
APDADP	Afram Plains District Agricultural Development Project
BIC	Bayesian Information Criterion
CSIR	Council for Scientific and Industrial Research
CIAT	International Center for Tropical Agriculture
CMVD	Cassava Mosaic Virus Disease
CM	Choice Modelling
EMQAP	Export Marketing Quality Awareness Project
FAO	Food and Agriculture Organization
GSS	Ghana Statistcal Service
IVRDP	Inland Valleys Rice Development Project
IITA	International Institute of Tropical Agriculture
IIA	Independence of Irrelevant Alternatives
IID	Identically and Independently Distributed
LCM	Latent Class Model
MoFA	Ministry of Food and Agriculture
NARP	National Agricultural Research Project
RTIMP	Root and Tuber Improvement and Marketing Program
TFP	Total Factor Productivity
WAAPP	West Africa Agricultural Productivity Programme
WTA	Willingness To Accept
WTP	Willingness To Pay

CHAPTER 1

GENERAL INTRODUCTION

1.1. Background

Cassava (*Manihot esculenta crantz*) is one of the most important food crops grown in the tropics (Phillips *et al*., 2004). It is a significant source of calories for more than 600 million people world-wide (FAO, 2007a). It is the fourth most important staple in the world after rice, wheat and maize. An estimated 40% of Africans rely on the crop as a significant source of calories (Nweke, 2004). In Africa, in terms of production, it ranks first followed by maize, plantain and rice and, in Ghana, it is followed by yam, plantain and maize (MoFA, 2013). Ghana is the third largest producer of cassava in Africa (FAO, 2007b) and over 90% of Ghana's farming population cultivate the crop (Gratitude Project, 2013).

The importance of cassava as a food crop in Africa is noticeable in terms of its annual consumption per capita. Its annual consumption is above 80 kg/capita in Africa compared to a global average of 17 kg/capita (Scott *et al.*, 2000; Nweke, 2004). According to Nweke (2004), 95% of the total cassava production, after accounting for waste, is used as food in Africa. In the Democratic Republic of Congo, cassava contributes more than 1,000 calories per person per day to the diet and many families eat cassava for breakfast, lunch and dinner. In Ghana, MoFA (2013) estimated levels of per capita consumption of cassava as rising from 151.4 kg/head/year in 2000 to 154 kg/head/year in 2010. Over the same period, per capita consumption of yam increased from 42.3 kg/head/year to 50 kg/head/year. Per capita consumptions of plantain, maize and rice in 2010 were 85 kg/head/year, 45 kg/head/year and 24 kg/head/year respectively in 2010 (MoFA, 2013).

The national importance of cassava is due, in part, to its good adaptation in marginal soils, but even more, to a long and strongly held tradition among Ghanaians for eating cassava.

Cassava has been identified as a single commodity that could generate desired economic growth, fight poverty and improve food security in Ghana (Nweke, 2004; Al-Hassan and Daio, 2007). The production of cassava has been increasing in Ghana over the years (MoFA, 2009; MoFA, 2010). However, the increases are due to land expansion rather than yield (Hillocks, 2002; Steedman, 2003; Breisinger *et al*., 2010), which is not sustainable. There is the need for increasing yield per unit of land and labour due to population growth and its associated pressure on land. Technical changes in the form of adoption of improved agricultural production technologies have positive impacts on agricultural productivity and growth in the developing world (Nin *et al*, 2003). In Asia for example, the widespread adoption of improved varieties of wheat and rice led to major increases in yields and food security (Evenson and Gollin, 2003). Increase in cassava productivity will increase the food stock of many poor rural households and significantly improve food security in rural areas. The urban consumers will also benefit from increased supply which will enable them to consume more without increasing their total food expenditure.

1.2. Problem statement

Cassava yields in Ghana are unimpressively low due largely to farmers using traditional technologies such as traditional cassava varieties, traditional agronomic practices, and overdependence on rainfall (Nweke, 2004; Manu-Aduening *et al*., 2005; MoFA, 2007; MoFA, 2010). Due to the enormous challenge these pose to cassava production and marketing in Ghana, a number of interventions have been implemented by the Council for

Scientific and Industrial Research (CSIR), Ghana in collaboration with others research institutions. Some of the interventions are the National Agricultural Research Project (NARP) which spanned from 1991 to 1999, the Agricultural Services Sub-Sector Investment Programme (AgSSIP) in 2000 (World Bank 2007a), and the Root and Tuber Improvement and Marketing Program (RTIMP). Recently in 2008, the West Africa Agricultural Productivity Program (WAAPP) was initiated to develop improved technologies for roots and tubers in close collaboration with the Root and Tuber Improvement and Marketing Program (RTIMP) (World Bank 2007b).

These efforts have led to the official release of 18 improved cassava varieties which are early maturing and high yielding, and also able to tolerate biotic and abiotic stresses. All the varieties are tolerant to the cassava mosaic virus and have moderate resistance to the cassava mealybug pests. The new cassava varieties out-yield local varieties on farmers' fields by 40 percent without fertilizer. Table 1.1 shows the cassava varieties that have been released by the National Agricultural Research Systems in Ghana since 1993 and their characteristics.

Table 1.1. Improved cassava varieties released by the National Agricultural Research Systems since 1993 and their characteristics

Variety	*Maturity period (Months)*	*Mean root yield (T/ha)*	*Uses*	*CMD resistance*
Afisiafi	12-15	28	Starch, Flour, gari	Tolerant
Abasafitaa	12-15	29	Starch, Flour, gari	Tolerant
Tekbankye	12-15	28	Poundable	Tolerant
Dokuduade	12	35	Starch, gari	Resistant
Agbelifia	12	40	Starch, gari	Resistant
Essam bankye	12	42	Flour, gari	Resistant
Bankyehemaa	12	40	Flour, gari, poundable	Resistant
Eskamaye	12-15	20	Poundable	Tolerant
Nyerikogba	12-15	25	Poundable	Tolerant
Filindiakong	12-15	17	Poundable	Tolerant
Nkabom	12-15	30	Poundable	Tolerant
IFAD	12-15	33	Poundable	Tolerant
Capevars bankye	12	54	Poundable	Tolerant
Bankye botan	12	64	gari, flour, agbelima	Tolerant
Ampong	12	45	Flour, starch, poundable	Resistant
Broni bankye	12	40	Flour and bakery products	Resistant
Sika bankye	12	40	Starch, flour	Tolerant
Otuhia	12	35	Starch and flour	Resistant

Source: Authors compilation from Crops Research Institute's Various Annual Reports

In spite of these, cassava production in Ghana is still reliant on landraces developed by generations of farmers using traditional breeding techniques (Manu-Aduening *et al.*, 2005; Manu-Aduening *et al*., 2006; Dankyi and Agyekum, 2007; Owusu and Donkor, 2012; Acheampong *et al*., 2012).

Nweke *et al*. (1994) and Manu-Aduening *et al*. (2005) note that the rather low rate of adoption of improved cassava technologies in Ghana have been due to their inability to satisfy farmers and end users unique preferences and requirements. Improved crop varieties, although may be high yielding, may not be attractive to farmers unless they possess other traits that farmers consider important (Asrat *et al*., 2009). Recent studies on farmers' crop variety choices consider crop as a bundle of multiple characteristics (Wale *et al*., 2005, Smale *et al*., 2001; Edmeades *et al*., 2008; Badstue *et al*., 2003). Specifically for cassava, such bundle of traits may include production characteristics such as disease and pest resistance, high yielding, early maturity and adaptability to harsh environments (Nweke, 2004), consumption characteristics such as taste and colour, subjective importance farmers place on seeds (Wale *et al*., 2005) and other non-market benefits farmers get from farm production. High yielding varieties without farmer preferred traits leads to failure of adoption (Mkumbira *et al*., 2003).

Smale *et al*. (2001) argue that farmers choose crop varieties based on a set of attributes that best respond to production constraints assures consumption preferences and satisfies specific market requirements. Other technology adoption studies have confirmed this variety attributes hypothesis (Adesina and Zinnah, 1993; Adesina and Seidi, 1995). Farmers' behaviours are therefore not only driven by profit motive but rather on the results of complex processes that are affected by several socio-economic and psychological variables (Willock *et al.* 1999; Traxler and Byerlee, 1993). Moreover, farmers grow crops that satisfy their concerns (input supply, farm implements, consumption, markets and extension services) and once there is harmony between these concerns and variety attributes, the result is varietal preference and land allocation decision (Wale and Mburu, 2006). Abdulai and Huffman (2005) report that technologies that would improve productivity are not adopted by farmers for the reason that crop variety improvements at research stations have mainly focused on yield and yield stability. Initial identification of farmers' preferences for crop variety traits is not sought and that has been blamed for the low adoption of improved varieties (Batz *et al*., 2003; Asrat *et al*., 2009). As noted by Pingali *et al.* (2001), limited adoption is a failure of the technology development process to produce varieties adapted to heterogeneous production conditions or with traits valued by producers and consumers.

1.3. Research questions

From the forgoing, this study therefore addressed the following research questions:

- How do farmers perceive cassava variety traits?
- What cassava variety traits do farmers prefer?
- What factors influence farmers' preferences for cassava variety traits?
- What values are assigned to the preferred cassava traits?
- How do farmer perceptions of cassava traits influence adoption of cassava varieties?

1.4. Objectives of the study

The primary objective of the study was to assess farmers' preferences for cassava traits and their adoption of improved cassava varieties in the Ashanti, Brong Ahafo and the Eastern Regions of Ghana.

The specific objectives were:

- To assess farmers perceptions of the cassava traits.
- To identify the major cassava variety traits preferred by farmers.
- To determine factors that influence preferences for cassava variety traits.
- To assess farmers' willingness to pay for preferred cassava traits.
- To determine the effect of cassava trait perception on adoption of improved cassava varieties.

1.5. Justification of the study

The national food security is time and again attached to the availability of root and tuber crops, especially cassava. The food security role of cassava is widely attributed to its availability during times of food shortages. Because cassava has the potential to provide multiple opportunities for poverty reduction and nourishment for poor people in Ghana, lots of research efforts have gone into its development and dissemination. Cassava varieties released in Ghana are known to have superior qualities over the traditional ones. The surprisingly low adoption of these varieties has led to some studies that have identified several factors that influence the adoption or non-adoption of improved cassava 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-demography characteristics (e.g., household heads' gender, age, education, household size) and institutional factors (e.g., access to extension services, credit and infrastructure). Cassava producers' preferences for cassava traits are hardly looked into. This study fills this gap by analysing cassava producers' variety 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 (Adesina and Zinnah, 1993).

To enhance the likelihood of adoption of improved crop varieties it is necessary to identify and focus contemporary crop research on traits that significantly contribute to utility while de-emphasizing insignificant plant attributes (Wale and Mburu, 2006). This study provides important information for cassava researchers as to farmer preferences for different cassava variety attributes. It is 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 Ghana. The study also considers adoption of the improved cassava varieties. In consequence, the study evaluates the effects of cassava traits perception on the adoption of improved cassava varieties and looks at the overall acceptance of the already introduced varieties. The results provide needed facts for setting cassava breeding programmes and informed policy on cassava variety attributes preferred by farm households.

The study is also important in the following ways. It provides 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 Ghana (Dankyi and Agyekum, 2007; Owusu and Donkor, 2012) 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 explores Ghanaian farmers' preferences for cassava variety traits and the values (willingness to pay) that farmers place on different traits. Most studies on 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 Ghana is not known. Therefore the study contributes to literature on farmers' crop varieties preferences in

Ghana and also expands the literature on crop variety traits in Africa by employing choice experiment to elicit farmers' preferences.

1.6. Organization of the thesis

The thesis is organised into six main chapters. Chapter 2 presents a review of literature on preferences and adoption of varieties. The chapter presents the various approaches to the study of preferences for variety traits and adoption of varieties. The empirical literature on farmer preferences for variety traits and adoption of varieties are explored in this chapter. The conceptual and theoretical frameworks of choice experiments and adoption of agricultural technologies as well as the empirical models are dealt with in Chapter 3. Chapter 4 presents the study methodology. In this chapter, the study area and the research methodology are presented. All the data issues relating to types, sources, sampling technique, data collection methods and data analysis are discussed. The methods employed in the choice experiment, including the experimental design, are presented in this chapter. Cassava traits used in the choice experiment survey are also described in Chapter 4.

Chapter 5 presents the results of the study as well as interpretations and discussions of these results. The survey data are described and the characteristics of respondents, farm characteristics and livelihood activities of farm households are presented. The results of the econometric modelling estimations of cassava trait preferences from the choice experiments are presented. Results from the conditional logit model and the mixed logit model are discussed. The chapter also deals with the results of empirical analysis of cassava trait perceptions and adoption of improved cassava varieties.

Finally, in Chapter 6, the findings of the study are summarised to answer the research questions formulated above. The policy implications of the research findings for the development and adoption of agricultural technologies in Ghana concludes the chapter.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter presents a review of relevant literature on farmer preferences for crop variety traits and adoption of crop varieties. It reviews literature on cassava and cassava variety development to ascertain cassava breeding objectives. Literature on farmer variety traits preferences and adoption of varieties are also reviewed to determine methods for estimating farmer preferences for variety traits and for assessing farmer adoption of crop varieties. In addition, the chapter reviews and compares the various approaches for studying preferences and adoption found in the literature, discussing the advantages and disadvantages of each.

2.2. Cassava production and utilization

Cassava (*Manihot esculenta, Crantz*) is an important root crop in sub-Saharan Africa. It has numerous traits that confer comparative advantages in marginal environments, where farmers often lack the resources to improve the income-generating capacity of their land through purchased inputs. Cassava tolerates acid soils, periodic and extended drought, and defoliation by pests. It is highly compatible with many types of intercrops, and has flexible time of harvest. These attributes make cassava a significant sustaining force benefiting the poor in the tropics (Hahn *et al*., 1980; Kawano, 2003).

The world's total cassava utilization has been projected to 275 million tons by 2020 (IFPRI, in Westby, 2008). Africa produces 62% of the total global cassava. Nigeria leads with nineteen percent of global market share (FAO, 2009). Since its introduction in Africa, cassava has become one of the most important crops in Africa. It is an important source of dietary energy for over 600 million people in developing countries within the tropics and sub-tropics (Scott *et al*., 2000). In Africa, it is mainly produced by small scale farmers. Storage roots are its most valuable parts. Starch forms about 80% of the storage roots' dry matter content. It is currently grown as a subsistence crop, cash crop, for animal feed or as an industrial raw material for starch extraction or alcohol production.

Cassava has very high yield potential of about 80t/ha (Legg and Thresh, 2003) under optimal conditions. However, average yield of cassava in Africa is estimated at about 12t/ha (Nweke, 2004) and that of Ghana is 16.8t/ha. Its high yield potential makes it a suitable alternative to grain staples in areas where population pressure and crop failure are a challenge (Nweke, 2004). The exceptional ability of cassava roots to be stored in the ground and harvested when needed, makes it a food security and famine reserve crop (DeVries and Toenniessen 2001; Sayre, 2011; Nweke, 2004).

Cassava roots can be processed into a wide range of products for human and industrial consumption, ranging from simple boiling, to fermented products and beverages (Nweke *et al*., 1999). Most of the products are consumed domestically within the countries in which they are produced. In industry, cassava flour is used in the food manufacturing sector for improved traditional foods such as instant *fufu*, and in paper board and plywood industries. Cassava starch is used for textiles, biodegradable plastics and pharmaceuticals, and cassava-derived glucose syrup which are also used in the pharmaceutical industry (Henry and Hershey, 2002; Westby, 2002; Dziedzoave *et al*., 2000). Leaves, pellets, chips and dried roots are increasingly being used by the livestock industry (Lancaster and Brook, 1983; Henry and Hershey, 2002; Westby, 2002). Cassava starch is used in the foodstuff, textile and paper industries, and in the manufacture of plywood, veneer adhesives, glucose and dextrin syrups. Through fermentation, it can also be used for alcohol production, and as a waste material it can be processed to biogas (Kenyon *et al*., 2006).

Global trade in cassava was projected to increase annually by 32 % up to 12.5 million tons in 2009, reflecting a moderate growth in import demand for cassava feed (used for chicken, pigs, cattle and fish) and other novel cassava food products (cassava instant meals, cassava snacks, and cassava ingredients for sweeteners and prepared foods) and non-food products (starches and flours for sizing textiles and papers) (FAO, 2009). The market potential of most of these products remains largely underexploited in the tropics. Cassava provides employment, food and cash income to farmers, processors and distributors along the value chain.

2.3. Constraints to cassava production

Cassava production has three broad constraints - socioeconomic, biotic and abiotic factors (Ceballos *et al*., 2004; DeVries and Toenniessen, 2001). Prominent amongst the socioeconomic factors are poor communication network, lack of functional technology transfer systems and lack of ready markets for cassava storage roots and products (DeVries and Toenniessen, 2001). Abiotic stresses include extreme drought, low soil fertility, and alkaline or acidic soils (Ceballos *et al.*, 2004). There are significant yield reductions if drought is frequent and if the crop is grown on soils with a low water-holding capacity (poor soils).

Pests and diseases are the major cassava biotic stresses (Ceballos *et al.*, 2004; DeVries and Toenniessen, 2001). Cassava is susceptible to attacks by various diseases. The most important cassava diseases are the cassava mosaic virus disease caused by a *Begomovirus* species, cassava brown streak virus disease (CBSD) caused by *Ipomovirus* species, and bacterial blight caused by *Xanthomonas campestris pv* (Hahn *et al.*, 1980; Hillocks and Thresh, 2000). Tubers are reduced in size and number as a result of cassava mosaic disease. Stem diameter and overall size are also reduced. Yield reduction may be severe; losses of up to 95% have been reported (Thresh *et al.*, 1994). It is estimated that losses in Africa due to cassava mosaic virus disease is 15-24% of root production (Thresh *et al.*, 1998). The constraints above are mostly combated by the development and use of improved varieties and agronomic practices (IITA, 1990).

2.4. Cassava variety development

Plant breeders fashion out their breeding objectives based on the socio-economic and production constraints faced by farmers as well as consumer preferences. Breeding objectives are classified into four. These include breeding for high yield potential[1], resistance to biotic stresses, resistance to abiotic stresses and for preferred end-use traits. Emphasis has always been placed on increasing the yield potential. Yield reductions in crops are brought about as a result of plants' susceptibility to diseases, pests, soil and environmental stresses.

To achieve their objective, breeders have had to follow some procedures which result in

[1] The yield of a cultivar when grown in environments to which it is adapted, with nutrients and water non-limiting, and with pests, diseases, weeds, lodging and other stresses effectively controlled.

changes in the genetic makeup of a plant population[2] (Witcombe *et al.*, 1996). This population would hopefully compose of phenotypes[3] that meet the breeders' criteria and farmers' needs.

Cassava breeding and selection starts from crosses or open pollinated seeds, to the nursery, to clonal evaluation trials, to preliminary yield trials, then to advanced yield trials, uniform yield trials, to multi-locational testing and on farm testing towards release (Jennings and Iglesias 2002; Kawano 2003). In Ghana, cassava breeding spearheaded by the Crops Research Institute (Ghana) has focused mainly on increasing yields and resistance to diseases (Gibson, 2003). Cassava breeding at the Crops Research Institute of Ghana involves: Screening and selection of superior genotypes amongst seedlings derived from seed obtained from IITA (International Institute of Tropical Agriculture) or CIAT (International center for Tropical Agriculture), clonal evaluation and selection on station leading to preliminary yield trials, advanced yield trials, uniform yield trials, final multilocational yield trials, and testing of yield stability of few clones across different ecological zone. Farmers and/or other stakeholders are involved after completion of the stages, which last 8-10 years with on farm trials to validate and promote new clones[4] (in participatory breeding farmers are involved early).

Bellon (2006) states that, in subsistence and semi-subsistence agricultural systems, farmers are interested in multiple traits and yield is only one of them. Farmers may measure yields in different ways (yield by volume versus yield by weight) or be interested

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[2] Population refers to a group of individuals of a given variety that are maintained as a group under particular conditions.

[3]. Phenotypes include traits of production (yield, yield stability, postharvest traits, etc.), storage, food quality (processing, cooking, taste), and aesthetics (colour, shape and texture of seed and other plant parts) (Cleveland *et al*., 1999).

[4] Clones are assemblage of organisms derived by vegetative multiplication from a single individual

in the yields of multiple products (root and leaves) or relate it with processing. The demand for multiple traits is evident from adoption and participatory plant breeding literature (Adesina and Baidu-Forson, 1995; Edmeades *et al*., 2004). The absence of a preferable trait can make a variety undesirable, even though it may be considered highly desirable by formal plant breeders (Thiele *et al.*, 1997). The difficulty in accounting for the traits valued by farmers is that they are not revealed in prices making them undetectable from market perspective. Bellon (2006) points out that the inability of markets to value traits preferred by farmers' means that these farmers have the tradition and resources to produce the varieties with such traits themselves.

As a result of the limitations mentioned above, participatory plant breeding has evolved. Two levels of farmer participation are involved: participatory varietal selection where there is collaboration and consultation between the breeder, farmers and consumers during variety selection and participatory plant breeding where breeders, extension staff, farmers and consumers collaborate in all stages of variety development right from breeding objectives development to variety evaluation and seed multiplication (Joshi and Witcombe, 1996; Atlin *et al*., 2001; Sperling *et al*., 2001). Crop varieties developed this way have been shown to easily diffuse to farmers, thus increasing adoption rate (Joshi *et al*., 2001; Joshi and Witcombe, 2002). In Ghana, participatory plant breeding as applied to cassava has been introduced only recently (Manu-Aduening *et al*., 2006).

2.5. Farmer preferences for variety traits

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 rainfed 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, Asrat *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 drought 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, Sibiya *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 non-tradable 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 programmes 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 cassava variety traits in selected cassava production areas in Ghana.

2.6. Factors influencing farmer preferences for variety traits

There are differences in the preferences for attributes depending upon economic status of the farmer, geographic locations and his/her 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 inter crop 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 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 labour. 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 motive, 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 analysing 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.

2.7. Farmer willingness to pay for variety traits

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) analysed 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 vigour trait.

2.8. Farmer trait perception and adoption of improved crop varieties

Factors influencing farmers' choice of technology include technology characteristics, household characteristics and farm characteristics. Whereas for a long time adoption studies have concentrated on the effects of farms and farmers' characteristics on adoption decisions, there is scanty evidence on the effect of technology characteristics. As pointed out by Soleri *et al.* (2000), acceptability of agricultural technologies of improved varieties by farmers depends on how well farmers' constraints and trait preferences have been identified and incorporated. The role of technology characteristics on adoption of technologies has been studied by some authors (Adesina and Zinnah, 1993; Adesina and

Baidu-Forson, 1995). Studying technology characteristics, farmers' perceptions and adoption decisions in Sierra Leone using a Tobit model, Adesina and Zinnah (1993) found that perceptions of the technology-specific attributes of the varieties are the major factors determining adoption and use intensities. The perceptions of the appropriateness or inappropriateness of the characteristics of the technology affect the adoption and use of the technology. Applying a similar method to sorghum and rice varietal technologies in Burkina Faso and Guinea, Adesina and Baidu-Forson (1995) established that farmers' perception of technology characteristics significantly affects their adoption decisions. The need for future adoption studies to expand the range of variables used away from the broad socio-economic, demographic and institutional factors to include farmers' subjective perceptions of the characteristics of new agricultural technologies was advocated.

In modelling the effects of farm, farmer and technology specific factors on the decision of semi-arid farmers to adopt cassava into their farming systems in West Africa (Ghana, Chad, Nigeria, Burkina Faso, Niger) by using Probit and Logit models, Udoh and Kormawa (2009) found farmers perceptions of improved cassava varieties characteristics such as pest and disease resistance to be significant and positive in decision to adopt cassava varieties. Using structured interviews and applying descriptive analysis, Tumuhimbise *et al*. (2012) examined farmers' perceptions on early storage root bulking in cassava in East and Central Uganda. Results showed that famers' perceptions of cassava varietal characteristics such as high storage root yield, resistance to pests and diseases, and sweetness were important in growing new cassava varieties. In analysing ex-ante adoption of new cooking banana (Matooke) hybrids in Uganda based on farmers' perceptions and applying a Zero 4Inflated Poisson (ZIP) regression model to estimate the effect of farmers' perceptions about the hybrid banana attributes, Kenneth *et al*. (2012) found farmer perceptions of varietal attributes, disease and pests, yield and agronomic attributes, as positively associated with the likely of adoption of most of the hybrid bananas.

2.9. Farm and farmer characteristics and adoption of improved crop varieties

Considerable evidences have been gathered concerning farmers' adoption behaviour including technology specific characteristics, farm and farmer-associated characteristics and farming objectives (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) analysed 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 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 cassava 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 cassava 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 cassava 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 cassava 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 cassava 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 cassava varieties adoption is of no exception. Farm size is found to influence adoption of improved cassava 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 cassava 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 cassava adoption, Tarawali *et al*. (2012) and Udensi *et al*. (2011) found negative relationship of land ownership with improved cassava adoption in Nigeria. Onyemauwa

(2012) however found positive relationship of land ownership with improved cassava 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 cassava varieties in Ghana. Orebiyi *et al*. (2005) and Okpukpara (2010) analysed determinants of contract farmers' adoption of improved cassava technologies in Nigeria. They found that credit access played significant role in the adoption of the improved cassava 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 and 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) report of positive impact of access to extension on adoption of improved cassava varieties in Uganda. In Nigeria, many studies (Omonona *et. al*., 2006; Madu *et. al*., 2008; Onyemauwa, 2012; Omoregbee *et. al*, 2013) on determinants of improved cassava adoption have found extension access as very influential in farmers' decision to adopt improved cassava 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).

2.10. Assessment of crop traits: 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. 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:

$$H = v_1 G_1 + v_2 G_2 + ... + v_j G_j \qquad (2.1)$$

Where H = relative economic value, v_1 = economic value for trait 1, G_1 = genetic value for trait 1.

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 realised 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 multilocational 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 for traits of economic importance. However, formal breeding systems have emphasised 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 technology such as high yielding and disease-resistant varieties.

2.11. Approaches to modelling farmers preferences for crop variety traits: the social scientist perspective

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 (Merino-Castello, 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 behaviour. 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 behaviour 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 behaviour, 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 behaviour (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 behaviour 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 found 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 revealed 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‘s choice, while choice modelling tends to examine a respondent‘s preference by providing an excellent description of the attributes trade-offs 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 modelled 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 researchers 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.

2.12. Approaches to modelling adoption of crop technologies

Several analytical approaches have been developed to analyse adoption 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 productivity (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 productivity 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, productivity 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 behavioural assumptions. The underlying technology is entirely unspecified and allowed to vary across firms.

Parametric approaches commonly used to analyse adoption are the logit, probit, tobit, the linear probability model and multinomial logit models. In the case of dichotomous dependent variable such as improved 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 Rubinfield, 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 t, 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, the Logit Model is adopted since the dependent variable is binary, measured as improved variety adoption or non-adoption while the independent variables are the combination of both continuous and discrete variables.

2.13. Chapter summary

The literature reviewed has shown that cassava is undoubtedly one of the most important food staples in Sub-Sahara Africa, yet its production is challenged by socioeconomic and technical constraints. Attempts to tackle the constraints have focussed on the development of high yielding cultivars resistant to biotic and abiotic stresses. The breeding approach has been towards producing high yielding varieties that are resistant to diseases on-station where end-users have little or no involvement in the identification of preferred priority traits. The economic literature reviewed revealed differences in preferences of farmers. Farmers' preferences for crop traits are mainly driven by socioeconomic factors such as market and credit access and personal characteristics. Yield is mainly preferred by farmers that have access to markets who actually form a small segment of the farming population in Sub-Sahara Africa including Ghana. The review has also shown that technology adoption is not only conditioned by farm and farmer characteristics and institutional factors but also by technology specific characteristics. The need to expand the range of variables used away from the broad socio-economic, demographic and institutional factors to include farmers' subjective perceptions of the characteristics of new agricultural technologies is important.

Economics of plant breeding assumes that genetic improvement should be for traits of economic importance. Plant breeders appear to have emphasised too much on market traits and have overlooked traits of non-market value and the socioeconomic diversity of end-users. Stated and revealed preference approaches used in most economics studies on trait valuations provide a useful framework for valuing traits without market value since they are based on the utility theory. The approaches are also able to capture socioeconomic diversity of end users.

For technology adoption the literature has revealed that depending on whether the dependent variable is dichotomous or censored the Logit, the Probit or the Tobit Models can be applied. In this study, the Logit Model is adopted since the dependent variable is binary, measured as improved cassava variety adoption or non-adoption.

CHAPTER 3

THEORETICAL AND CONCEPTUAL FRAMEWORKS OF THE STUDY

3.1. Introduction

This study employs stated preference choice experiment to estimate farmer preferences for cassava variety traits. This chapter presents the theoretical and conceptual compositions of choice experiment and adoption of improved agricultural technologies. The chapter provides a basic background to the development of choice experiment. The economic and econometric models that have been used to model choice experiment data are presented. The subsequent sections present the theoretical and conceptual frameworks of adoption of improved agricultural technologies.

3.2. Theoretical framework of choice experiment

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 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 (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.

3.2.1. 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 *per se* (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. Lancaster's model is defined as follows: A consumer maximizes an ordinal preference function for traits, $U(z)$ where z is a vector of traits 1,........, r, possessed by a single good or combination of goods subject to the budget constraint $\rho\chi \leq \mathrm{K}$ where p is a vector of prices for each of these goods and K is income. Goods, x, are transformed into traits, z, through the relation $\mathrm{Z} = \mathrm{B}\chi$, where B is an r x n matrix which transforms the n goods into r traits of the alternatives and is invariant for all consumers. The model is therefore written as:

$$\begin{aligned} &\mathrm{Max}\, imise \quad U(z) \\ &Subject \quad to \quad px \leq k \\ &\quad with \quad z = \mathrm{B}x \\ &\qquad\quad z, x \geq 0 \end{aligned} \tag{3.1}$$

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 equation $z = \mathrm{B}x$ 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 z and not how the preference function, $U(z)$ 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 behavioural theory (Louviere *et al*., 2000; Ben-Akiva *et al*., 2002)

3.2.2. 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 $C_n \subseteq C$. 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. Using Lancaster's framework, the utility function is defined in terms of attributes:

$$U_{in} = U\left(z_{in}\right) \tag{3.2}$$

where z_{in} is a vector of attribute values for alternative *i* as viewed by decision maker *n*. Income and other constraints determines the choice set C_n. In empirical applications, a vector of socio-economic characteristics of the decision maker S_n is included to capture observed heterogeneity across the population to which the model of choice behaviour applies, thus:

$$U_{in} = U\left(z_{in}, S_n\right) \tag{3.3}$$

The function $U(.)$, which maps the attributes values and socioeconomic characteristics to a utility scale is an ordinal utility function. The utility function $U(.)$ can usually take several forms but is often assumed additive to simplify it (Ouma, 2007).

3.2.3. Random utility and probabilistic choice 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 (3.3). 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 behaviour 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). According to Ouma (2007), the behavioural model for the analyst is that a decision maker n chooses alternative i from a finite set of alternatives in choice set C_n, with probability $\mathrm{P}(i)$ if the utility associated with U_i is greater than the probabilities associated with all other alternatives in the choice set. This can be written as follows:

$$\mathrm{P}(i / C_n) = \mathrm{P}(U_{ni} > U_{nj}) \forall_j \in C_n = 1, ..., J; i \neq j \quad (3.4)$$

The utility function U can also be decomposed into deterministic (V_n) and stochastic (ε_n) components:

$$\mathrm{P}(i / C_n) = \mathrm{P}\left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}\right) \forall \in C_n = 1, \ldots, J; i \neq j \tag{3.5}$$

The deterministic component consists of the attributes of the alternatives and the socioeconomic characteristics of the decision maker as presented in equation (3.3). For the analyst, ε is a random variable with some joint density function, denoted as $f_{\varepsilon}(\varepsilon_1 \ldots \varepsilon_m)$ which induces a density on utility function, U. The distributional assumptions on ε 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 behaviour deterministic choice sets, easily measurable characteristics of decision makers and simple error structures (ε) 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 behavioural 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. 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 behavioural 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 is identical in quantity and relationship between pairs of alternatives due to the identical and independent distribution assumption. The conditional logit 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),

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 behaviour. The nested logit model, initially derived by Ben-Akiva (1973), is an extension of the conditional logit 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, ε. 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. Early applications of mixed logit have been in the fields of transportation research and consumer behaviour (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.

3.3. The conceptual framework of a choice model for cassava traits

The conceptual framework for discrete choice models is derived following Lancaster's approach and the random utility framework. The primary focus of this framework is to identify the underlying factors that influence an individual or group choice actions for cassava traits. A choice decision can be viewed as a decision-making process linked to factors both external and internal to the decision maker. This is as presented in Figure 3.1.

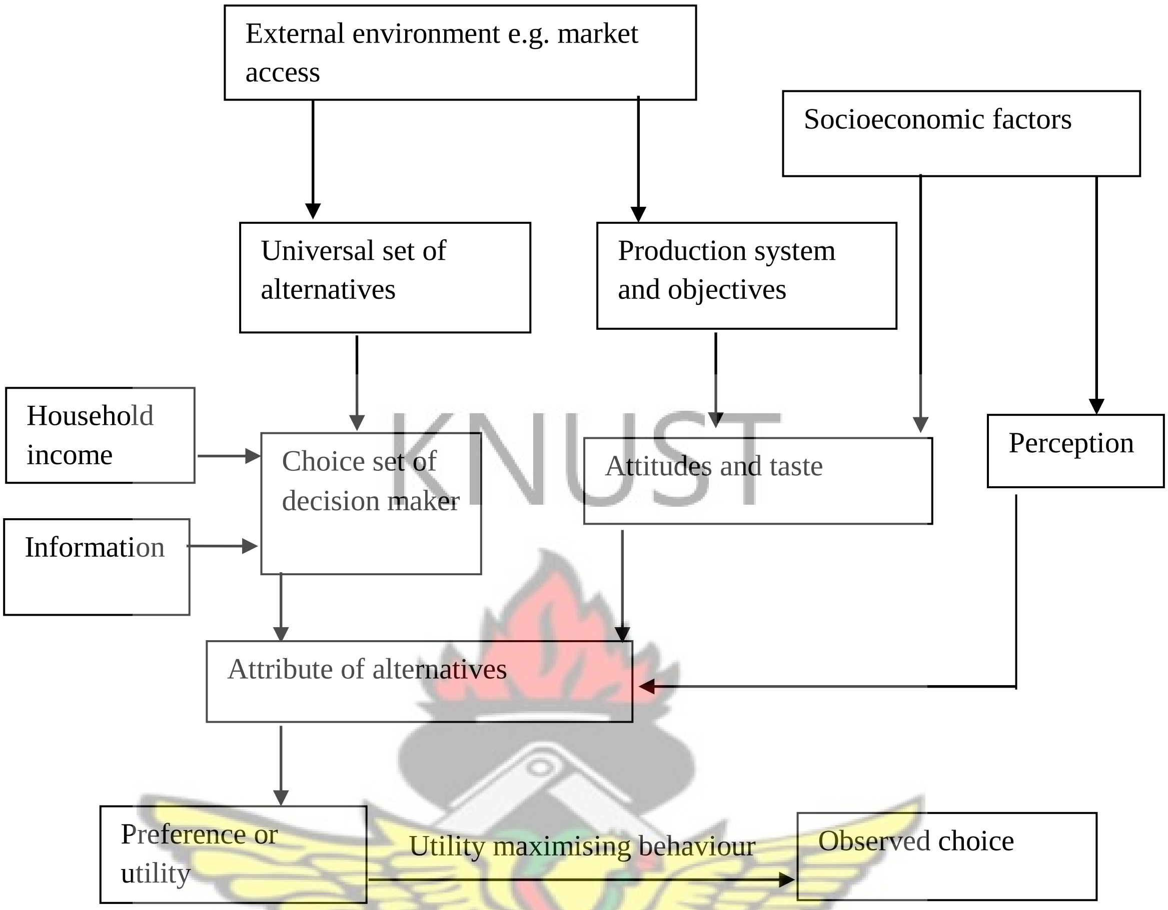


Figure 3.1. Choice modelling frameworks for cassava variety attributes

Source: Adapted from Ouma (2007)

Given that cassava is a discrete choice good with varying traits with potentials to meet several objectives, the decision maker's problem is the choice of cassava 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 cassava varieties with varying trait levels. The universal set of alternative cassava 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 marker n is faced by personal constraints such as household income and information access that determine the feasible choice set, which is a sub-set of the universal set of alternatives, represented as $C_n \in C$.

Following Lancaster (1966), the utility derived from alternative cassava profiles within the choice set of the decision maker is perceived to be determined by the attributes of the alternatives. The decision maker is assumed to form a utility function for the alternatives and assign a utility value for each alternative by valuing and trading off the attributes that are important in his/her choice decision. A utility maximizing behaviour is assumed to be exhibited, resulting in preference and choice of an alternative with the highest positive utility value. Though the sources of utility are strictly linked to the attributes of the alternatives, the contextual characteristics and socio-economic characteristics of the decision-maker are 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 a cassava 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 cassava attributes in Figure 4.1 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 cassava 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 cassava profile from the competing *J* alternatives subject to the budget constraint.

Following the random utility theory, an individual *n* receives utility *U* from choosing an alternative equal to $U_{njt} = U\left(X_{n\mathrm{jt}}\right)$ from a finite set j alternatives in a choice set *t*, if and only if, this alternative generates at least as much utility as any other alternative, with $X_{n\mathrm{jt}}$ 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.

$$u_{njt} = v_{njt} + \varepsilon_{njt} \tag{3.6}$$

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).

$$U_{njt} = V\left(Z_{njt}, S_n\right) + \varepsilon_{njt} \tag{3.7}$$

Due to the inherent stochastic or random error component of (U_{njt}), a researcher 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 *nth* individual chooses the *jth* alternative can be expressed as:

$$p_{njt} = p\left(u_{njt} > u_{njh}, \forall_j \neq h\right) \tag{3.8}$$

From (3.8) we can derive (3.9)

$$p_{njt} = p_{rob}\left(v_{njt} + \varepsilon_{njt} > v_{njh} + \varepsilon_{njh}\right) \qquad \forall_j \neq h \tag{3.9}$$

And:

$$p_{njt} = p\left(\varepsilon_{njt} - \varepsilon_{njh} > v_{njt} - v_{njh}, \forall_j \neq h\right) \tag{3.10}$$

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

3.4. The econometric choice model

This section presents a description of the conditional logit and mixed logit discrete choice models that have been applied to empirically model the choices made by the decision makers from the choice experiment study and to estimate economic values of the cassava traits. The conditional logit model enables the measurement of the effect of each choice-specific explanatory variable on the individual choices. The conditional logit however assumes homogeneous preferences. The mixed logit model therefore is presented in addition to account for preference heterogeneity in this study which is realistic as individuals cannot have the same preferences.

3.4.1. The Conditional logit model

Discrete choice models 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 (Train, 2003). In this choice model, decision makers are farmers and the alternatives represent cassava varieties. With the assumption that the deterministic component of the utility function is linear in the explanatory variables, the utility functions in (3.6) an (3.7) can be expressed as

$$\cup_{njt} = \beta_n \chi_{njt} + \varepsilon_{njt} \tag{3.11}$$

where χ_{njt} is a vector of observed variables that includes the cassava traits and socioeconomic characteristics of the farmer. Extending the argument to multiple choices alternatives, suppose there is a choice between M different alternatives indexed by $j = 0 \ldots M$, with the ordering being arbitrary. Assume that the utility that individual n attaches to each alternative is given by $Unjt$, $j = 1, 2 \ldots M$. The farmer will prefer alternative j if it can be expected to give him the highest utility. That is,

$$\cup_{njt} = \max\{\cup_{n0}, \ldots, \cup_{nM}\} \tag{3.12}$$

The probability that farmer n prefers cassava variety j from among M alternatives is given by

$$\mathrm{P}\left(c_n = j\right) = \mathrm{P}\left(\cup_{njt} = \max\left(\cup_{n0}, \ldots, \cup_{nM}\right)\right) \tag{3.13}$$

where C_i denotes the preference of individual n.

Assuming that the error terms in the utility function are independently and identically distributed (IID), the logistic model results (McFadden, 1974). This model is more appropriate and makes it possible to study the determination of the factors influencing farmers' preference when the explanatory variables consist of individual specific characteristics and these characteristics are the determinants of the choice (Bakele, 2004). In its multivariate generalization it gives rise to the multinomial logit or the conditional logit model (McFadden, 1974). In a conditional logit framework, the probability that a farmer prefers alternative j is given by:

$$p_r\left(c_n = j\right) = \frac{e^{\beta_j \chi_n}}{e^{\beta_o \chi_n} + e^{\beta_1 \chi_n} + \ldots + e^{\beta_M \chi_n}} \qquad (3.14)$$

Ouma et *al*. (2004) noted that the multinomial or the conditional logit presents χ_n which is the independent variable which does not vary across choice alternatives but varies only across individuals. The conditional indirect utility function generally is given by:

$$v_{njt} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + \ldots + \beta_n Z_n + \beta_a S_1 + \beta_b S_2 + \ldots + \beta_m S_k \qquad (3.15)$$

where β is the alternative specific constant (ASC), that captures the effects in utility from any attributes not included in choice specific attributes. However, in this study, the constant term dropped from the model estimations because the choice sets do not include a status quo or an opt-out option (Bateman *et al.*, 2003). The ASCs are largely included to retain the differences in utilities for each alternative relative to the base (status quo) when all attributes are equal (Asrat *et al.*, 2009). The number of crop variety attributes considered is n and the number of social and economic characteristics of the farm household employed to explain the choice of the crop variety is k. The vectors of coefficients $\beta_1 to \beta_n and \beta_a to \beta_m$ are attached to the vector of attributes (Z) and to vector of interaction terms (S) that influence utility, respectively. Since, at a point in time, social and economic characteristics are constant across choice occasions for any given farm household, they can only enter as interaction terms with the crop variety attributes.

This basic model was used to estimate attribute values for smallholders across different districts, and to test whether the demand for each attribute is significant. The higher this value, the more preferred the attribute level and the stronger its relative influence on respondents' choices. Attribute levels with negative estimates of β have a negative effect on utility levels, and are considered unattractive. The maximum likelihood method was used to estimate the parameter β.

3.4.2. The Mixed logit model

The conditional logit model assumes preference to be homogenous across respondents. Preferences, however, are in fact heterogeneous and accounting for this heterogeneity enables estimation of unbiased estimates of individual preferences and enhances the accuracy and reliability of estimates of demand, participation, marginal and total welfare (Greene, 2003). Furthermore, accounting for heterogeneity enables prescription of policies that take equity concerns into account. An understanding of who will be affected by a policy change in addition to understanding the aggregate economic value associated with such changes is necessary (Boxall and Adamowicz, 2002). The random parameter logit (RPL) or mixed logit model (Train, 1998; Adamowicz and Boxall, 2001), which accounts for unobserved, unconditional heterogeneity, 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.

From equation (3.11), χ_{njt} is a vector of observed variables that includes the cassava variety traits and socioeconomic characteristics of the farmers. Coefficient vector β is unobserved for each i and varies in the population density $f\left(\beta_n / \theta\right)$, where θ is vector of parameters of a continuous population distribution, ε_{njt} is an unobserved random term that is assumed to be identically and independently distributed. The focus in random parameter shifts from finding estimates of β_n to finding estimates of θ, the population parameters which determines the behaviour of β_n. Conditional on β_n, the probability that a person n chooses an alternative J in a choice set t is the conditional logit specification as in equation (3.16).

$$L_{njt}\left(\beta_n\right) = \frac{e^{\beta_n \chi_{njt}}}{e^{\beta_o \chi_{njt}} + e^{\beta_n \chi_{njt}} + \ldots + e^{\beta_M \chi_{njt}}} \tag{3.16}$$

Given that β_n is unknown to the analyst, the unconditional probability is usually employed. The unconditional probability is the integral of the conditional probability over all possible values of *β* which depends on the distribution of *β*. This integral takes the form:

$$P_{njt}(\theta) = \int L_{njt}\left(\beta_n\right) f\left(\beta_n / \theta\right) \partial \beta_n \tag{3.17}$$

The coefficient vector β_n is the parameters associated with person n, representing that person's preference. These preferences vary over people; the density of this distribution has parameters θ. The aim of the estimation procedure is to estimate θ, that is, the population parameters that describe the distribution of individual parameters.

The log-likelihood function is

$$LL(\theta) = \Sigma_n InP_n(\theta) \qquad (3.18)$$

This log-likelihood function is maximized via simulation, specifically $P_n(\theta)$, and is approximated by a summation over values of β_n generated by Halton draws (Train, 1998).

The distribution of β_n can be either continuous or discrete. A model with continuously distributed coefficients is usually called a mixed logit model (Hole, 2008). The mixed logit has been applied in several circumstances in economics including environmental, transport and agricultural economics (Asrat *et al*., 2009; Greene *et al*., 2006; Ouma *et al*., 2007).

Even though the unobserved heterogeneity can be accounted for with the use of mixed logit model, the model fails to explain the sources of heterogeneity (Boxall and Adamowicz, 2002). To detect the sources of heterogeneity while accounting for unobserved heterogeneity would be by inclusion of respondent characteristics in the utility function as interaction terms. This would permit mixed logit model to pick up preference variation in terms of both unconditional taste heterogeneity (random heterogeneity) and individual characteristics (conditional heterogeneity), and hence improve model fit (Asrat *et al*., 2010).

3.4.3. The latent class model

Whilst the Mixed Logit model unequivocally accounts for preference heterogeneity by allowing estimated parameters to vary randomly over individuals, it is not able to detect the sources of heterogeneity. Latent class model (LCM) is more able to identify consumer heterogeneity by separating individuals into several classes. Consumers within each class have similar preferences. Following Boxall and Adamowicz (2002), the LCM assumes that a discrete number of classes or segments of respondents are sufficient to account for preference heterogeneity among classes. The LCM allows the choice attribute data and individual consumer‘s personal characteristics to simultaneously explain choice behaviour (Boxall and Adamowicz, 2002). This study also presents LCM estimations results. The latent classes identify the unobserved heterogeneity in the population, and each class is estimated with a different parameter vector. If we assume the existence of *C* segments in the population, the choice probability of individual *n* choosing alternative *j* in class *c* of the Latent Class Model is expressed as:

$$\mathrm{P(njt/\,c)} = \frac{\exp\left(\beta_c \mathrm{X}_{njt}\right)}{\sum_{c=1}^{C} \exp\left(\beta_c \mathrm{X}_{njt}\right)} \tag{3.19}$$

Equation 3.19 is a standard probability specification of the Conditional Logit model for class *s*. The LCM simultaneously estimates the above probability equation and predicts the latent class probability *Hntj* of individual *n* being in class *c*. So the unconditional probability equation of the LCM is expressed as (Boxall and Adamowicz, 2002):

$$\mathrm{P}_{njt} = \sum_{c}^{C} \mathrm{P}_{njt/\mathrm{c}} H_{njt} \tag{3.20}$$

Another issue in the LCM concerns how to choose the number of classes, *S*. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are 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 is found where the values of AIC and BIC are minimized (Louviere *et al*., 2000).

3.4.4. 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 in equation (3.11) can be re-written as:

$$U_{njt} = \alpha_j + X_j\beta_n + \mathrm{P}_j\beta_p + \varepsilon_{njt} \tag{3.21}$$

where most terms are as earlier defined in equation (3.11), 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 X_j represents the coefficient vectors for the other traits, for individual *n*. β_p and X_j are assumed to be random. The implicit prices for the traits X_j 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:

$$-\frac{\partial U / \partial X_j}{\partial U / \partial P_j} = -\frac{\beta_j}{\beta_p} \tag{3.22}$$

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

3.4.5. Estimation technique of preferences

From an econometric viewpoint, data were such that, for each individual, there were as many observations as choice questions she or he was asked to answer (i.e., there were T = 6 observations per individual). The conditional logit model was used to estimate choice-specific data through maximum likelihood. Suppose that our sample was made of I individuals, each making T choices. Each choice set is made of J = 3 alternatives. Let us define δ_{njt} as being a dummy variable such that:

$$\delta_{njt} = \begin{cases} 1 & \textit{if the individual n had chosen alternative j from the choice set t} \\ 0 & \textit{otherwise} \end{cases}$$

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

$$L(\beta_x, \beta_p) = \prod_{n=1}^{I} \prod_{t=1}^{T} \prod_{j=1}^{J} \left(P(y_n = j/t) \right)^{\delta_{njt}} \tag{3.23}$$

Then, taking the logarithm of L gives us the log-likelihood function associated with the conditional logit model. With the mixed logit model maximum likelihood estimation would require integrating over v_n. This would amount to computing a high-dimensional integral. Hence, the log-likelihood is approximated by a simulator that is based on S draws of v_n from the normal given current estimates of $\sum \beta_x$. The maximum simulated likelihood estimator then maximizes the logarithm of $L(\beta_x, \beta_p) = \prod_{n=1}^{I} \prod_{t=1}^{T} \prod_{j=1}^{J} \left(P(y_n = j/t) \right)^{\delta_{njt}}$, where $\hat{P}(y_n = j/t)$ is a simulator for $P(y_n = j/t)$. Here the frequency simulator is a smooth simulator. In this study, the log-likelihood function has been maximized directly using STATA's general optimization package.

3.5. Theoretical framework of adoption of improved varieties

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 theories that deal with the adoption of agricultural technologies. These are the innovation-diffusion theory, the economic constraint theory, the central source of innovation theory and the multiple source of innovation theory.

3.5.1. The innovation-diffusion theory

The innovation-diffusion theory 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 theory 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 theory 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 sceptical and resist adoption until absolutely necessary. In many cases, they never adopt the innovation (Rogers, 1995).

The theory of rate of adoption suggests that the adoption of innovations is best represented by an s-curve on a graph. The theory 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 theory 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 theory 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 characterised according to his behaviour without considering factors that influence his behaviour. 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).

3.5.2. Economic constraint theory

The economic constraint theory assumes that, in the short run, inputs such as access to credit, land, labour or other critical inputs are fixed. These actually limit production flexibility and condition technology adoption decisions (Smale *et al*., 1994; Shampine, 1998). Economic theory 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 maximise 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 maximising the household utility would yield similar results as maximising individual functions.

3.5.3. The central source of innovation theory

Another important theory that has been used for a long time to explain agricultural research and technology diffusion is the central source of innovation theory. 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 programmes.

3.5.4. Multiple source of innovation theory

This theory 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 theory builds on the central source of innovation theory 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 organisations, 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).

3.6. Conceptual framework of adoption of improved technologies

Following the above discussions, this study employs the approaches of the innovation diffusion theory, multiple source of innovation and the economic constraint theories to analyse the adoption decisions of cassava farming households. 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 farmer has to become aware of the improved cassava variety and forms attitudes towards it before he can make a decision as to accept or reject it. The farmer is also recognized as having assets and capabilities which enable him to pursue his objectives of increased production to maximize his utility. Adesina and Zinnah (1993) and Rahm and Huffman (1984) found that the farmers decision to adopt new technology is based on the assumption of utility maximization which remains unobserved. This study seeks to identify key variables affecting a decision with a dichotomous outcome depending on a farm's characteristics and a farmer's characteristics and the specific attributes of the improved cassava varieties. The dependent variable is the fact of adoption and it is represented by ''1'' when there is adoption and ''0'' when no adoption takes place (Amemiya, 1981), assuming that an individual decision-maker makes rational choices in maximizing his/her utility (Amemiya, 1981; Rahm and Huffman, 1984). In this study adoption decision refers to the use of improved cassava variety.

Take the situation facing a farmer considering whether to adopt the improved cassava variety or to continue with the current traditional variety. If *'t'* denotes a technology and it equals *'1'* for an old technology and *'2'* for a new technology, the utility of each technology depends on a vector S_i, the socio-economic factors of the individual, and a vector A_i, the attributes of the technology itself. For the farmer, U_{i1} and U_{i2} are indirect utilities derived from continuing with the cultivation of the traditional variety and the adoption of improved cassava variety, respectively. In their linear form, these utilities can be stated as:

$$u_{i1} = d_i S_i + g_{i1} A_{i1} + \varepsilon_{i1} \qquad (3.24)$$

And

$$u_{i2} = d_i S_i + g_{i2} A_{i2} + \varepsilon_{i2} \tag{3.25}$$

where d_i and g_{i1} are vectors of coefficients corresponding to the variables in the vector representing socio-economic factors (S_i) and of the vector of technology attributes (A_i) respectively, and ε_{i1} is an additive error term.

A farmer adopts the improved cassava variety if $u_{i2} > u_{i1}$ or continues with the traditional variety if $u_{i1} > u_{i2}$. Defining a qualitative variable for the adoption of new technology, $y_i = 1$ if a farmer adopts improved cassava variety, otherwise $y_i = 0$. Now the probability of adoption can be written as:

$$\begin{aligned} P_i &= P(y_i = 1) = P(u_{i2} > u_{i1}) = P(\varepsilon_{i1} - \varepsilon_{i2}) \\ &< \left[(d_{i1} - d_{i2}) S_i + (g_{i1} - g_{i2}) A_i\right] = P(u_i) < (\beta_i X_i) \\ &= F(\beta_i X_i) \end{aligned} \tag{3.26}$$

where X_i embodies both S_i and A_i as stated earlier and $u_i = (\varepsilon_{i1} - \varepsilon_{i2})$ is a random distribution term; P(.) is a probability function; and F is a distribution function for u_i. Thus, the probability of a farmer adopting the new technology is the probability that the utility of the old technology is less than the utility of the new one or the cumulative distribution function evaluated as $\beta_i X_i$. The exact distribution of F depends on the distribution of the random term u_i. If it follows a logistic distribution then the F is a cumulative logistic function. If u_i is normal then F is a cumulative normal distribution function; therefore, the distribution for u_i determines the type of model that reflects the adoption behaviour.

3.6.1. Econometric models of adoption of improved cassava variety

Three types of models can be used to measure binary response behaviour. They are linear probability model, the logit model and the probit model. 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 quite similar as the cumulative normal and logistic distributions are very close to each other except at their tails. 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 Rubinfield, 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 t, 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.

In the logit model, the farmers are assumed to make decisions based upon an objective of utility maximization. The underlying utility function depends on household specific attributes *X* (e.g. age of household head, sex of the household head, education, household size, access to credit, etc.) and a disturbance term having a zero mean:

$$u_{i2}(X) = \beta_2 X_i + \varepsilon_{i2} \quad for \quad adoption \tag{3.27}$$

$$u_{i1}(X) = \beta_1 X_i + \varepsilon_{i1} \quad for \quad non \quad adoption \tag{3.28}$$

As utility is random, the *i*th farmer will select the improved cassava variety if and only if $u_{i2} > u_{i1}$. Thus, for the farmer *i*, the probability of adoption is given by:

$$P(1) = P(u_{i2} > u_{i1}) \tag{3.29}$$

$$P(1) = P(\beta_2 X_i + \varepsilon_{i2} > \beta_1 X_i + \varepsilon_{i1}) \tag{3.30}$$

$$P(1) = P(\varepsilon_{i1} - \varepsilon_{i2} < \beta_2 X_i - \beta_1 X_i) \tag{3.31}$$

$$P(1) = P(\varepsilon_i < \beta X_i) \tag{3.32}$$

$$P(1) = F(\beta X_i) \tag{3.33}$$

where *F* is the cumulative distribution function of the error term ε_{i1}. Various cumulative functions can be assumed for *F (.)*. If we assumed that *F(.)* has a logistic distribution, the probability P_i, of a farmer adopting improved cassava variety is given by:

$$P_i = \frac{\exp^{Z_i}}{1 + \exp^{Z_i}} \tag{3.34}$$

where *Zi* is a random variable (i.e. the stimulus index) that predicts the probability of the *i*th farmer adopting improved cassava variety.

Therefore for an individual farmer:

$$Z_i = \ln \frac{P_i}{1 - P_i} = \sum_{n=1}^{n} \beta_n X_i \tag{3.35}$$

where β is an unknown parameter, X is the identified factor contributing to the decision to plant improved cassava variety. The unknown parameter β associated with each contributing factor X is determined by an iterative process that makes use of a maximum likelihood estimate. The final form of the logistic model therefore becomes:

$$Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + ... + \beta_n X_{ni} + \varepsilon_i \qquad (3.36)$$

Since the β parameters are unbiased and normally distributed, a Student's t-test was employed as a test of the significance of the regression. The significance of the coefficients of the variables present in the logistic model was tested using a log-likelihood ratio test assuming a χ^2 data distribution (Pindyck and Rubinfield, 1981). In this study, in order to consider the adoption of different improved varieties and to determine their joint determinant factors, the multinomial logit model is considered in addition to the logit model.

Let the probability that the i^{th} farmer chooses the j^{th} variety be P_{ij} and denote the choice of the i^{th} farmer by $Yi = (Y_{i1}, Y_{i2}, \ldots , Y_{iJ})$ where $Y_{ij} = 1$ if the j^{th} variety is chosen and all other elements of Yi are zero. If each farmer is observed only a single time, the likelihood function of the sample of values $Y_{i1}, \ldots, Y_{iJ}$ is:

$$L = \prod_{i=1}^{T} P^{Y^{i1}}{}_{i1} P^{Y_{i2}}{}_{i2} \ldots , P^{Y_{ij}}{}_{ij} \qquad (3.37)$$

Assuming that the errors across the variety (ε_{ij}) are independent and identically distributed leads us to the following multinomial logit (MNL) model (Greene, 2003).

$$P\{y_i = t\} = \frac{\exp(X_{it}\beta)}{1 + \exp(X_{i2}\beta_2) + ... + \exp(X_{ij}\beta_j)} = \frac{\exp(X_{it}\beta)}{1 + \sum_{j=2}^{j} \exp(X_{ij}\beta_j)} \qquad (3.38)$$

where y denotes the choice of cassava varieties taking the values (1, 2…j) and χ represents the set of conditional variables. χ is a *1xK* vector with first element unity and β_j is a $K \times 1$ vector with j = 2… J. In this study, y denotes cassava varieties or categories while χ denotes specific household and institutional characteristics of the cassava farmer.

Apart from the traditional cassava varieties three other cassava varieties were popular and they were *Bankyehemaa*, *Afisiafi and Abasafitaa*. These varieties comprised the decision categories for the multinomial Logit model. The parameter estimates of the MNL model in (4.38) would be unbiased and consistent if the Independence of Irrelevant Alternatives (IIA) is assumed not to hold (Tse, 1987). The IIA assumption requires that the probability of using one variety by a given cassava farmer must be independent of the probability of choosing another cassava variety. The basis of this assumption is the independent and homoscedastic disturbance terms of the basic model in equation (3.38). The multinomial logit model predicts the probability that a farmer demands a certain variety and how that demand is conditioned by different farm and farmer characteristics and attributes of the variety valued by the farmers.

The empirical specification for examining the influence of explanatory variables on the choice of cassava varieties (y) is given as follows:

$$Y_i = 1 \ldots j = \beta_0 + \beta_1 \chi_{1i} + \beta_2 \chi_{2i} + \ldots + \beta_n \chi_{ni} + \varepsilon \qquad (3.39)$$

where β_0 is the intersect, β_{1-n} are the coefficients of the various explanatory variables and χ_{i-n} are the various explanatory variables, ε is the error term.

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable, but estimates do not represent either the actual magnitude of change nor probabilities. Differentiating equation (3.38) with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\partial P_j}{\partial X_k} = P_j \left(\beta_{jk} - \sum_{j=1}^{j-1} P_j \beta_{jk} \right) \tag{3.40}$$

The marginal effects or marfinal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean(Green, 2003).

3.7. Chapter summary

The chapter explored the underlying theories of choice experiment and the framework that emanated from them. The conceptual framework for discrete choice models is derived following Lancaster's approach and the random utility framework. The conditional logit and mixed logit discrete choice models were applied to empirically model the choices made by farmers from the choice experiment data and also estimate farmers' willingness to pay for cassava traits. Also the Latent class model was used to estimate the sources of heterogeneity. Logit and multinomial logit models were chosen for analyses of the determinants of adoption of improved cassava varieties. To identify key variables affecting a decision with a dichotomous outcome (''growing improved cassava variety'' and ''not growing improved cassava variety'') depending on farm characteristics and a farmers' characteristics and the specific attributes of the improved cassava varieties, the logit model was used. In order to consider the adoption of different improved cassava varieties and to determine their joint determinant factors, the multinomial logit model was considered.

CHAPTER 4

METHODOLOGY

4.1. Introduction

This chapter describes the study area and the methods employed for data collection. The chapter begins with a rationale for selecting the study sites and a general description of the area. This is followed by a brief overview of the population trends and then the agricultural and other economic activities in the study area. The sampling approach adopted and the methods of data collection and analysis are then discussed.

4.2. The study area

The study was conducted in three Districts located in three Regions of Ghana. These are Techiman Municipality in the Brong Ahafo Region, Atwima Nwabiagya District in the Ashanti Region and Fanteakwa District in the Eastern Region (Figure 4.1). In each district, 10 communities were selected for the study. These were Abira, Mfensi, Nkawie Panin, Kobeng, Nerebehi, Koforidua, Sedi, Anwona Nkwanta, Amankyea and Nkansakrom in the Atwima Nwabiagya District; Dua Police, Bepoase, Ehiamankyene, Ahomahomaso, Bososo, Nkankama, Sabrima, Kuradaso, Akwanserem and Apaa in the Fanteakwa District; and Aworowa, Asoee, Nkwaeso, Krobo, Agosa, Atrensu, Nsuta, Ofuman, Fiaso and Faaman in the Techiman Municipality. The next sections present a general description of the study regions and districts.

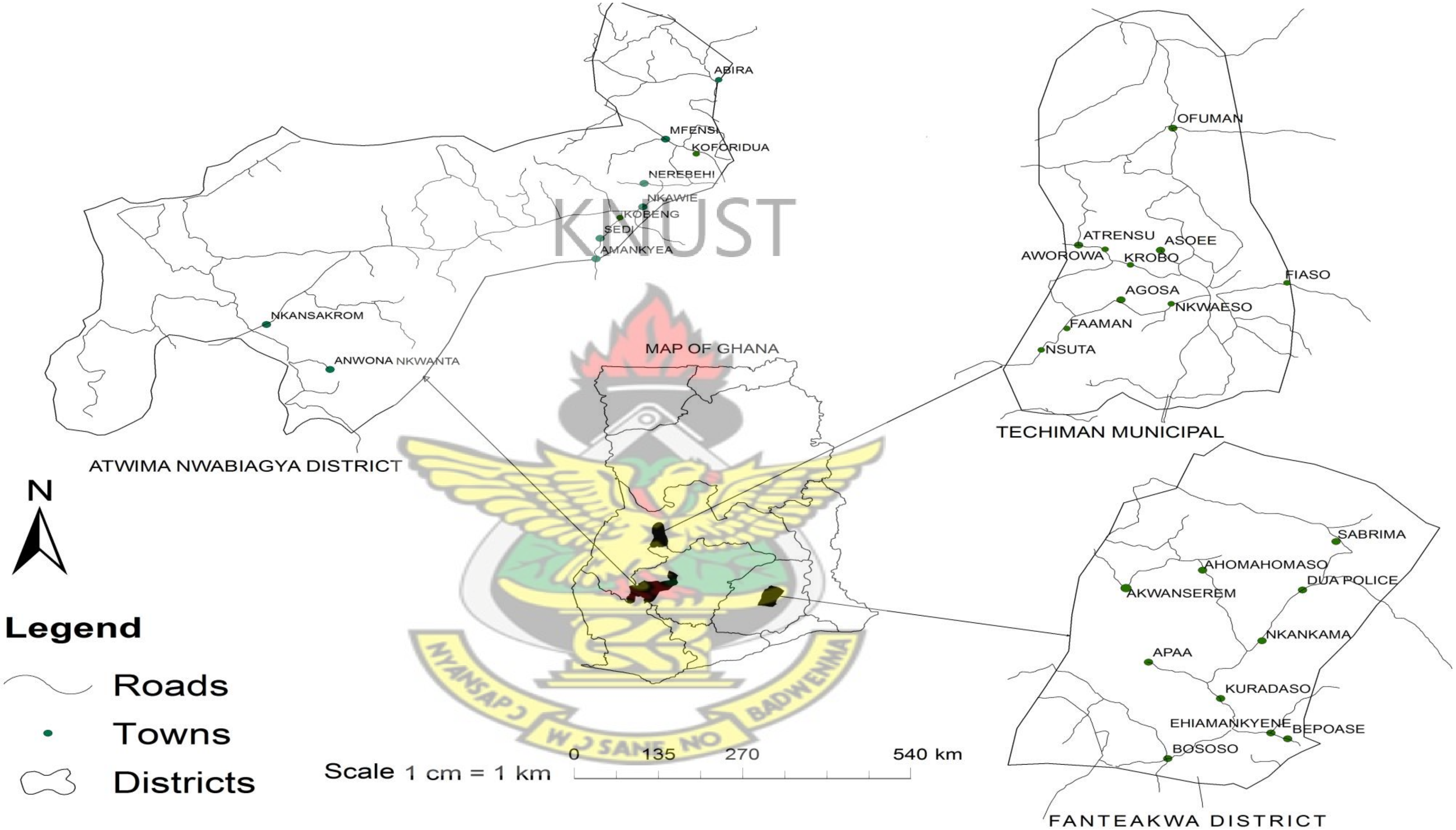


Figure 4.1. Map of the study areas (Source: Mapping Unit of Resource Management Support Centre, Forestry Commission of Ghana)

4.2.1. The Brong Ahafo Region and the Techiman Municipality

The Brong Ahafo Region covers an area of 39,557 km^2 and shares boundaries with the Northern Region to the north, the Ashanti and Western Regions to the south, the Volta Region to the east, the Eastern Region to the southeast and La Cote d'Ivoire to the West. The Region lies within longitude 0°15' East and 3° West and latitude 8°45' and 7°3' North (www.ghanaDistricts.com, accessed: March 2012). The Techiman Municipality is one of the 22 administrative districts of the Brong Ahafo Region. It lies in the northern part of the Region between longitudes 1°49' East and 2°30' West and latitudes 8°00' North and 7°35' South. It shares borders with the Wenchi Municipal to the North-west, Kintampo South District to the north-east, Nkoranza District to the south-east and Offinso North District in the Ashanti Region to the south. The Municipality covers a total land area of 669.7 km^2 which represents about 1.69% of the total surface area of the Brong Ahafo Region making it the smallest District in the Region. The Techiman Municipality is characterized by semi-equatorial and tropical conventional climates marked by moderate to heavy rainfall. The District has bimodal rainfall. The mean annual rainfall ranges between 1250mm and 1650mm. The average highest monthly temperature is about 30°C (80°F) and the lowest is 20°C (79°F). Relative humidity is generally high throughout the year (TMA, 2006).

The Brong Ahafo Region has three main soil types: forest ochrosols, savannah ochrosols, and laterite ochrosols from which many soil associations emanate. In the Techiman Municipality, however, three major soil associations are found. They are the Damongo-Murugu-Tanoso Association, the Bediesi-Bejua Association and the Kumasi-Offin Association. The Damango series are developed from voltaian sandstone under savanna vegetation and are red, deep (over 200cm), well drained and permeable. This soil is favourable for crops such as yam, cassava, maize, tobacco, vegetables, legumes, and cotton (Obeng, 2000). They can be found in the middle part of the District. The Murugu series are similar to that of the Damango series and support crops such as maize, cassava, cotton and tobacco. They can be found in the transitional zone stretching to the north eastern part of the District. The Tanoso series are located in low slopes and valley bottoms in the savanna zone at the north-western part of the District. They are deep, poorly drained and subject to seasonal water logging. The Bediesi-Bejua association is developed from voltaian sandstone under forest vegetation. They are very deep, red, porous and well drained. They support crops like cocoa, coffee, oil palm, plantain, among others (Obeng, 2000).

Generally, the Brong Ahafo Region has two main vegetation types: the moist semi-deciduous forest, which stretches from the south to the south eastern parts and the guinea savannah woodland located in the north eastern part of the Region. However, Techiman Municipality has three main vegetation types due to its location within the fringes of the transition belt. The three main vegetation zones found in the Municipality are the guinea savanna woodland located in the north-west, the semi-deciduous zone in the south and the transitional zone which stretches from the south-east and west up to the north of the Municipality. The semi-deciduous forest is relatively denser and characterised by trees such as wawa, odum, sapele and teak. The Asubima Forest Reserve is located in the Municipality and covers about 32.5 km^2 and represents about 5 percent of the total land area of Techiman Municipality. The guinea savannah woodland is characterised by shrubs and grasses (www.ghanaDistricts.com, accessed: March 2012).

The population of the Brong Ahafo Region has increased since the 2000 population and housing census. During the 2000 population and housing census, the Region had a population of 1,824,822 with an estimated growth rate of 2.6 % (GSS, 2002). In the 2010 population and housing census, the population of the Region increased to 2,282,128 with an estimated growth rate of 2.2% (GSS, 2012). The density of population in the Region currently stands at 58 persons per square km (GSS, 2012) compared to that of year 2000 which was 46 persons per square km (GSS, 2002). The Techiman Municipality in 2000 had a population of 174,600 with a density of 260 persons per square km, far higher than the Regional average of 46 persons per square km and the national average of 79 persons per square km (GSS, 2002). The 2010 population and housing census puts the population of the Municipality at 206,856 with a population density of 343 people per square km compared to the Regional average of 58 persons per square km and the national average of 103 persons per square km (GSS, 2012). The population increases in the Municipality is largely due to its strategic position between the south and north of Ghana. Many migrant populations from the north settle in the Municipality (TMA, 2006). Apart from its strategic position, the Municipality abounds in fertile lands for arable crops production and this has partly contributed to the population increases over the years.

The Brong Ahafo Region is one of the agricultural hubs of the country. It has 69% of her labour force in agriculture. Non-Agricultural labour force including mining, manufacturing, services, trading and others constitute 31% of the total labour force of the Region (GSS, 2012). The Region is noted for food and cash crops production. Major staple crops produced in the Region are maize, cassava, plantain, yam, and cocoyam. Of the total staple crops produced in the country in 2010 the Region produced 27%, 1.3%, 20%, 39%, 25% and 27.7% respectively of maize, rice, cassava, yam, cocoyam and plantain. Major cash crops produced in the Region are cashew, cocoa, cotton, tobacco, coffee, oil palm, and Mango. The Region is the third largest producer of cocoa in the country mainly in the Ahafo area, which shares common border with the Western and Ashanti Regions. There is also lots of cashew production in the Region and occurs mainly in the Wenchi and Techiman areas of the Region (MoFA, 2011). Apart from food and cash crops, a forest product like timber is also produced in the Region. They are also found in the Ahafo areas of the Region. The Techiman Municipality is one of the agricultural areas of the Region. Agriculture accounts for about 57% of the labour force of the Municipality. Techiman is well known for the production of yam, maize and cassava and production of cash crops like cashew and coffee (TMA, 2006). The Techiman Municipality is home of the famous Techiman Market, the largest food crops market in Ghana and a major commercial centre in the Region.

The level of agricultural development is largely due to the two vegetation types, moist semi deciduous forest and guinea savannah wood land and the favourable climatic conditions. Also, there have been a lot of interventions that have helped increase agricultural activities in the Region. Interventions such as the fertilizer subsidy programme and block farming have helped to increase production (MoFA, 2011).

The region is the second largest producer of cassava in the country. Major cassava processing centres are located in the region. Most of the people derive sustenance from the crop through production, processing and marketing. However, cassava yields in the region is 16t/ha far below the potential yield of 48.7t/ha (MoFA, 2013). Techiman Municipality is an area in the region where a lot of production, processing and marketing of cassava take place and it is selected to assess the possible existence of differences in the cassava trait preference among cassava farmers in the district.

4.2.2. The Ashanti Region and the Atwima Nwabiagya District

The Ashanti Region covers a total land area of 24,389 km^2 representing 10.2 percent of the total land area of Ghana. It is the third largest Region after Northern (70,384 km2) and Brong Ahafo (39,557 km2) Regions. It lies between longitudes 0^{o} 15’ W and 2^{o} 25’ W and latitudes 5^{o} 50’ N and 7^{o} 46’ N. The Region shares boundaries with four of the ten political regions of Ghana: Brong-Ahafo Region in the north, Eastern Region in the east, Central Region in the south and Western Region in the southwest (www.ghanaDistricts.com, accessed: March 2012).

The Atwima Nwabiagya District is one of the 27 administrative districts of the Region. It covers an estimated area of 294.84 km^2 and it is one of the largest in the Ashanti Region. It lies approximately on latitude 6^{o} 75’ N and between longitude 1^{o} 45’ and 2^{o} 00’ W. It is situated in the western part of the Region and shares common boundaries with Ahafo Ano South and Atwima Mponua Districts to the west, Offinso Municipal to the north, Amansie-West and Bosomtwe-Atwima-Kwanwoma Districts to the south, and Kumasi Metropolis and Kwabre District to the east. The Atwima Nwabiagya District has the wet semi-equatorial climate with double maxima rainfall ranging between 170 cm and 185 cm per annum. Temperature is fairly uniform, ranging between 27ºC and 31ºC. The District has a mean relative humidity of about 87 to 91 percent (http://ghanaDistricts.com, accessed: March 2012).

The Ashanti Region has two major soil types, the forest and savannah ochrosols. The forest ochrosols are found in the southern districts whilst the savannah ochrosols are confined to the northern districts. The detailed soil associations are the following: Kumasi-Offin Compound Association; Bomso–Offin Compound Association; Nhyanao-Tinkong

Association; Bomso–Suko Simple Association; Bekwai–Oda Compound Association and Bekwai–Akumadan–Oda Compound Association (Adu, 1992). The soils have a fairly high moisture holding capacity. The soils are good for tree and arable crops. Their moisture holding capacity is fairly high although surface layers are susceptible to dry season drought. These soils are favourable for tree crops and arable crop production.

Unlike the Techiman Municipality, the Atwima Nwabiagya District has two soil associations, the Kumasi-Asuansi/Nsuta-Ofin Compound Associations and the Bekwai-Nzema/Oda Complex Associations. The Kumasi-Asuansi Compound Associations, developed over Cape Coast Granites, are generally medium to coarse textured, good structured and moderately gravelly. The soils have a fairly high moisture holding capacity. They are suitable for tree and arable crops such as cocoa, citrus, oil palm, mangoes, guava, avocado, maize, cassava, yams, cocoyam, plantain, pawpaw, groundnuts pineapple and ginger. The Bekwai-Nzema/Oda Complex Associations developed over Birimian Phyllites, Greywacks, Schist and Gneisses are very deep, red, well drained and brown. Their moisture holding capacity is fairly high although surface layers are susceptible to dry season drought. The soils are moderately good for agriculture. The upland and slope soils are suitable for all the tree and arable crops mentioned already (Adu, 1992). The valley bottoms are good for the cultivation of rice, sugarcane and vegetables.

The Ashanti Region has two vegetation zones: the wet semi-equatorial forest zone which covers more than half of the Region and the transitional savannah woodland which covers the north-eastern parts of the Region. The transitional savannah vegetation consists of tall grasses interspersed with short fire-resistant tree species. The Atwima Nwabiagya District lies within the wet semi-equatorial forest zone. The vegetation found in the District is predominantly the semi-deciduous type. The vegetation used to be denser and thicker with economic trees such as odum, Wawa and sapele but has been replaced by exotic species such as teak, acacia, gmelina and eucalyptus. The Owabi and Barekese forest reserve are located within the District and has some economic trees such as odum, wawa and sapele (http://ghanaDistricts.com, accessed: March 2012).

The Ashanti Region is the most populated region in Ghana. The 2000 population and housing census put the population of the Ashanti Region at 3,612, 950 with a population density of 148 persons per sq. km, higher than the national average of 79 persons per sq. km. In 2010 the population of the Region increased to 4,780,380 with population density of 196 persons per sq. km, still higher than the national average of 103 persons per sq. km (GSS, 2012). The total population of the Atwima Nwabiagya District, according to the 2000 population and housing census, was 129,375, with a population density of 439 persons per square km, far higher than the regional population density of 148 persons per square km and the national population density of 79 persons per square km in 2000 (GSS, 2002). According to the 2010 population and housing census, the District had a population of 149,025. The proximity of the District to Kumasi, the capital of the Region, is the main reason for its population increases as many people now prefer to settle at the peri-urban centres. The District is predominantly urban with 64% of the population living in the urban/peri-urban areas of the District and 36% living in the rural areas (http://ghanaDistricts.com, accessed: March 2012).

The Ashanti Region is endowed with abundant arable lands which support the production of cash crops such as cocoa, coffee, oil palm, citrus, cashew, and mango and food crops like cassava, plantain, rice, yam, cocoyam, maize, and vegetables. The climate of the

Region supports all year production of cash and food crops. The Region is the second largest producer of cocoa in Ghana. Agriculture employs 44.5% of its labour force. About 18% of the Region's population are engaged in wholesale and retail business, 12.2% in manufacturing and 9.9% in the services sector. Over the years the areas under cultivation of all major crops have been increasing. Land under cultivation of rice, maize, cassava, yam and plantain since 2006 have increased by 11%, 19%, 4%, 7% and 6% respectively (MoFA, 2011). Of the major food crops produced in the country in 2010, the Region contributed 13.5% of maize, 5.6% of rice, 13.6% of cassava, 7.8% of yam, 30% of cocoyam and 26% of plantain. Maize and yam are predominately produced in the transition zone. The significant increase in rice production is due to rice projects which have provided credit support, introduced improved technologies and high yielding and quality rice varieties which resulted in the expansion of area and significant increase in yields. Such projects included Inland Valleys Rice Development Project (IVRDP) and New Rice for Africa Project (NERICA). Cash crops production is also important in the Region. The Region is the second largest producer of cocoa in Ghana (ibid). Agricultural development interventions that have helped boost agricultural production in the Region includes block farm, fertilizer subsidy, Root and Tuber Improvement and Marketing Programme (RTIMP), Unleashing the Power of Cassava (UPoCA) and others.

The Region is the third largest producer of cassava in the country. One of the country's main agricultural research institutes, the Crops Research Institute is located in the Region. Cassava based programmes and projects have been undertaken in the region over the years. Most of the people derive sustenance from the crop through production, processing and marketing. However, cassava yields in the region is 17.78t/ha far below the potential yield of 48.7t/ha (MoFA, 2013). Due to its proximity to the Crops Research Institute, the

Atwima Nwabiagya District has received a lot of cassava based development interventions, however, the challenge of low productivity still remains.

4.2.3. The Eastern Region and the Fanteakwa District

The Eastern Region covers an area of 19,323 km^2 and constitutes 8.1 per cent of the total land area of Ghana. The Region is bordered on the north by the Ashanti Region and the Brong Ahafo Region, on the east by the Volta River, on the south by the Central Region and the Greater Accra Region, and on the west by the Ashanti Region and the Central Region. It is the sixth largest Region in terms of land area. It lies between latitudes 6° and 7° North and between longitudes 1°30' West and 0º30' East. The Eastern Region has a minimum temperature of 22°C and a maximum temperature of 32°C. Mean annual rainfall is between 1500mm and 2000mm. The Fanteakwa District is one of the 15 districts within the Eastern Region of Ghana. It lies within longitudes 0°32.5' West and 0°10' East and latitudes 6° 15' North and 6° 40' North. It is bordered by the Volta Lake to the north, the Kwaha South District to the northwest, East Akim Municipal to the southwest, Manya Krobo District to the east and the Yilo Krobo District to the southeast (http://ghanaDistricts.com, accessed: March 2012).

The Eastern Region, unlike the two other Regions, has four main soil types: the forest ochrosol, forest lithosol, forest rubisol and savanna ochrosol. The major soil compound of Eastern Region is Nankese-Koforidua /Nta-Offin compound with many soil associations. Soil associations of the Fanteakwa District are the Atiwa-Anum simple formation (association), Nzema-Bekwai/Oda compound association, Atewiredu-Katie Simple Association, Bediesa-Yaya/Asuansi-Atewa Complex Association, and Nankesi-Akrosi/Nta-Offin Compound Association. The soils are very deep and well drained and have very poor moisture retention during dry seasons. The top soil is easily eroded. These soils are suitable for hand cultivation of coffee, cocoa, cocoyam, plantain and maize. The Nzema-Bekwai/Oda compound association is Greyish brown loamy soils overlying red clay soils at lower elevations of slopping hills and are favourable for cultivation of Cash crops such as cocoa, coffee, rubber, and oil palm and food crops such as maize, cassava, plantain, cocoyam, dry season vegetables, pepper, soybean, sugar cane, sweet potato and rice (Obeng, 2000). The Bediesa-Yaya/Asuansi-Atewa Complex Association is yellowish red, gravely soil with moderately shallow depths. It is suitable for wildlife conservation, forest reserve and watershed protection purposes. It can only be used for cultivation under appropriate cultural practices. The Nankesi/Nta-Offin soil Associations are moderately to well drain soils found both on the uplands and on the lowlands. The uplands support crops like Cocoa, coffee, maize and cassava and the lowlands support sugar cane and vegetables cultivation (Obeng, 2000).

There are three main vegetation zones in the Region; the semi-deciduous, transition and coastal savannah zones. The semi-deciduous rain forest covers the southern and central portions of the Region, the transitional savannah zone covers the northern parts behind the Kwahu Scarp and the coastal savannah covers the Eastern fringes behind the Akwapim Range. The vegetation of Fanteakwa District consists basically of the wet semi-deciduous rain forest and the savanna scrub which is found to the north of the District on the hills close to the Volta Lake (http://ghanaDistricts.com, accessed: March 2012).

The Eastern Region has also seen consistent increases in population since 2000. In 2000 the population of the Region was 2,106,696 which increased to 2,633,154 in 2010 (GSS, 2002; GSS, 2012). The population density in 2000 and 2010 were respectively 109 and

136 persons per square km. According to the 2000 population and housing census, the Fanteakwa District had a population of 86,154 with population density of 75 persons per square km. The 2010 population and housing census put the population of the District at 108,614. The fast population increase is attributed to in-migration as there is about 29% of the District's population being immigrants. There is therefore greater diversity in the Region than the two other Regions. Apart from the production of major food staples, the Region also produces exotic vegetables such as cucumber, cabbage, green pepper, and chilli in large quantities for export. Crop production accounts for 70-85% of the agricultural output of the Region. Food staples such as maize, plantain, cocoyam, cassava and yam are produced in the Region. Over 54% of the Regions labour force is in agricultural production. There have been increases in the production of the major staples since 2006. In 2010 production level of maize appreciated by 25.41% while that of rice and cassava rose by 4.88% and 18.16% respectively (MoFA, 2011). The Region contributed 20.3% of maize, 4.2% of rice, 26.8% of cassava, 12% of yams, 18.7% of cocoyam and 23.7% of plantain to the overall food crops production in the country in 2010.

There are interventions in the Region that are helping to boost agricultural production. Similar to the other two Regions, they operate the block farm system and the fertilizer subsidy programme. Projects supported by donors, non-governmental organizations, research institutes and the Ministry of Food and Agriculture (MoFA) are present in the Region to further help boost agricultural production. These projects are the Inland Valley Rice Project (IVRP), the Export Marketing Quality Awareness Project (EMQAP), the Afram Plains District Agricultural Development Project (APDADP) and the Millennium Development Authority (MoFA, 2011).

Eastern Region is by the far the largest producer of cassava and has appreciable average yield of 22.35t/ha. The Fanteakwa District produces the bulk of cassava in the Region with an average yield of 22t/ha (MoFA, 2012). The challenges to cassava production still remain and as such the District is selected as one of the study sites to assess farmers' preference structure.

4.3. Data collection and analysis

4.3.1. Sampling

A multi-stage sampling method was adopted for the study, involving the selection of regions, districts, communities and cassava farmers. The three regions in which the study was conducted were purposively selected to reflect cassava production and distribution patterns in the country. These were the Ashanti, Brong Ahafo and Eastern Regions. Cassava is produced all over Ghana; nevertheless, the crop is of much importance in some regions of the country. According to MoFA (2011), the Eastern, Brong Ahafo and Ashanti Regions produce the bulk of cassava in Ghana.

The next stage of the sampling process was the selection of districts. Since the study was concerned with improved cassava varieties, the Root and Tuber Improvement and Marketing Programme (RTIMP), which is responsible for the dissemination of improved cassava varieties in the country, was consulted for a list of its operational districts. The Programme has operational areas in each region of Ghana. From the list of operational areas provided, one district was purposively selected from each of the three regions based on accessibility, cassava production levels, marketing and processing. These districts were the Atwima Nwabiagya District in the Ashanti Region, Fanteakwa District in the Eastern Region and Techiman Municipal in the Brong Ahafo Region.

A simple random sampling technique was employed for the selection of study communities and cassava farmers. In each of the three selected districts, the RTIMP office was contacted for a list of all communities in the district in which they operate. Ten (10) communities were randomly selected from each of the three districts, making a total of 30 communities. From the list of cassava farmers in the communities, 15 farmers were again randomly selected from each of the 30 communities. Thus, a total of four hundred and fifty (450) cassava farmers were sampled across the three regions, three districts and 30 communities for the study. Table 4.1 summarizes the sampling procedure.

Table 4.1. Sampling procedure for the farm level survey

Regions	Districts selected	No of communities	Farmer respondents
Ashanti	1	10	150
Brong Ahafo	1	10	150
Eastern	1	10	150
Total	**3**	**30**	**450**

4.3.2. Types and sources of data

The study used both primary and secondary data for the analyses. Relevant secondary data were obtained from various sources including the Regional Directorate of Agriculture, the District Assemblies, the District Agricultural Directorates, the national coordinating office of the RTIMP, Ministry of Food and Agriculture, research reports, refereed journal articles and books. The secondary data provided background information on the study as well as on the study areas.

The required primary data were gathered from the sampled cassava producers. Cross-sectional data was collected from cassava farmers in the selected study areas from October 2010 to March 2011. Two sets of primary data were collected for the implementation of the study. The first set of data was on farmer and farm characteristics, asset ownership, factors related to farmers' variety choice decisions, agricultural extension, markets and incomes. The second set of data was the choice experiment data. A detailed discussion of the design and collection of the choice experiment data is provided below.

4.3.3. Methods of data collection

In the context of investigating farmers preferences for cassava variety traits in order to identify reasons for low adoption of improved cassava varieties, it seemed neither qualitative nor quantitative methodology alone was able to achieve the research objectives. Therefore an integration of qualitative and quantitative methods was used to understand the factors that influence their preferences and hence their adoption of improved cassava varieties. 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.

4.3.3.1. The qualitative survey

The qualitative data was collected in two phases: the orientation phase and the focus group discussions phase. The orientation phase involved reconnaissance visits to the study area. The objectives of the visits were to explore 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 crop production and other relevant district information such as data on topography and drainage, climate and vegetation, and geology and soils. During the visits discussions were held with the extension staff from the Ministry of Food and Agriculture (MoFA) on the trends in crop production over the last few years. The major cassava producing communities in the study districts were identified in consultation with the RTIMP district offices in order to select the specific locations for the study. Visits were also made to some farmers that were growing both improved and local cassava varieties and this helped in establishing contacts that proved to be very useful later on in the survey implementation process.

The focus group discussions phase involved the organisation of five focus group discussions in each of the three selected districts. In conducting the discussions, three important aspects were carefully considered: selection of the participants, the composition of the focus groups and the size of the groups. The size of the groups was guided by recommendations of some authors (Russell, 2002; Ritchie, 2003) that a minimum of four to ten members should make up a group in focus group discussions. This ensured free discussions and ample time for participants to contribute. There was conscious effort to include both males and females in the focus groups.

Agricultural Extension Staff from the Ministry of Food and Agriculture were asked to mobilize cassava farmers, both males and females, for the focus group discussions on agreed dates, venues and times. Checklists were developed and used to guide discussions with farmer groups. The objectives of the study were explained and communication procedures established to ensure that farmers and resource persons had the same understanding of the issues under discussions. The discussions were organised from October 2010 to January 2011. Table 4.2 shows the number of participants in the focus groups for each district. During the discussions, farmers were asked to mention both local and improved cassava varieties grown in their communities and their associated characteristics. They were also asked to give their ratings of five main cassava traits (yield, disease resistance, multiple usage, early maturity and in-soil storage) on a Likert-type scale ranging from 1 (very important) to 3 (somewhat important). The sources of the traits were findings from the reconnaissance survey and past research on cassava traits preferred by farmers. The selection of the traits or attributes above was guided by attributes that are expected to affect farmers' choices, as well as those that are policy relevant.

Table 4.2. Numbers of participants in focus group discussions in the study area

District	Villages	Women participants	Men participants	Total number of participants
Techiman	Nkwaeso	4	7	11
	Agosa	5	6	11
	Faaman	2	7	9
	Aworowa	3	5	8
	Fiaso	2	7	9
	Total	***16***	***32***	***48***
Atwima Nwabiagya	Abira	2	7	9
	Mfensi	6	8	14
	Nkawie	4	6	10
	Kobeng	3	5	8
	Nerebehi	3	6	9
	Total	***18***	***32***	***50***
Fanteakwa	Ehiamankyene	4	8	12
	Kuradaso	6	8	14
	Bepoase	3	6	9
	Bososo	4	5	9
	Ahomahomaso	2	6	8
	Total	***19***	***33***	***52***
	Overall total	**53**	**97**	**150**

Source; Field survey, 2011

The researcher moderated all the focus group discussions with the help of two principal technicians who also took notes on the discussions. Two local extension officers (male and female) were involved in the discussion as facilitators. The qualitative survey helped the researcher to establish rapport with the local people as well as the community leaders and key informants. It also helped in the gathering of some important information on issues such as culture, land tenure, attitudes and perceptions regarding farming practices.

4.3.3.2. The quantitative survey

The quantitative survey involved the development of structured questionnaires and administration of the questionnaires. The survey was conducted from the beginning of Febuary 2011 to the end of April 2011. Surveys in all the districts were carried out by administering questionnaires through face-to-face interviews with farmers. All household activities (farm and non-farm), enterprise types, crop area and production levels, inputs, expenditures and sales for the past season 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 were related to farmers' management capacity and demographic characteristics such as the supply of on-farm family labour 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 I) contained 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 researcher was trying to measure in the questionnaire, and measurement indicators were specific and precise (Fowler, 1994). The questionnaire preparation took into account factors found to minimise 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 cassava variety traits preferred by farmers, determining the adoption of the already available improved varieties and assessing the factors that influence both adoption and preferences.

4.3.3.3. Measurement of variables and hypothesized relationships

Adoption of improved cassava variety is taken as the dependent variable. It equals 1 if the farmer planted improved cassava variety during the 2009/2010 cropping season and 0 if 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 cassava variety is hypothesized to depend on the explanatory variables of age, gender, education, household size, farm size, credit access, land tenure security, extension access, market access, farming experience, knowledge or awareness and trait perception. These represent both continuous and categorical variables used in the analysis. The continuous variables take any numerical value in a real value. Categorical variables take a numerical value of one or zero and are also called binary or dummy variables.

The age variable (AGE) is measured in number of years. This is a continuous variable and it is expected *a priori* to be negatively (Bekele and Drake, 2003) or positively (Langyintuo and Mekuria, 2008) influence the decision to adopt new technologies. 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 technologies. It could also be that older people have more experience and are in a better position to assess characteristics of new technology than younger farmers, and hence a higher probability of adopting the new technology.

The gender (GENDER) of the household head is a dummy variable that takes the value of 1 if the head of the household is female, and 0 if male. 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 is therefore hypothesized to have a positive or negative sign. The Education (EDUCN) variable is measured as the number of years of schooling. The importance of education (EDUCN) and experience (EXPER) in enhancing human capital through acquisition and learning of skills has been well documented (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 is expected to positively influence the decision to adopt improved cassava varieties. Farming experience (EXPER) will increase the probability of uptake of new technologies because experienced farmers have better knowledge and information on management practices. Farming experience is measured as the number of years one has spent in farming.

Farm size (FARMSIZE) is 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 is hypothesised that larger land holdings will positively influence adoption of improved cassava varieties.

Farmers contacts with extension agents (EXTENSION) is 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 is expected to have a positive effect on adoption of improved cassava 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) is 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 cassava varieties is hypothesized to positively influence their adoption.

The number of times of extension visit is measured as a continuous variable. The number of times (TIMESEXT) a farmer is visited by an extension agent may influence the farmers decision to adopt new technology. A positive relationship is therefore hypothesised between the number of extension agents' visit and adoption of improved cassava varieties. Participation in extension programmes (Cassava field days) (FIELDDAY) may affect adoption of technologies. It is measured as dummy variable: participated in cassava field day or otherwise. Based on the innovation diffusion theory, it is hypothesized that farmers who have participated in extension programmes are more likely to adopt (Feder and Slade, 1984; Shampine, 1998; Smale *et al.,* 1994). FIELDDAY is 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 is measured as dummy variable: 1 = owner, 0 = not the owner. Land ownership is 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 cassava 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 cassava 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) is measured as dummy variable and is expected to positively influence the adoption of improved cassava varieties as farmers have to increase input use. 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 is expected to negatively influence adoption of improved cassava varieties. Input markets allow farmers to acquire the inputs they need such as pesticides and weedicides 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).

Farmers' perception of improved cassava variety traits is measured as dummy variable. Concerning technology specific characteristics, farmers were asked to compare an improved cassava variety with their choice of the best traditional variety in terms of *disease resistance (*DISEASER), *soil storage (*SOILSTOR), *productivity (*PRODUCT), and *usage (USAGE)*. The perceived superiority of improved cassava varieties over the traditional in terms of yield and disease resistance is expected to positively influence adoption. If an improved variety is perceived to better meet desirable consumption (preparation of fufu) and production attributes (in-soil storage) compared to traditional varieties, then it will be highly demanded by farmers. A positive relationship is therefore expected for improved varieties that can be used for fufu preparation and improved varieties that can store longer in the soil after maturity as this serves as the best storage technique for cassava by smallholder farmers. Table 4.3 provides a summary of the variables measurement.

Table 4.3. 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
EXPERIENCE	Number of years in cassava farming	Years	+ve
FARMSIZE	Size of farm	Hectares	+ve
EXTENSION	Extension contact	Dummy(1=contact; 0=otherwise)	+ve
AWARENESS	Knowledge of the improved cassava varieties	Dummy(1=yes; 0=otherwise)	+ve
TIMESTEN	Number of times of extension visit	Count	+ve
FIELDDAY	Attendance in a farmer field day on cassava	Dummy(1=attend;0=otherwise	+ve
LANDT	Ownership of cassava farmland	Dummy(1=owner; 0=otherwise	+ve
CREDIT	Access to formal credit	Dummy (1=yes; 0=otherwise)	+ve
DISTANCE	Access to input and output market	Dummy(1=yes; 0=otherwise)	-ve
DISEASER	Perception of disease resistance of cassava variety	Dummy(1=perceived that cassava is disease resistant; 0=otherwise	+ve
SOILSTOR	Perception of longevity after maturity	Dummy(1=perceived that cassava stays longer; 0= otherwise	+ve
PRODUCT	Perception of high yielding of cassava variety	Dummy(1=perceived that cassava is high yielding	+ve
USAGE	Perception that cassava is poundable	Dummy(1=perception that cassava is poundable; 0=otherwise	+ve

The second type of questionnaire was the choice experiment questionnaire. From the information obtained through the reconnaissance survey and focus group discussions, relevant cassava variety attributes and attributes levels were selected to guide the design of the experiment. The discussions also provided information about the minimum and maximum attributes (traits) to include in the choice set design. The choice experiment questionnaire (Appendix II) was administered alongside the farm level questionnaire. The process of designing the choice experiment questions is explained in detail in the next section.

4.3.3.4. The choice experiment design and survey

The overall objective of the choice experiment part of the study was to estimate farmer preference and willingness to pay for cassava variety traits. Under this method, a sample of people is asked to choose their most preferred alternatives from a sequence of grouped options that relate to different cassava varieties. Each option is described in terms of cassava attributes and a monetary price to be paid for the trait by the respondents. By analysing the choices made by the respondents it is possible to infer the trade-offs that people are willing to make between money and the greater benefits of using improved cassava varieties. This in turn allows the estimation of changes of private benefits with changing levels of cassava variety traits.

Experimental levels of five cassava traits were identified through focus group discussions, expert interviews and literature review. A monetary attribute in terms of purchase of 91kg of cassava roots was included in order to estimate farmer willingness to pay for cassava traits. The cassava attributes and their levels used in this study are explained below:

Productivity: The total output per unit of total input is very important to farmers. Given the fact that farmers depend solely on output for their yearly incomes it is expected that high productivity of a variety will positively increase the choice of that variety. In the choice experiment, productivity was accounted for by including three levels: (1) 15t/ha;

(2) 30t/ha; and (3) 60t/ha. The productivity 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, productivity levels were reviewed from the Ministry of Food and Agricultures' data file on current cassava yields and the Crops Research Institutes' current field data files under research managed conditions.

Resistance to cassava mosaic virus disease (CMVD): Cassava mosaic virus disease is important in reducing cassava production and farmers are expected to be concerned. Disease resistance was accounted for in the choice experiment as having two levels: (1) resistant to CMVD; and (2) not resistant to CMVD. Disease resistance therefore should increase the utility of a farmer.

In-soil storage: The period of time within which mature cassava roots can be stored in soil before spoilage is also very important to farmers. This is an important attribute because it is a common practice for farmers to harvest cassava roots piecemeal based on demand. In the choice experiment, in-soil storage was accounted for as having two levels: (1) less than 12 months; and (2) 12 months or more. Since cassava deteriorates very fast and farmers normally leave their roots in the soil for a time it is expected that in-soil storage of 12 months or more should increase the utility of a farmer.

Multiple usage: Whether a cassava variety can be used as 'fufu', 'gari' or 'dough' is of particular importance to farming households. Farmers will only cultivate crops that satisfy first their consumption needs, and then their market needs. In the choice experiment, usage was accounted for by including three levels: (1) Dough and gari; (2) Gari and fufu; and (3) fufu, dough and gari. Here, it is expected that a cassava variety that can be used to prepare dough, fufu and gari will increase utility.

Purchase price of traits: The purchase price of the traits was based on prevailing market prices of 91kg bag at the study area. Three levels were used to account for purchase prices in the choice experiment: (1) Gh₵15; (2) Gh₵30; and (3) Gh₵45. The three levels represented the minimum, average, and maximum prices pertaining at the various districts. Farmers are expected to insist on lower payments for the attributes or demand lower prices. Table 4.4 presents the summary of attributes and attribute levels used in the choice experiment.

Table 4.4. Attributes and attribute levels used in the choice experiment

Attribute	Description	Attribute levels
Productivity	Average production harvested per hectare from planting a particular cassava variety.	• 15 tonnes • 30 tonnes • 60 tonnes
Disease and pest resistance	Whether a particular variety withstands cassava mosaic virus disease	• Not resistant to cassava mosaic virus disease • Resistant to cassava mosaic virus disease
In-soil storage	Whether a particular variety is able to remain in soil for 12 months or more or less than 12 months	• Less than 12 months • 12 months or more
Multiple Usage	Development of product from a particular cassava variety	• Gari and dough • Gari and fufu • Dough, gari and fufu
Purchase price	Purchase price of traits. This was based on the selling price per 91kg bag of harvested cassava roots	• Gh₵ 15[5] • Gh₵ 30 • Gh₵ 45

[5] 1USD=1.74 in 2012

As has already been mentioned, the selection of the attributes was guided by attributes that are expected to affect farmers' choices, as well as those attributes that are policy relevant. Once attributes and levels were 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 to minimise 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 to find designs that are statistically as efficient as possible in terms of predicted standard errors of the parameter estimates. Essentially, these designs attempt to maximise 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 due to the fact that efficient designs use the prior knowledge of parameters to optimise the design in which the most information is gained 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 design was 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 for an independent estimation of the influence of each design attribute on choice. Secondly, with the absence of prior parameters, there was no way to apply 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. In order 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 effects 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 would have resulted in $108(3^3 2^2)$ generic choice sets. A full factorial design is, in fact, very large and not easy to manage in a choice experiment. Since it was not 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 SPSS Conjoint software (SPSS, 2008) to obtain an orthogonal design, which consisted of only the main effects. The design resulted in 18 fractional factorial profile plans or alternatives.

The choice set that resulted from this design was used to construct profiles describing the differences in traits and levels of improved cassava variety and these were presented to respondents in terms of hypothetical settings. The profile plans (alternatives) were then grouped into 6 types of questionnaires with three profile plans (alternatives) forming a choice set. Table 4.5 provides an example of one of the choice sets used in the choice experiment.

Table 4.5. An example of a choice set

Assuming that the following cassava varieties were your ONLY choices, which one would you prefer to plant?

1.6	Cassava variety 16	Cassava variety 17	Cassava variety 18
Productivity	15 tons per hectare	15 tons per hectare	30 tons per hectare
Disease and pest resistance	Resistant	Resistant	Resistant
In-soil storage	12 months or more	12 months or more	Less than 12 months
Multiple usage	Fufu and gari	Fufu and gari	Fufu and gari
Purchase price	₵30	₵45	₵15
I would prefer to buy	☐	☐	☐

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

Generally, there are two types of choice experiments: labelled and unlabelled choice experiments (Louviere *et al*., 2000). Unlabelled choice experiments use nonspecific titles for the alternatives (e.g., cassava variety "A" or "B") whilst labelled choice experiments use alternative-specific titles for the alternatives (e.g., "Bankyehemaa" or "Afisiafi"). From a theoretical view point, the number of alternatives, whether labelled or unlabelled, in a choice set is unrestricted (Hensher *et al*., 2005). Unlabelled 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, unlabelled choice experiments generate estimates of the relative importance of the attributes of the products themselves and also 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 would be to consider cassava variety name that appeals to him/her only. In that case, respondents' perceptions of the cassava variety rather than the attribute descriptions in the choice scenario would 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 focussing attention on the attributes of the cassava variety they would be focusing on the names of the cassava. This action would compromise the estimation of the trade-offs between the attributes in the choice model which is the main aim of this studies. Presenting generic unlabelled cassava 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.

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 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 cassava variety profile to the survey respondents. Figure 3.2 presents an example of a choice card presented to farmers. Overall, a total of 8,100 choices were elicited from 450 farmers that took part in the choice experiment. The choice experiment administration was conducted in the following ways: the respondents were introduced to six choice sets and were asked to choose one out of the three given cassava profiles from each choice set. Unlike the traditional choice experiment, no “opt-out” was included in the choice sets. The farmer had to choose amongst one of the alternatives. The reasons being that the study did not focus on finding the willingness to pay for improved cassava varieties but rather marginal willingness to pay for the attributes of the variety and, therefore, it was not necessary to include an opt-out alternative (Carlsson *et al*., 2007). Also, cassava is traditionally part of the farming systems in the study areas and therefore compelling them to make a choice is not out of place (Asrat *et al*., 2009).

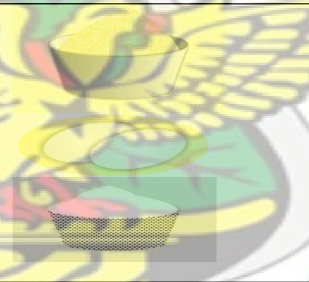
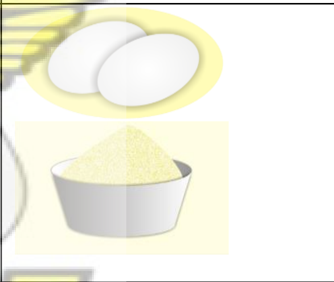
	Cassava variety 1	Cassava variety 2	Cassava variety 3
Productivity			
	15t/ha	30t/ha	30t/ha
Disease and pest resistance			
	Not resistant	Resistant	Not resistant
In-soil storage			
	less than 12 months	12 months or more	12 months or more
Fresh tuber usage			
	Dough and Gari	Gari, Fufu and dough	Fufu and gari
Purchase price			
	GH¢15	GH¢15	GH¢45

Figure 4.2. An example of a choice card

4.3.4. The empirical model specification of farmer preferences

The conditional logit, mixed logit and latent class models discussed in chapter 3 are used in this study to investigate farmers' preferences and the existence of cassava trait preference heterogeneity amongst cassava producers in the study area. Estimation of the models requires a specification of the functional form of the utility function. In this study, a linear in parameters utility function is assumed. The vector X_{njt} in equation (3.11) contains cassava traits and trait levels of cassava profiles from the choice experiment. The choice experiment was designed with the assumption that the observable utility function would follow a strictly additive form (Birol, 2004). The model was specified so that the probability of selecting a particular cassava variety was a function of attributes of that variety. That is, for the population represented by the sample, indirect utility from cassava variety attributes takes the form;

$$v_{nj} = \beta_1 Z_{pprice} + \beta_2 Z_{productivity} + \beta_3 Z_{diseaeR} + \beta_4 Z_{soilstor} + \beta_5 Z_{usage} + \varepsilon \qquad (4.1)$$

where β_{1-5} refer to the vector of coefficients associated with the vector of attributes describing a cassava 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 is dropped in the above specification of the indirect utility function because the choice sets do not include a status quo or an opt-out option (Bateman *et al*., 2003). This is a base model which specifies the utility function with the main effects variables in the choice experiment. Besides the mean coefficients of variables from the sample population, mixed logit also estimates the amount of spread that exists around the mean of the random parameter and provides estimates of individual specific parameter estimates. Each farmer makes repeated choices for six cassava profiles.

Several socio-economic factors influence preference and choice behaviour as presented in the choice model framework in Figure 3.1. These factors enter into the models as interactions with the *X's* in the utility function in equation (4.1). The indirect utility function is as presented in equation (4.2).

$$Vnj = \beta_1 Z_{pprice} + \beta_2 Z_{productivity} + \beta_3 Z_{diseaeR} + \beta_4 Z_{soilstor} + \beta_5 Z_{usage} + \partial_1 \left(Z_{pprice} * sex \right)$$
$$+ \partial_2 \left(Z_{productivity} * sex \right) + \partial_3 \left(Z_{diseaser} * sex \right) + \ldots + \partial_5 \left(Z_{usage} * sex \right) + \ldots + \partial_{10} \left(Z_{usage} * hh \right)$$
$$+ .. \partial_{35} \left(Z_{pprice} * \exp \right) + \varepsilon \tag{4.2}$$

4.3.5. Variable description and hypothesized relationships with preference of cassava variety trait

Table 4.5 presents the cassava trait levels that entered the deterministic portion of the utility functions for the conditional logit and the mixed logit models and their expected direction of influence on the utility function. The data were coded according to the levels of the attributes used in the choice experiment. Attributes with two levels entered the utility function as binary variables that were effects coded (Louviere *et al*., 2000).

For Disease resistance (resistance to cassava mosaic virus disease) variable, not resistant to cassava mosaic virus disease was entered as -1 and resistant to cassava mosaic virus disease was entered as 1. For in-soil storage variable, cassava varieties that are able to remain in the soil for 12 months or more were entered as 1 whilst those that are unable to remain in the soil for that period were entered as -1.

For usage attribute, varieties that are good for “Gari and dough” were entered as 0, those that are good for “fufu and Gari” were entered as -1 and those that are good for “gari, fufu and dough” were entered as 1. The levels used for purchase price and productivity were entered in a cardinal-linear form using their actual levels. As a result, the purchase price attribute took levels 15, 30, and 45. In the same way, the productivity attribute took levels 15, 30, and 60.

Table 4.5. Choice experiment variable coding and expected sign

Attribute	Description	Levels	Codes	Expected sign
Productivity	Yield per hectare	15t/ha 30t/ha 60t/ha	15 30 60	Positive
Disease resistance	Whether resistant or not resistant to cassava mosaic virus disease (CMVD)	Not resistant Resistant	-1 1	Positive
In-soil storage	Whether the variety can remain in the soil for 12 months or more or less than 12 months after maturity	Less than 12months 12 months or more	-1 1	Positive
Multiple usage	The use of variety for 'fufu', 'gari' or 'dough'	Gari and dough Gari and fufu Fufu, gari, and dough	0 -1 1	Positive
Purchase price	Selling price per 91kg of cassava roots	₵15 ₵30 ₵45	15 30 45	Negative

What is observable by the analyst is the choice made by the decision maker, which is assumed to be the utility maximizing alternative. Choice is a binary dependent variable which takes the value of 1 for the chosen alternative and 0 for the non-chosen alternatives. From an a priori perspective, the trait levels 'high productivity', 'high resistance to diseases', 'high root longevity in the soil' and 'multiple usage' are expected to increase a producer's utility. High productivity is expected to increase production per hectare and thus increase farmers' food stock and income. Therefore high productivity is expected to influence farmers' utility positively. A high resistance to cassava diseases such as cassava mosaic virus diseases would have a positive impact on productivity and thus on utility. Since cassava harvesting is spread over a period of time in the study area, good root longevity in the soil is expected to increase utility. Similarly, multiple usage is expected to influence utility positively as that guarantees all year round consumption. Finally, the trait coefficients associated with purchase price, that is, selling price of cassava is expected to have a negative sign due to the negative marginal utility for cost generally exhibited by most individuals.

Most important socio-demographic variables considered are gender, age, experience and education of the decision maker, 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 cassava farmers who have education will be able to 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 labour constrained, especially if some of the cassava traits require special type of labour. For instance, a trait such as high productivity often requires lots of hired labour during harvesting and the cost of hired labour may be unable to be realized by female headed households. Lack of market access for cassava and cassava products may adversely affect utilities for high productivity traits and multiple usage. It is therefore hypothesized that farmers who are closely located to a market or an urban centre will most likely be interested in increased cassava production due to a secure opportunity to market their produce.

4.3.6. Enumerator training and pretesting

Four enumerators were trained to carry out the farmer survey in each district. They included the two extension agents and the two technicians who helped in the focus group discussions. The principal investigator doubled as an enumerator and a supervisor. The criteria for the selection of the enumerators were level of education; fluency in spoken and written English; and good knowledge of the local language. 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 as to the right interpretation of questions since the interview involved translating the questionnaire into the local language. The need for the interviewers to keep sensitive information confidential was also emphasized during the training. The questionnaires were pre-tested with thirty households (ten from each district) that did not form part of the study. Pre-testing was essential to determine the strengths and weaknesses of the survey concerning question clarity, format, wording, flow, order and timing. After pre-testing, the researcher 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 understandable to both the interviewers and the respondents without changing the original meaning of questions.

4.3.5. Data analysis

The study employed both descriptive and inferential statistical analysis. 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 cassava variety traits. Farmers' preferences and willingness to pay were analysed using the conditional and the mixed logit models. Finally, the adoption data was evaluated using the logit and the multinomial logit regression models. Details of the theoretical and analytical frameworks for the above mentioned models are as presented in Chapter 3. Analyses were carried out using SPSS 16.0 and Stata 11.2.

4.3.6. Limitations of the study

There was no genetic information, as recognized by geneticists, used to differentiate improved varieties from local varieties. There were no real measurements (e.g. DNA testing) but physical appearance was mainly used to detect whether a cassava variety is local or improved. Another problem involved questions that required the respondents to recall events from the past. These included 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 were thoroughly trained before starting the survey, to minimize possible lack of clarity.

4.4. Chapter summary

The study area covered three districts - Atwima Nwabiagya District in the Ashanti Region, Techiman Municipal in the Brong Ahafo Region and Fanteakwa District in the Eastern Region. These Districts are important for cassava production and have high concentration of farmers who are relatively poor and depend on subsistence agriculture as an important livelihood option, contributing to a significant portion of their household income.

The study was carried out in multiple and carefully sequenced phases. It began by exploring the magnitude of the problem and this served as a basis for the formulation of farm level and choice experiment questionnaires that were used to collect primary data. The choice experiment method is a useful tool for valuing non-priced traits. In order for the choice experiments to be effective, the experimental design and profile presentation to the decision makers need careful consideration. Experimental designs are fundamental components of choice experiments as they are mainly used to construct the choice profiles. Careful consideration is therefore needed to ensure that the designs are optimal or statistically efficient. Besides, it is also necessary to ensure that the choice experiment profiles do not place a significant level of cognitive burden on respondents since this is likely to result in response unreliability. Due to the high illiteracy rates and some differences in language the use of both paragraph and pictorial presentations were deemed plausible.

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Introduction

This chapter presents and discusses the results of the study. The chapter is organised into six sections. Following this introduction, the second section deals with the demographic characteristics of respondents and farm and institutional characteristics of the study area. In the third section, farmers' perceptions of technology characteristics are presented and discussed. Cassava trait preferences and willingness to pay of cassava traits by farmers are deduced and discussed in the fourth and fifth sections. The final section focuses on trait perception and adoption of improved cassava varieties.

5.2. Description of the survey data

5.2.1. Demographic characteristics of respondents

Farmers' demographic characteristics are known to affect their adoption decisions. Table 5.1 presents the demographic characteristics of the survey respondents. The proportions of male respondents were higher compared to the female respondents. Fifty two percent of respondents from the Atwima Nwabiagya District were males and 48 % were females. In the Techiman Municipal Area the percent of males and females were 54 and 46 respectively. Fanteakwa District had the highest proportion of respondents being males (77% males and 23% females). Fanteakwa District, compared to the other two Districts, is typically rural. In typical rural communities females mainly help their male counterparts to undertake farming activities. The males are thus the owners of the farms and participate in any activity concerning the farm.

Table 5.1. Demographic characteristics of respondents

Variable	Atwima Nwabiagya District (N=150)		Techiman Municipal Area (N=150)		Fanteakwa District (N=150)		All households (N=450)	
	N	%	N	%	N	%	N	%
Gender of respondents								
Male	78	52	81	54	115	76.7	274	60.9
Female	72	48	69	46	35	23.3	176	39.1
Age category								
15-30	10	6.7	13	8.7	26	17.3	49	10.9
31-50	91	60.7	76	50.7	79	52.7	246	54.7
51-65	39	26.0	51	34.0	39	26.0	159	28.7
66 through 80	10	6.7	10	6.7	6	4.0	26	5.8
Household size								
1-3	17	11.3	15	10.0	24	16.0	56	12.4
4-6	57	38.0	65	43.3	76	50.7	198	44.0
7-9	55	36.7	45	30.0	35	23.3	135	30.0
>9	21	14.0	25	16.7	15	10.0	61	13.0
Level of education								
None	31	20.7	52	34.7	26	17.3	109	24.2
Primary (basic)	104	69.3	84	56.0	109	72.7	297	66.0
Senior high school	10	6.7	12	8.0	8	5.34	20	6.6
Tertiary	5	3.3	2	1.3	7	4.67	14	3.1
Experience (years)								
1-5	26	17.3	20	13.3	17	11.3	63	14.0
6-10	26	17.3	23	15.3	29	19.3	78	17.3
11-15	19	12.7	9	6.0	19	12.7	47	10.4
16-20	28	18.7	27	18.0	44	29.3	99	22.0
>20	51	34.0	71	47.4	41	27.3	163	36.2
Use of hired labour								
Yes	134	89.33	131	87.33	122	81.33	387	86.00
No	16	10.67	19	12.67	28	18.67	63	14.00

Source: Farm level survey, 2011

Farmers from the three locations had higher proportions of respondents in the 31-50 years age category. The proportion of respondents from the Atwima Nwabiagya District, the Techiman Municipality and the Fanteakwa District in this age category were 60.7%, 50.7% and 52.7% respectively (Table 5.1). However, the Techiman Municipal Area had a significant proportion (34%) of respondents in the 51-65 years category. Generally, respondents from the Techiman Municipal seemed to be older than those in the other two

Districts. On household size, Fanteakwa District had the highest proportion (50.7%) of respondents with household size of 4-6 persons whilst Atwima Nwabiagya District had many respondents (36.7%) with household size of 7-9 persons. The majority of the respondents in all the three locations had basic level of education. Fanteakwa District had 72.7% of her respondents with the basic level of education, 5.4% with the senior high level of education and only 4.6% with tertiary level of education. In the Techiman Municipality, 34.7% of the respondents had no formal education, 56% had basic level education, while 8% and 1.3% had senior high and tertiary level of education respectively. The farming experiences of the respondents were quite substantial, meaning that respondents had accumulated a lot of knowledge. Respondents in Techiman Municipal Area had the highest number of respondents (47.4%) with more than 20 years farming experience. In all the three locations, many respondents had 16-20 years experience in farming.

Hired labour was very important in the study area. The majority of respondents in the study area hired labour to supplement family labour. Small proportions from all the locations did not hire labour during the 2009-2010 farming season. In the Atwima Nwabiagya District, as many as 89.3% of the respondents reported hiring labour during the 2009-2010 cropping season. In the Techiman Municipal Area and the Fanteakwa District, 87.3% and 81.3% of respondents respectively hired labour during the same period.

5.2.2. Farm characteristics

5.2.2.1. Farm size

Generally, respondents in all three locations possessed substantial pieces of land with an average farm size of 9.5 acres (3.8 ha). Average farm size was about 8 acres (3.2 ha) in Atwima Nwabiagya District, 11 acres (4.4 ha) in Techiman Municipal Area and about 10 acres (4 ha) in Fanteakwa District. The farm sizes in the surveyed area were bigger compared with the national average of 5 acres (2 ha) (MoFA, 2011). The seemingly larger farm sizes in the study areas may be attributed to easy access and land abundance in relation to other parts of the country

5.2.2.2. Land ownership and land tenure arrangements

The traditional and customary concepts of land ownership still prevail in the study areas. In two of the locations (Atwima Nwabiagya District and Techiman Municipality), inheritance of land was the dominant means of getting access to land. In these locations, most of the farmers contacted were natives. Table 5.2 presents the types of land tenure arrangement.

Table 5.2.Frequencies of types of land tenure arrangements by locations

Land tenure arrangement	Atwima Nwabiagya District (N=150)		Techiman Municipal Area (N=150)		Fanteakwa District (N=150)		All household (N=450)	
	N	%	N	%	N	%	N	%
Inheritance	100	66.7	105	70	63	42.0	268	59.6
Sharecropping	23	15.3	12	8.0	36	24.0	71	15.8
Renting	27	18.0	33	22.0	51	34.0	111	24.7

Source: Farm Level Survey, 2011

Land acquisition is mainly through inheritance whereby farmers indicated that their lands were either handed down to them or were family lands. This was very different in the Fanteakwa District as most (59%) of the farmers were settlers compared to 41% who were indigenes. Here, means of land ownership or access was mixed with inheritance still dominating. According to the respondents, land could be owned by purchasing and can also be inherited through relatives that first settled in the area. Fanteakwa District is part of the Afram plains where poor infrastructures are evident and most land owning indegenes sell their lands and migrate to the cities. The highest proportion of respondents that acquired land through sharecropping arrangements was in the Fanteakwa District and the lowest proportion was in the Techiman Municipal Area. The Fanteakwa District had the highest proportion of respondents that got access to land through land renting, followed by Techiman Municipal Area and Atwima Nwabiagya District.

5.2.3. Institutional characteristics

5.2.3.1. Market and market access

In the study area farmers sold their produce on the farm, on the roadside and in the marketplace. Many farmers marketed their produce on the farm. This was common with food crops like cassava, yam and plantain. Other marketers also bought food produce from the road side. Food crop farmers therefore looked for fields close to the roads and to market centres so that they could take advantage of the market systems that existed. Significant proportions (>85%) of respondents from Atwima Nwabiagya District, Techiman Municipal Area and Fanteakwa District reported they had access to markets. Table 5.3 shows the mean and standard deviations of distances to markets by locations.

Average distance from a community to a food crop market was 4 km in Atwima Nwabiagya District compared with about 9 km in Techiman Municipal Area and Fanteakwa District. Techiman Municipal Area and Fanteakwa District were quite rural with communities quite distant from the District centres where a lot of marketing activities took place. In all the study areas farmers did not have to travel for long distances to their fields. The mean length of trekking to their fields was about 3.5 km in Techiman Municipal Area and Fanteakwa District and 2.5 km in Atwima Nwabiagya District. The average length in kilometres a farmer had to walk from field to the road is also relatively short. The mean distance from field to main road is about 1km in Atwima Nwabiagya District and 2km in Techiman Municipality and Fanteakwa District.

Due to poor road network to farmers' fields, food produce from the production sites are headloaded to the road sides where vehicles cart them to the market centres. Major food crops like cassava, plantain and cocoyam are not sold out immediately after maturity due to the cost involved in bringing them to the road side. They are allowed to stand in the field and harvested only when the means of transport is assured. For example, cassava fields are normally sold to traders who then harvest and transport at their own cost. This is the main reason why farmers preferred fields close to the road.

Table 5.3. Means and standard deviations of distances to market centres by locations

Variable		Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households (N=450)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Distance to field from village (km)		2.46	1.74	3.54	3.44	3.43	3.59	3.14	3.13
Distance to main road from field (Km)		1.34	1.13	2.41	2.66	2.34	3.84	2.03	2.11
Distance from farm to food crop market (km)		4.43	3.07	8.61	9.50	8.59	4.70	7.22	6.65
Market access (%)	no	2	1.33	26	17.33	28	18.67	56	12.44
	yes	148	98.67	124	82.67	122	81.33	394	87.56

Source: Farm level survey, 2011

5.2.3.2. Access to credit

Farmers in the study areas had limited access to credit. Farmers access to credit and sources of credit are presented in Table 5.4.

Table 5.4. Distribution of farmers on access and sources of credit

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households(N=450)	
	N	%	N	%	N	%	N	%
Access to credit								
Yes	19	12.7	16	10.7	16	10.7	51	11.3
No	131	87.3	134	89.3	134	89.3	399	88.7
Sources of credit								
Government programme	6	4.0	2	1.3	3	2.1	11	2.3
Commercial/rural bank	6	4.0	9	6.0	9	6.0	24	5.3
Family member	1	0.7	2	1.3	3	2.1	8	1.8
Money lender	6	4.0	3	2.1	1	0.5	8	1.8

Source: Farm level survey, 2011

Though formal and informal financial institutions existed, lack of collateral made it impossible to access credit from them. Also, interest rates charged on loans were very high and farmers thought the risk involved in loans acquisition was too high and so preferred to use their own savings. Banks' lending rates to the agricultural sector in 2010 ranged between 27.63% and 32.75% (MoFA, 2011). Only 4% of respondents from the Atwima Nwabiagya District had access to formal credit. In the Techiman Municipal Area and Fanteakwa District only 6% of respondents reported accessing loans from a commercial bank. The only government programme that gave credit to farmers was the Block Farm Programme through the Ministry of Food and Agriculture. Through the programme, farmers are given inputs for all farming activities in kind. At the end of the farming season farmers are expected to pay back in cash. The limitation of loans tied to programmes is that the farmer is restricted as he is not able to buy other important inputs. For example, labour input is hardly covered by such loans despite its importance. Only 4% of farming households in Atwima Nwabiagya District participated in such credit facility. In Techiman Municipal Area and Fanteakwa District, 1.3% and 2% respectively of the respondents participated.

With limited sources of external credit facilities, farmers rely on their own resources. Farmers sourced funding from three sources: crops sales, livestock sales and nonfarm activities. Incomes from crops were the main source of funds for farming activities. Table 5.5 shows the incomes from crops, livestock and off farm activities in the three locations for 2010-2011 cropping season.

Table 5.5. Means and standard deviations of incomes from crops, livestock and nonfarm activities by location for 2009-2010

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Crop income (₵)	2729	4546	3758	12947	1115	1157	2533	8007
Livestock income(₵)	65	217	302	1256	124	285	164	758
Nonfarm income (₵)	709	1556	788	1457	455	892	361	1337

Source: Farm Household survey, 2011

From Table 5.5, the mean incomes from crops were ₵2729, ₵3758 and ₵1115 respectively for Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District. Mean incomes from livestock were ₵65, ₵302 and ₵ 124 and that from nonfarm activities were ₵709, ₵ 788 and ₵ 455 for Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District respectively. Farmers therefore receive less in livestock sales and nonfarm activities. They earn significantly more from crops sales which they use to fund domestic and farm activities. Crop production, of which cassava is key, is therefore very important in the study areas.

5.2.3.3. Access to extension services

Agricultural extension is seen as the entire set of organizations that support and facilitate engagements in agricultural production to solve problems and to obtain information, skills, and technologies to improve livelihoods and well-being (Birner *et al*., 2006). In Ghana the role of agricultural extension agents is to transfer agricultural innovations from development centres to implementation centres. Technologies generated by research institutions and by the farmers are expected to be disseminated amongst end users through the extension system. In the study area the majority of respondents have had access to extension agents. Table 5.6 presents farmers' access to extension in the study areas.

Table 5.6. Distribution of respondents on extension access

Variable	Atwima Nwabiagya (N=150)		Techiman Municipal (N=150)		Fanteakwa District (N=150)		All households (N=450)	
	N	%	N	%	N	%	N	%
Extension contact								
Yes	96	64.0	82	54.7	83	55.3	261	58
No	54	36.0	68	45.3	67	44.7	189	42
Cassava field day participation								
Yes	13	8.7	21	14.0	16	10.7	50	11.1
No	137	91.3	129	86.0	134	89.3	400	88.9

Source: Farm level survey, 2011

Sixty four percent (64%) of respondents from the Atwima Nwabiagya District were visited by extension agents in the 2009-2010 cropping season. In the Techiman Municipal and Fanteakwa District, 54.7% and 55.3% of respondents respectively had ever had contact with extension agents. Extension activities such as Farmer field days and field demonstrations are important in the dissemination of agricultural technologies. However, farmers in the study area had limited access to these activities. Only 8.7%, 14% and 10.7% of respondents respectively from the Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District participated in cassava field days in the 2009-2010 cropping season.

5.2.4. Livelihood activities and strategies

Livelihood activities are observed by the consideration of economic activities engaged in by farmers, and the importance of the different sources of cash incomes (Niehof, 2004). In the study areas two groups of livelihood strategies are recognized: farming and nonfarm enterprises.

5.2.4.1. Farming

Farming is the main livelihood activity of households in all the three study areas. Mixed farming involving crop, livestock and birds production was common amongst the farming households. Also, mixed cropping involving the cultivation of more than one crop on the same field was a common practice. Crop production was a primary activity for all respondents. Livestock and birds production, however, was not undertaken by all farming households. Livestock produced included sheep, goat, and pigs. The production of livestock is very paramount as they are used to offset shortfall in crop incomes during periods of food crops scarcity and also serve as source of meat during festive occasions. The most important food crops produced in all the locations in order of importance were cassava, plantains, maize, cocoyam and yams. Cash crops like cocoa, oil palm and cashew were produced by some farmers as well. Table 5.7 presents the land under production of food crops as well as cash crops and their value in 2009-2010 production seasons. The three most significant crops in terms of acreage and value of produce are cassava, plantain and maize. The value of produce was computed by multiplying the quantity produced by the prevailing market prices at the time of the study. These crops are staples of all the three locations. Cassava-maize-plantain intercrop is a common practice amongst all the respondents.

Cash crops productions are not so important in the study areas. Cocoa, the leading cash crop, is produced to some extent across the locations. Techiman Municipal Area had no land under oil palm production and Atwima Nwabiagya had no land under cashew production (Table 5.8). For cash crops production, large stretch of land are normally needed which can be obtained very far from the communities and so few farmers take up the challenge.

Compared with plantain and maize, cassava provides the highest cash income across the locations. Techiman Municipal Area had the highest value of cassava and it is due to some commercial production of cassava in that area. All the food crops are primarily grown for home consumption and the surplus marketed.

Table 5.7. Means and standard deviations of land size and value of food produced in the three surveyed locations for 2009-2010 production season

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households (N=450)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Food crop production								
Land under cassava (ha)	1.00	0.68	1.40	1.76	1.20	1.04	1.20	1.24
Land under maize (ha)	0.32	0.56	1.04	3.60	0.88	1.04	0.76	2.20
Land under plantain (ha)	0.44	0.68	0.44	0.68	0.36	0.52	0.40	0.60
Land under cocoyam(ha)	0.16	0.76	0.08	0.28	0.20	0.36	0.16	0.52
Land under yam (ha)	0.04	0.03	0.36	0.44	0.04	0.20	0.12	0.03
Value of cassava produced (₵)	793	986	3964	1444	279	278	1632	876
Value of maize produced (₵)	189.7	367.5	684.95	2300	251.0	271	341	240
Value of plantain produced(₵)	390	831	202	474	295	723	335.3	757
Value of cocoyam produced (₵)	93	404	31	116	326	442	128	395
Value of yams produced (₵)	0.33	4.0	693	779	118	201	190	500

Source: Farm level survey, 2011

Table 5.8. Means and standard deviations of land size and value of cash crops produced by location for 2009-2010 production season

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households (N=450)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cash crops production								
Land under cocoa (ha)	0.48	1.12	0.28	1.08	0.16	0.24	0.32	0.96
Land under oil palm (ha)	0.12	0.68	0.0	0.0	0.032	0.36	0.08	0.68
Land under cashew(ha)	0.0	0.0	0.03	0.10	0.003	0.01	0.01	0.06
Value of cocoa produced (₵)	311.7	818	323.2	658.8	251.5	313.6	309.7	766
Value of palm oil produced (₵)	13.4	81.7	0.0	0.0	117.5	285.4	14.4	89.5
Value of cashew produced (₵)	0.0	0.0	24.1	92.17	960.0	2145.6	29.9	355.5

Source: Farm level survey, 2011

Vegetables like tomatoes, garden eggs, pepper and okra are also produced in all the locations. However, very few farmers commit any significant farm lands to vegetable production. From Table 5.9 it is apparent that very small pieces of land are used to produce vegetables. The average land sizes under vegetables production in all the three districts are comparable. The vegetables are grown near river bodies and sold in the local urban markets or in bigger cities. Vegetable production is usually practiced by young men as it is labour-intensive and involves watering, frequent weeding, pest and disease control and frequent picking.

Table 5.9. Means and standard deviations of land and value of selected vegetables produced by locations for 2009-2010 production season

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households (N=450)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Land under tomatoes (ha)	0.00	0.00	0.08	0.05	0.06	0.18	0.03	0.28
Land under garden eggs (ha)	0.004	0.24	0.02	0.20	0.04	0.12	0.20	1.12
Land under pepper (ha)	0.004	0.03	0.004	0.28	0.028	1.96	0.08	1.12
Value of tomatoes (₵)	0.0	0.0	13.5	89.3	156.9	595.4	56.8	354.0
Value of garden eggs (₵)	3.1	34.4	11.4	100.2	18.38	71.1	10.73	73.8
Value of pepper (₵)	0.9	11.0	45.8	272.1	26.9	98.83	24.5	167.6

Source: Farm level survey, 2011

5.2.4.2. Nonfarm employment

Although agriculture was the main livelihood activity in the study area, many other activities contributed to household income. However, the importance of these activities compared to agriculture is minimal in the study area. Table 5.10 depicts the distribution of nonfarm activities of farmers in the three Districts.

Table 5.10. Distribution of nonfarm employment by District

Variable	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District		All households(N =450)	
	N	%	N	%	N	%	N	%
Employment type								
Formal employment	3	2.0	4	2.7	6	4.0	13	2.9
Trading	28	18.7	50	33.3	41	27.3	119	26.5
others	4	2.7	11	7.3	13	8.7	28	6.2

Source: Farm level survey, 2011

Only 2% of the respondents in the Atwima Nwabiagya District were employed in the formal sector. In the Techiman Municipal Area and the Fanteakwa District only 2.7% and 4% respectively of respondents were in formal employment. Similarly, 18.7% of respondents from the Atwima Nwabiagya District were engaged in trading. Techiman Municipal Area had the highest proportion of respondents engaged in trading activities (Table 5.10). Techiman Municipality has one of the most vibrant markets in Ghana as traders from all over the country and beyond participate in that market. Farmers here take active part in that market, trading mostly in agricultural produce. Trading activities include buying and selling of maize, yams, cassava, plantain, vegetables and livestock. Others types of employment include carpentry, masonry and tailoring.

5.3. Farmers perception of cassava variety traits

This section presents the findings on cassava varieties that are grown in the study area, their characteristics and farmers' perceptions on the characteristics of the varieties grown. In addition, farmers' perceptions of both improved and local varieties are reported. The analysis is drawn mainly from the qualitative data.

5.3.1. Farmers cassava varieties and perceptions of characteristics of the varieties

Many local cassava varieties were cultivated by farmers in the study regions and districts. Only a few improved varieties were cultivated. The most common local and improved varieties grown are as shown in Table 5.11.

Table 5. 11. Cassava varieties grown in the study area

Name of Cassava variety	% of farmers growing a variety		
	Atwima Nwabiagya N=51	Techiman Municipal N=49	Fanteakwa District N=53
Local varieties			
Debor	100	100	100
Esiabayaa	80	-	-
Amodogo	60	-	-
Tuaka/Bosomnsia	90	-	75
Bankye fofoo	-	80	-
Wenchi Bankye (Nkruwa)	-	100	-
Bensere bankye	-	100	-
Nkomte	-	60	-
Ahaban green	-	-	70
Bensere	-	-	100
Anti Bea	-	-	80
Ankra	-	-	65
Improved varieties			
Afisiafi	19.6	20.4	17
Abasafitaa	-	8.2	8.2
Bankyehemaa	11.7	16.3	-

Note: Percentages are computed based on opinions of the number of farmers who attended the focus group discussions and rounded to the nearest tenth.

From Table 5.11 it is obvious that a number of cassava varieties are cultivated in all the Districts. All the farmers cultivated more than one cassava variety on their farms probably due to the different characteristics exhibited by different varieties. One variety that seemed to be planted by all the farmers across all the three districts was D*ebor*. *Debor* was popular because its roots could be used for *fufu* throughout the year. It is high yielding, stores longer in the soil after maturity and it is good for intercropping, the main cropping system practiced in the study area. The local varieties had various names from each of the districts. In all instances, the same local varieties were known by different names depending on the location. For instance, at the Atwima Nwabiagya District in the Ashanti

Region, *Tuaka*, a local variety known to mature in 6 months is similar to *Bosomnsia* at the Fanteakwa District in the Eastern Region which also matures in 6 months.

The names of the local cassava varieties were often descriptive, referring to certain key identifiable characteristics especially stem colour, appearance, growth habit and the perceived place of origin. For example, *Esiabaayaa* literally refers to a young woman by name *Esi*, probably because that woman first planted that variety in the district. Odendo *et al.,* (2001), in their study of maize variety preferences, also found similar results from the farmers in Kenya concerning the names of the local varieties.

Tables 5.12, 5.13 and 5.14 show the local and improved cassava varieties commonly cultivated at the various districts and their perceived characteristics as mentioned during the focus group discussions.

Table 5.12. Farmers' perception of attributes in different categories of cassava varieties at Atwima Nwabiagya District

	Varieties					
Attributes	*Edebor*	*Esiabayaa*	*Amodogo*	*Tuaka*	*Afisiafi*	*Bakyehemaa*
Yield	5	3	3	4	5	5
Disease tolerance	5	4	5	5	5	5
Days to maturity	3	4	5	5	4	4
Soil storage	5	5	5	2	3	3
Intercropping	5	2	5	5	1	5
Lodging	1	1	5	1	1	1
Usage (Fufu+gari)	5	5	5	5	1	1

Key: 1= poor and 5 = very good

Table 5.13. Farmers' perception of attributes in different categories of cassava varieties at Techiman Municipal

Attributes	Varieties						
	Edebor	*Bankye fofoo*	*Wankyi Bankye*	*Bensere*	*Nkomte*	*Afisiafi*	*Bankye hemaa*
Yield	5	4	5	5	4	5	5
Disease tolerance	5	5	5	5	5	5	5
Days to maturity	3	5	3	3	4	4	4
Soil storage	5	4	5	5	5	4	4
Intercropping	5	3	5	5	5	1	5
Lodging	1	1	1	1	1	1	1
Usage(Fufu+gari)	5	5	5	3	5	1	1

Key: 1= poor and 5 = very good

Table 5.14.Farmers' perception of attributes in different categories of cassava varieties at Fanteakwa District

Attributes	Varieties						
	Edebor	*Bensere*	*Anti Bea*	*Bosumnsia*	*Ankra*	*Afisiafi*	*Bankye hemaa*
Yield	5	4	5	4	5	5	5
Disease tolerance	5	5	5	5	5	5	5
Days to maturity	3	4	4	5	4	5	5
Soil storage	5	5	5	5	5	3	3
Intercropping	5	5	5	5	5	1	4
Lodging	1	1	1	1	1	1	1
Usage(Fufu+gari)	5	5	5	5	5	1	2

Key: 1= poor and 5 = very good

The characteristics of the local varieties were comparable with the improved varieties (*Afisiafi* and *Bankyehemaa*) in all the Districts. The only exceptions were with the usage and soil storage characteristics where the improved varieties were rated poor compared with the local varieties. Farmers claimed that the improved varieties deteriorate shortly after maturity in the soil and cannot be used for "fufu" (local food) preparation. Farmers are therefore discouraged to participate in the production of improved varieties as they have to wait for buyers before harvesting and this sometimes can take a year or more.

Also, the fact that the improved varieties could not be used for "fufu" was enough for them not to participate in their production.

5.3.2. Cassava variety attribute ranking

To gain an understanding of the importance of various cassava characteristics, farmers were asked to rate the following characteristics: early maturing, productivity, disease resistance, fresh root usage and in-soil storage as very important, important and somewhat important. The results are as shown in Figure 5.1.

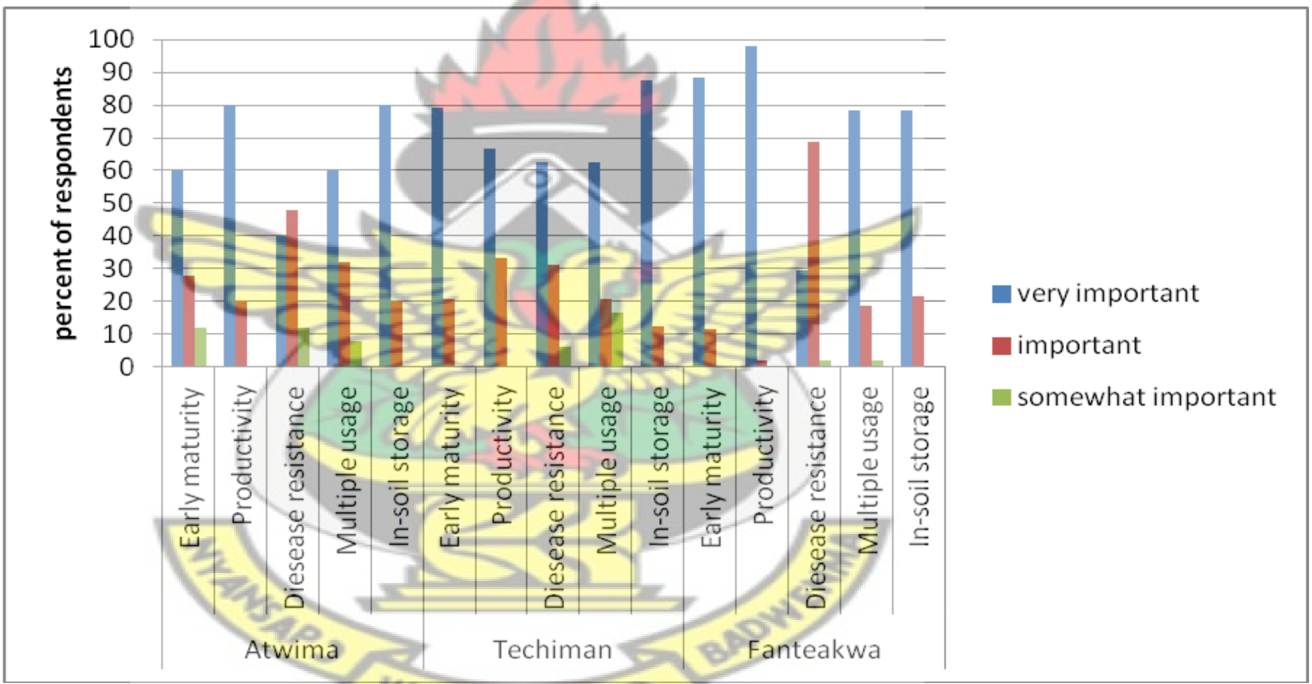


Figure 5.1. Rating of some cassava variety traits from the focus group discussions (N=150)

Depending on the district, different percentages of farmers placed different level of importance on different characteristics. The majority of farmers (60% from Atwima Nwabiagya District, 79.2% from Techiman Municipal and 88.2% from Fanteakwa District) placed great importance on early maturity. The early maturing varieties, according to farmers, are harvested in 6 months when most food crops cannot be harvested and thus help fill hunger gaps.

Productivity was very important to all the farmers in the entire three districts. Almost all the farmers (98%) from the Fanteakwa District thought productivity was very important. Cassava is no more a subsistence crop - it is now grown primarily as a source of income generation either by direct marketing of the fresh cassava roots or processed cassava products, for example 'gari'. Farmers now want more efficient production - production in which cost per unit area is lower with higher yields and a higher market price. Though it was evident that farmers needed high yielding varieties to be able to improve livelihoods, they had not taken advantage of the high yielding improved varieties that met their concerns.

Many cassava farmers were keen on in-soil storage because that is the main storage system for cassava in many cassava growing areas in Ghana. Thus, 87.7%, 80% and 78.4% of farmers from the Techiman Municipal, Atwima Nwabiagya and Fanteakwa Districts respectively rated in-soil storage as very important. Cassava has no sharply defined maturity period and harvest may extend over several weeks or even months, determined by utilization systems (Nweke, 2004). The farmers interviewed affirmed that some local varieties like *Ededor* could remain in the soil for up to 36 months and could be pounded (used for fufu) all through those months.

Rating of disease resistance was, however, mixed. In the Fanteakwa District only 29.4% rated disease resistance as very important. In the Techiman Municipal Area 62.5% of respondents rated it as very important whilst 40% from the Atwima Nwabiagya District rated it very important. The result was not very surprising as most farmers had limited knowledge of diseases that affected cassava and their consequences on yields. They attributed low yields to bad weather conditions. Manu-Aduening *et al*. (2007) found similar responses in their study of farmers' perceptions and knowledge of cassava pests and diseases whereby most cassava farmers in Ghana were unaware of cassava diseases.

5.3.3. Assessment of characteristics of improved and local cassava varieties

Adoption or non-adoption of technologies may indicate farmer's assessment of appropriateness of the characteristics of the technology. Farmers' assessment of improved cassava varieties were solicited by asking farmers growing improved cassava to compare some characteristics of improved cassava varieties with that of local varieties in terms of disease susceptibility (CMVD), yield advantage, tuber usage ('Fufu') and in-soil storage. Figure 5.2 presents farmers' assessment of improved cassava varieties across the three districts. Most (86.96%) of the farmers perceived the improved cassava varieties as yielding higher than the local cassava varieties. Conversely, the local varieties are perceived to be more resistant to diseases than the improved varieties by 71.3% of the respondents. Again, the local varieties are perceived as better for 'fufu' preparation (local food) than the improved varieties. This concern was expressed by 79.01% of the respondents. The majority (95.56%) of the respondents also believed that the local varieties are more able to store longer in the soil after maturity than the improved varieties. The production (in-soil storage) and consumption (fufu preparation) characteristics of the local varieties are rated higher than the improved varieties.

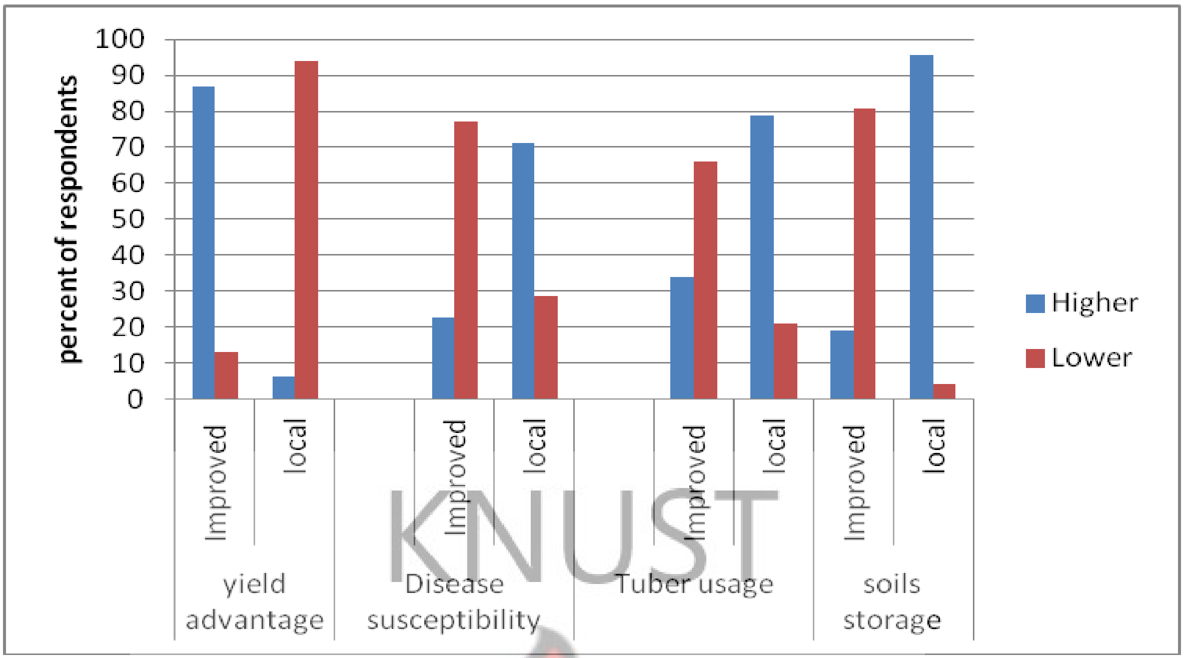


Figure 5.2. Assessment of improved and local cassava varieties by farmers growing improved cassava varieties (N=115)

Adoption studies have reiterated farmers' assessment of technology characteristics of improved technologies before adoption (Doss, 2003). Feder *et al*. (1985), in their seminal work on adoption of agricultural innovations in developing countries, found that yield performance is one of the characteristics of improved varieties that affect farmers' technological adoption behaviours. Adesina and Forson (1995) also reported that farmers in Burkina Faso adopted a modern sorghum variety because it gave high yield compared to the traditional sorghum variety that farmers planted in previous agricultural years. Again, Akankwasa *et al.* (2012) reported of farmers planting local banana varieties due to farmers' assessment of the improved hybrid bananas of being inferior in terms of consumption and production characteristics.

5.4. Farmers cassava traits preferences

This section presents the results of the econometric modelling estimations of choice behaviour and cassava trait preferences from the choice experiments data. The section is divided into two parts. The first part discusses results from the conditional logit analysis while the second part discusses results from the mixed logit analysis. A total of 450 complete choice experiment interviews were carried out for cassava, yielding panel data of 8100 complete choice sets. The conditional and the mixed logit models were estimated using StataTM statistical software version 11.2 (StataCorp, 2009).

5.4.1. Results of farmers preferences for cassava traits from conditional logit estimates

Table 5.15 presents the results of the maximum likelihood estimates for cassava traits for the pooled sample and the subsamples. The overall fit of the model is measured by McFadden's Pseudo-R^2. The Pseudo-R^2 should be above 0.1 to accept the model, whereas a value between 0.2 and 0.4 is considered as extremely good fit (Louviere *et al*., 2000; Scarpa *et al*., 2003a). From the model specifications the Pseudo-R^2 is 0.33, 0.34, 0.31 and 0.35 respectively for the pooled sample, Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District, which suggest the acceptance of the models. Moreover, the statistical significance of most of the regressors suggest that the attributes selected for the choice experiment survey were generally what farmers considered to be among the most important factors in cassava variety selection.

Table 5.15. Maximum likelihood estimates from choice experiment for pooled and districts data

Attribute	Pooled		Atwima Nwabiagya District		Techiman Municipal		Fanteakwa District	
	Coeff	Std err	Coeff	Std err	Coeff	Std err	Coeff	Std err
Purchase price(₵)	-0.013***	0.0022	-0.0104***	0.0039	-0.0094***	0.0039	-0.021***	0.0041
Productivity [6]	0.0278***	0.0016	0.0359***	0.0030	0.0229**	0.0027	0.0258***	0.0027
Disease resistance	0.1384***	0.0603	-0.3176***	0.1073	0.2398***	0.1016	0.4929***	0.1093
In – soil storage	2.3514***	0.0627	2.7428***	0.1231	2.2277***	0.1039	2.1524***	0.1036
Multiple usage	0.0304***	0.0304	0.0948*	0.0515	-0.0529	0.0513	0.0493	0.0526
Number of observation		8100		2700		2700		2700
Log-likelihood function		-2887.03		-1000.09		-983.05		-882.25
Pseudo R-square		0.33		0.34		0.32		0.35
Huasman test statistic (restricted option1 ($\chi^2(4) = 65.71$ $p - value = 0.000$								
Huasman test statistic (option 2 ($\chi^2(4) = 116.05$ $p - value = 0.000$								

Source: Farm level survey, 2011

[6] Note that the coefficients and standard errors for producers' price and productivity appear lower than the other coefficients and their standard errors because actual values (₵15, ₵30, ₵60) and (15t/ha, 30t/ha, 45t/ha) were used respectively. For a similar result see Asrat *et al*., (2009).

The results show that all the choice specific traits are significant for the pooled sample. Except for the *multiple usage* traits that showed insignificant but negative coefficient in Techiman Municipality and insignificant but positive in Fanteakwa District, all of the cassava variety attributes variables are statistically significant and they have the expected signs. This shows that they are important factors in the choice of cassava varieties and that any of the significant attributes increases the probability that a cassava variety is selected, all other attributes remaining constant. The results thus suggest that farmers care not only about *productivity* and *disease resistance* but also about *in-soil storage*. This finding is in line with focus group discussion results where participants rated *productivity*, *disease resistance* and *in-soil storage* traits as very important.

The coefficients for the *purchase price* for all the Districts are negative and significant, indicating that farmers prefer lower prices for the traits. Farmers would always want to buy at a lower price and therefore their negative utility for purchase price is not surprising. Similar results were obtained in a study by Ouma (2007) who found that cattle farmers in Ethiopia and Kenya preferred lower prices for cattle traits.

Farmers from different areas, whether urban or rural, have different concerns and may have different trait preferences (Birol, 2004). Where such differences in trait preferences across production areas exist, they should be considered in order to ensure an efficient design of breeding programmes. In order to compare if parameter estimates of the pooled model are shared across the three different study areas, separate conditional logit models have been calculated to obtain estimates for each study area. The null hypotheses that the parameter estimates of all the models from the pooled data and the subsamples are equal are tested against the alternative hypothesis that they are not equal. This has been done by checking if the log-likelihood function from the conditional logit estimation for the different sub-samples is significantly larger than the pooled sample log-likelihood function. The results from hypothesis tests are as shown below.

$$L_{pooled} = -2887.03 \quad and \quad L_{Atwima} = -1000.09$$
$$L_{Techiman} = -1983.05, \quad L_{Fanteakwa} = -882.25$$

The results indicate that the pooled data and the subsamples data are statistically different and consequently should not be pooled together.

The subsample results in Table 5.15 reiterate the importance farmers place on *in-soil storage trait* of cassava, thus confirming that farmers need other traits apart from *disease resistance* and *productivity* traits which are overemphasized in breeding programmes. The *multiple usage* trait is only positive and significant at 10% level for the Atwima Nwabiagya District sample. Cassava is the main food staple for the inhabitants of Atwima Nwabiagya District and it is normal that they care about the usage trait.

5.4.2. Influence of socio-demographic characteristics on trait preferences

Several socio-demographic variables have been interacted with the trait levels to assess their influence on trait preferences using conditional logit models. The results are presented in Table 5.16. The results were reported after the interaction terms were tested by removing the insignificant interaction terms as revealed by their p-values one after another and then re-estimating the model over and over again until only the significant ones remained. That is, out of the 35 possible interactions only those interactions that were significant at 10% level are reported. These results reveal that differences among farm households in terms of household characteristics, endowments (land size and household size), and knowledge (education and experience) affect farmers' choices and preferences for cassava variety traits.

Table 5.16. Conditional logit estimates for cassava traits with socio-economic factors

Variable	Coefficient	Std error
Purchase price (₵)	-0.2690***	0.02674
Productivity	0.1370***	0.00978
Disease resistance	4.5851***	0.4370
In-soil storage	3.727***	0.3800
Multiple usage	-0.2921	0.2669
Productivity *Experience	-0.090***	0.002
Disease resistance*gender	-1.101***	0.1896
Disease resistance*household size	-0.0678***	0.0324
Disease resistance*gender	-0.0515***	0.00923
Disease resistance*experience	0.0905***	0.0086
In-soil storage*age	0.0195***	0.0085
In-soil storage*experience	0.0373***	0.0079
multiple usage*gender	-0.2192**	0.1220
multiple usage*household size	-0.0966***	0.0209
multiple usage*age	0 .0126**	0.0060
multiple usage*farm size	0.0116***	0.0047
multiple usage*experience	0.0250***	0.0055
N	8100	
Log likelihood at convergence	-2852.71	
Likelihood ratio	2951.65	
Significance level	0.0000	
Pseudo R^2 =	0.34	

Source: Field level survey, 2011

The results indicate that when the socio-demographic characteristics are included, the *multiple usage* attribute is no longer statistically significant for the pooled sample. The rest of the choice specific attributes remain statistically significant, indicating that the data supports choice specific unconditional unobserved heterogeneity for these attributes. This shows that most of the positive utility derived from *multiple usage* attributes of cassava varieties, as are reported in previous results, is explained by the interaction terms between these attributes and the socio-demographic characteristics.

The interaction between *disease resistance* and gender was negative and statistically significant at 1%. This shows that females have low demand for disease resistance trait. The highly negative and significant coefficient may imply lack of knowledge about cassava mosaic virus disease. Females do not participate much in extension activities due to social inequalities and institutional discrimination (Ragasa, 2012). They probably do not know the effect of susceptibility of cassava varieties to cassava mosaic virus disease.

The interaction between age and *disease resistance* is significant but negative, indicating that older farmers are less concerned about disease resistance attribute. This is probably due to lack of knowledge about the devastating effect of cassava mosaic virus disease. The result is consistent with the survey results where farmers' knowledge of cassava mosaic virus disease was only minimal. The interaction between age and *in-soil storage* trait is positive and statistically significant at 1%. There is high demand for in-soil storage (longevity of underground storage) by the older respondents. This may be due to experience with cassava root rot disease. The interaction between age and *multiple usage* is also positive and significant indicating older farmers demand for cassava varieties that can be used for different food preparations.

The interaction between experience and *disease resistance* attribute is positive and statistically significant at 1%. More experienced farmers might have experienced the devastating effect of cassava mosaic virus on cassava yields. The demand for disease resistance is to avert the shock towards yield decreases associated with disease and pest occurrences in order to guarantee good outputs for family consumption and for sale. This finding is in conformity with the work by Asrat *et al*. (2009) where they found that farmers with more family members demand yield stability as a way of averting the shock associated with disease and pest occurrences.

Experience and demand for *in-soil storage* attribute is positive and statistically significant at 1%. More experienced farmers might have encountered cassava varieties that rot shortly after maturity in the ground. Cassava has very short shelf life and so farmers more often leave the matured roots in the soil and only harvest as and when the need for them arises or as piecemeal based on demand. Farmers with more experience have positive utility towards multiple usage attribute. This result is expected as more experienced farmers have formed a particular liking with particular uses of cassava.

The null hypothesis that the regression parameters for the restricted and the unrestricted models are equal was rejected under a log-likelihood ratio test[7]. The test statistics is 129.24, which is larger than 50.89, the critical value of chi square distribution at 30 degrees of freedom and 1% significance level. This implies that the conditional logit model with interactions which allows taste variations fits the data better than the conditional logit model without interactions that assumes fixed taste parameters.

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[7] $LR = -2 \ln \left(L(m1)/L(m2) \right) = 2 \left(ll(m2) - ll(m1) \right)$

5.4.3. Results of farmers preferences for cassava traits from the mixed logit estimates

The conditional logit assumes homogeneous preferences across respondents. The mixed logit model is estimated to further account for preference heterogeneity in the sample as the mixed logit model relaxes the IIA assumptions (Morey and Rossmann, 2003). Simulated maximum likelihood results for the mixed logit model that allows correlated random parameters using 500 Halton draws are reported in Table 5.17.

The mean coefficients for all the random parameters are positive and significant. Like what was revealed from the conditional logit model, all the respondents have positive preference for all the attributes. The coefficients of the random parameters are of the expected signs and are all significant at the 1% level. The model reveals preference for cassava varieties that are high yielding, disease resistant, command higher price, have long storage life in the soil after maturity and can be used for gari, fufu and dough.

The mean coefficient estimates of each of the random parameters are linked with standard deviations which indicate the amount of spread that are present in the sample population. With the exception of *multiple usage*, the standard deviations of each of the random parameters are highly significant showing preference heterogeneity in the population. The results also show that respondents have constant preference for *multiple usage* attribute hence its insignificant standard deviation coefficient. This result was not surprising as the levels for the *multiple usage* attribute were all very much appreciated equally by the respondents and the distribution for each of the three levels in the sample was 33.33%.

Table 5.17. Simulated maximum likelihood estimates for preferences from mixed logit

Variable	Coefficient	Standard error	Derived std deviation	Standard error
Non-random parameters in utility function				
Purchase price (₵)	-0.01803***	0.0024	-	-
Random parameters in utility function				
Productivity	0 .0076***	0.0016	0.0118**	0.0037
Disease resistance	0.8101***	0.1064	0.7894***	0.1014
In-soil storage	1.5073***	0.0208	0.4161***	0.1553
Multiple usage	0.4272***	0.0501	-0.1357	0.1044
Diagonal values in Cholesky matrix, L				
Productivity	0.0179***	0.0030		
Disease resistance	1.015***	0.1074		
In soil storage	0.5103***	0.1349		
Multiple usage	0.1899***	0.0602		
Below diagonal values in L matrix.				
Productivity: purchase price	0.0179***	0.0306		
Disease resistance : Producer price	0.8132***	0.1574		
Soil storage: purchase price	0.1746	0.1553		
Multiple usage: purchse price	0.0346	0.0652		
Disease resistance: purchase price	0.5815***	0.2132		
Soil storage: Disease resistance	0.0750	0.2287		
Multiple usage: productivity	0.1016	0.0848		
Soils storage: disease resistance	0.4735***	0.1419		
Multiple usage: disease resistance	0.1564**	0.0757		
Multiple usage: soils storage	0.0084	0.1270		
N	8100			
Likelihood ratio	30.19***			
Mcfadden R-squred	0.24			
Log likelihood	-2547.88			
Halton draws	500			

Notes: ** significant at 5%, ***significant at 1%
Source: Choice experiment survey, 2011

The estimates in Table 5.17 show that the coefficients are independently distributed while, in reality, one would generally expect correlation. For instance, farmers who are especially concerned about purchase price might also be concerned about productivity, particularly since higher yield might reduce prices. To investigate these possibilities the Cholesky decomposition matrix[8] which reveals the correlation structure over the random parameter estimates is estimated, making it possible to calculate the independent standard deviations associated with each random parameter (Hensher *et al*., 2005). The coefficient vector is expressed $\beta_n = \beta + LU_n$, where L is a lower-triangular Cholesky factor of Ω, such that LL' = Ω. β and L are estimated and standard errors for elements of Ω is calculated.

The significant below-diagonal elements in the Cholesky decomposition matrix in Table 5.17 suggest significant cross-parameter correlations (Hensher *et al*., 2005). The diagonal values in the Cholesky matrix are statistically significant for all random parameters at the 1% level. This implies that most of the random parameters are actually independently heterogeneous in the population. The magnitudes of the diagonal value parameters are much higher than their reported standard deviations, revealing unconfoundment with other parameters. For instance, the diagonal value of Disease resistant parameter is 1.015 which is larger and statistically significant at 1%, but its standard deviation is 0.7894 which is lower and significant at 1%. The below diagonal values in the Cholesky matrix reveal that its significant standard deviation did not result from cross correlation with productivity, in-soil storage and multiple usage parameters. Its individual dispersion is statistically significant implying heterogeneity in the parameter estimate in the population.

The estimated means and recalculated standard deviations of the random coefficients provide information on the shares of the population that place a positive or negative value on each of the cassava traits. This is obtained by calculating the proportion of observations

[8] The Cholesky matrix is a positive definite matrix. The diagonal values represent the amount of variance attributable to a random parameter when the correlations with subsequently named random parameters have been removed. The below diagonal values represent the amount of cross-parameter correlations which are confounded with the standard deviation parameters of the model (Hensher *et al*., 2005).

covered by the standard deviation above and below the mean, for a normal distribution[9]. Productivity trait is preferred by 66% of the population, disease resistance trait is preferred by 78% of the population, in- storage trait is preferred by 99% of the population and multiple usage traits is preferred by 97% of the population. These results confirm that in as much as the productivity trait is preferred, the other traits (*in-soil storage, disease resistance and multiple usage*) are more preferred by the sample population.

Table 5.18 shows the maximum likelihood estimates of preferences for Atwima Nwabiagya District, Techiman Municipal Area and Fanteakwa District. The Pseudo-R^2 for the Districts are relatively low as compared to the Pseudo-R^2 of the pooled sample. The low Pseudo-R^2 suggests that other attributes such as canopy formation and tuber skin colour that were not accounted for may also be important characteristics for smallholders in the Districts.

Results from Table 5.18 indicate that the mean price coefficients are negative and significant in the three surveyed locations. This shows farmers' strong preferences for lower prices for inputs in all the Districts. Smallholders consider lower prices for inputs as beneficial since it increases their incomes and thereby improving their livelihoods.

[9]These figures are given by $100 \times \Phi(-\beta_k / S_k)$ where Φ is the cumulative standard normal distribution and β_k and S_k is the mean and standard deviations of Kth coefficient (Hole, 2008)

Table 5.18. Simulated maximum likelihood estimates of preferences for cassava traits for subsamples

	Atwima Nwabiagya District		Techiman Municipal Area		Fanteakwa District	
	Mean Coefficient	Standard error	Mean Coefficient	Standard error	Mean Coefficient	Standard error
Cassava attributes						
Purchase price (₵)	-0.010***	0.0040	-0.016***	0.0046	-0.031***	0.0046
Productivity	0 .0113	0.0025	0.00329	0.0034	0.0087***	0.00341
Disease resistance	0.1329***	0.1062	0.6060***	0.1618	1.0425***	0.1618
Soil storage	1.393***	0.1304	1.1210***	0.1316	1.0904***	0.1471
Multiple usage	0.3681***	0.0542	0 .1795***	0.0572	0.2579***	0.0579
Standard deviations of random parameters						
Productivity	0.010	0.0704	0.0101	0.060	0.0221***	0.0053
Disease resistance	0.4913***	0.1908	0.7438***	0.1736	1.1689***	0.1943
Soil storage	0.2741	0.3823	-0.3293	0.3032	0.6328***	0.2172
Multiple usage	0.0076	0.2236	-0.2152**	0.1231	-0.1865	0.1443
Likelihood ratio	2.32		9.18**		29.58***	
Halton Draws	500		500		500	
Log likelihood	-837.56		-867.25		-818.36	
Pseudo R^2	0.16		0.12		0.10	
N	2700		2700		2700	

Source; Choice experiment survey, 2011 ***significant at 1%

The *productivity* trait is only positive and statistically significant in the Fanteakwa District, while for the other two locations productivity seems to have a low rank in farmers' cassava trait preference, although the coefficients are positive. Fanteakwa District is mostly rural and farmers depend mostly on food crop production for their livelihoods. Atwima Nwabiagya District is mostly peri-urban and thus other off farm activities predominate. The farmers' dependence on food crops in this district may therefore be minimal. The Techiman Municipality is well known for the production of maize and yam. It is located in the Transition Zone and the aforementioned crops have production advantage and thus cassava may not be the most important crop.

The attribute, *Disease resistance*, is positive and statistically significant in all the three locations confirming the previous results. This implies that smallholders attach importance to cassava varieties that are resistant to cassava mosaic virus disease. This ensures low input use and guarantees yields. Ghanaian farmers mostly practice low input agriculture (MoFA, 2007) and so any cassava variety with tolerance to cassava mosaic virus disease and which would not need extra input would increase farmers' choice of that variety.

Estimates obtained for the full sample suggest that another important cassava breeding trait is *in-soil storage*. Subsample coefficients support this result. The mean coefficients for *in-soil storage* are positive and significant in all three sub-samples (Table 5.18). As mentioned in the previous section, the ability of cassava to store in the soil for some time after maturity is very important to farmers. That serves as storage facility for the rather high deteriorating product. The *multiple usage* trait is also very important in farmers' choice of a cassava variety as the coefficients for all the three locations are positive and statistically significant. Farmers produce foremost for household use and then for sale and therefore if farmers could consume a cassava variety and at the same time use it for the preparation of other products for sale, this could be an incentive for the choice of that variety.

5.4.4. Willingness to pay (WTP) for cassava traits

Table 5.19 shows the marginal willingness to pay estimates from the mixed logit model. WTP is estimated as the ratio of the respective attribute coefficients to the price coefficient. Each of these ratios is understood as a price change associated with a unit increase in a given trait. In this study, the willingness to pay is measured as the maximum amount that a farmer is willing to pay in order to secure a unit change in a particular trait.

Table 5.19. WTP estimates for pooled and subsamples

variable	Pooled data		Atwima Nwabiagya District		Techiman Municipal		Fanteakwa District	
	WTP (₵)	Std err	WTP(₵)	Std err	WTP (₵)	Std err	WTP (₵)	Std err
Productivity	0.42***	0.11	1.04**	0.48	0.21	0.19	0.28**	0.023
Disease Resistance	45.00***	5.10	12.85	10.47	37.49***	10.93	33.70***	5.60
In-soil storage	83.59***	9.66	127.68***	50.07	69.83***	19.44	35.50***	6.89
Multiple usage	23.69***	2.61	34.34***	13.45	11.17***	4.50	8.35***	2.16

***significant at 1%, **significant at 5%, *significant at 10%

For the pooled sample, respondents were willing to pay ₵83.59 in order to obtain a year more increase in *in-soil storage* trait. For the *disease resistance traits* respondents were willing to pay ₵45.00 in order to obtain cassava with resistance to cassava mosaic virus disease. WTP results from the three Districts are in support of the pooled sample results. Farmers were willing to pay ₵127.68, ₵69.83 and ₵35.50 for a year more increase in the *in-soil storage* trait respectively at Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District. By contrast, farmers were willing to pay ₵12.85, ₵37.49, and ₵33.70 for an increase *in resistance to cassava mosaic virus disease* traits respectively at Atwima Nwabiagya District, Techiman Municipal and Fanteakwa District. These results also confirm the high value farmers in the study area place on *in-soil storage* (longevity). This is perhaps one major reason behind the low adoption rates of high yielding improved cassava varieties, which are generally believed to deteriorate a few months after maturity in the soil (Acheampong *et al*., 2012). This result has important implication for breeding of cassava varieties and for subsequent adoption. It shows how important the *in-soil storage* attribute is in motivating farmers to participate in improved cassava varieties adoption.

The results prove that farmers do not look for a single attribute of the variety when making their seed selection decisions but also other more important but non-tradable attributes like *in-soil storage* and thus forcing them to make difficult trade-offs (substantial WTP amounts). This finding lends support to the work by Asrat *et al*. (2010) who found that farmers in Ethiopia were willing to make trade-offs in order to obtain yield stability and environmental adaptability. This, however, contrasts Mendis and Edirisinghe (2013) who found high positive WTP for yield in their study of farmers WTP for rice traits in Sri Lanka.

5.4.5. Latent class model (LCM) estimation results

As discussed earlier in this chapter, the conditional logit model assumes that farmers' preferences are homogeneous. The mixed logit model however confirmed the existence of preference heterogeneity in the sample population. With the LCM the assumption is that respondents can be intrinsically grouped into a number of latent classes where, in each class, individuals' preferences are still assumed to be homogenous but heterogeneous across classes (Boxall and Adamowicz, 2002). The optimal number of latent classes to be used in the latent class model was selected based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) proposed by Boxall and Adamowicz (2002). The log likelihood value at convergence improved as the number of classes increased from 2 to 5. The BIC values also got smaller as number of classes increased.

Based on the lower is a better criterion, the latent class with 5 classes was used in the estimation (Tabel 5.20).

Table 5.20. Criteria for determining the optimal number of segments

Number of Latent classes	Log likelihood value	BIC
2	-2508.67	5017.35
3	-2501.17	5002.34
4	-2482.13	4964.26
5	-2462.95	4956.27

Table 5.21 presents latent class estimation results for five latent classes. The latent class presents five different preference groups with the estimated latent classes' probabilities of 28.4%, 17.9%, 17.1%, 17.3% and 19.3% respectively. These are the probabilities of a randomly chosen respondent belonging to the first, second, third, fourth or fifth class, respectively.

In the first class, farmers within this group have positive utility towards purchase price, productivity, in-soil storage and multiple usages. They however have negative utility towards disease resistance. As indicated by the class membership, this group have members who are males, who are educated, have smaller farm sizes and are younger. There is a 28.4% probability that a randomly chosen individual belongs to this class, indicating that a slight majority of respondents are not concerned about disease resistance. Members of class two are males, they are younger, have not had much education and have smaller farm sizes. In this group, apart from productivity, they showed positive utility towards purchase price, disease resistance, in-soil storage and multiple usages.

Table 5.21. LCM estimation results for five latent classes

Variable	Class 1	Class 2	Class 3	Class 4	Class 5
Choice model parameter					
Purchase price	0.063***	0.023***	-0.053**	-0.026***	0.020***
	(0.025)	(0.005)	(0.032)	(0.004)	(0.003)
Productivity	0.026**	-0.006***	0.001	0.020	-0.006*
	(0.015)	(0.002)	(0.003)	(0.027)	(0.004)
Disease	-0.779***	2.195***	1.826***	-0.023***	0.074**
Resistance	(0.053)	(0.452)	(0.228)	(0.003)	(0.042)
In-soil storage	1.443***	0.546***	3.472***	2.062***	0.847***
	(0.225)	(0.223)	(0.504)	(0.228)	(0.078)
Multiple usage	0.554***	0.009***	1.062***	0.038***	0.545***
	(0.034)	(0.004)	(0.221)	(0.006)	(0.230)
Class membership parameters					
Age (Years)	-0.040***	-0.082***	-0.024***	-0.058***	
	(0.002)	(0.024)	(0.002)	(0.015)	
Gender(1=female)	-0.144***	-1.383***	-0.184***	-0.398***	
	(0.026)	(0.236)	(0.022)	(0.045)	
Education (Years)	0.038***	-0.064**	0.150***	0.169***	
	(0.005)	(0.008)	(0.054)	(0.048)	
Farm size(ha)	-0.006***	-0.032***	-0.003**	-0.058***	
	(0.0023)	(0.011)	(0.002)	(0.013)	
Constant	2.494***	5.958***	0.934**	3.233***	
	(0.225)	(1.145)	(0.201)	(0.286)	
Class share	0.284***	0.179***	0.171	0.173	0.193
	(0.054)	(0.040)	(0.039)	0.038)	(0.135)

Note: class 5 is the reference class;
***significant at 1%, **significant at 5%, *significant at 10%
Standard error in parenthesis

Class three members are concerned for disease resistance, in-soil storage and multiple usages. They are males, they are younger, and they are educated with smaller farm sizes.

Class 4 members have similar characteristics as those in class 3, however they are not concerned for disease resistance.

These results have allowed for explicit testing and identification of important socioeconomic and crop specific variables. Targeting in dissemination of agricultural technologies is therefore important. The Latent class results have shown that in all the classes males and younger farmers are more likely to participate in improved cassava varieties that can store longer in the soil after maturity and have multiple usages. This is consistent with previous findings by the study that revealed high preference for in-soil storage by respondents.

5.5. Cassava trait perception and adoption of improved cassava varieties

This section presents farmers adoption of improved cassava varieties. The section commences by presenting the adoption rates of the improved cassava varieties. It then presents distribution of the common improved cassava varieties in the study area. The section finally presents the empirical findings from the logit and the multinomial logit models.

5.5.1. Adoption of improved cassava varieties

Farmers in the study area grow mostly traditional varieties. Of the total sample (450) interviewed, 335 farmers representing 74.4% of the total sample cultivated traditional cassava varieties in the 2010-2011 production season (Table 5.22). Only 25.6% of the total sample cultivated improved cassava varieties. Improved cassava varieties most popular in the study area were *Afisiafi, Bankyehemaa and Abasafitaa*. *Afisiafi* was cultivated by 12.2% of the sample, followed by *Bankyehemaa* which was cultivated by 7.8% and then

Abasafitaa which was grown by only 5.6% of the farm households. *Abasafitaa* and *Afisiafi* were released in 1993 and *Bankyehemaa* was released in 2005 but they seemed to be popular amongst farm households. The newer varieties which are supposed to have better qualities and higher yield seemed not to be known by farm households. The probable explanation may be that extension has not been able to create much awareness of the newer varieties. The low rates of adoption of improved cassava varieties are also found in various cassava adoption studies in Ghana (Manu-Aduening *et al*., 2005; Dankyi and Agyekum, 2007; Owusu and Donkor, 2012).

Table 5.22. Cassava varieties grown in the study area and proportion of households growing them (2010-2011 production seasons)

Variety	Number of households	Percent of households
Traditional varieties	335	74.4
Afisiafi	55	12.2
Bankyehemaa	35	7.8
Abasafitaa	25	5.6
Total	450	100.0

Source: Farm household survey, 2011

The distribution of farmers interviewed that had adopted the improved varieties by location is as presented in Table 5.23.

Table 5.23. Distribution of households growing and not growing improved cassava varieties by District

District	Growing improved cassava varieties		Not growing improved cassava varieties		N
	N	%	N	%	
Atwima Nwabiagya	21	14.0	129	86.4	150
Techiman Municipal	32	21.3	118	78.6	150
Fanteakwa	62	41.3	88	58.6	150
All Districts	115	25.6	335	74.4	450

Source: Farm Household survey, 2011

The results show that the adoption rate of improved cassava varieties is low (25.6%) across the districts. The adoption rate was highest (41.3%) in the Fanteakwa District of the Eastern region followed by the Techiman Municipal Area of 21.3%. These two Districts are mainly rural with availability of farm labour that can be used for cassava production. Surprisingly, only 14% had adopted the improved cassava varieties in Atwima Nwabiagya District of the Ashanti Region. This District is very close to the Crops Research Institute, the hub of cassava development technologies in Ghana.

5.5.2. Constraints to the adoption of improved cassava varieties

Despite the high productivity of the improved cassava varieties, the percentage of farmers growing the improved cassava varieties in the total sample is surprisingly low, just 25.6%. To understand the reasons behind this low adoption rate, farmers were asked to rank the limitations to the cultivation or production of improved cassava varieties. The questions were designed to fit a Likert scale, with farmers scoring statements on a measurement scale of 1 to 5 with 1= very high, 2= high, 3=low, 4=very low, and 5=none. The responses were then ranked by assigning weights from one to five in declining order such that rank one has the highest weight of five and rank five has the lowest weight of one. Following Nguthi (2007)[10], the overall score for each constraint is then calculated by summing up the number of households that mentioned the constraint multiplied by the rank position assigned to the constraint. Table 5.24 shows the ranking of constraints by the farming households.

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[10] $C_A = \sum_{i=1}^{5} Freq\left(\mathrm{A}_i\right)\left(6-i\right)$; C_A= the overall score for constraint A,
i = Rank position (1, 2 …5)

The respondents ranked acquisition of credit as the number one constraint militating against improved cassava production. Farmers are unable to access credit due to the cumbersome process prior to credit acquisition and also the high interest rates charged on loans. Improved cassava production is capital intensive (Nweke, 2004) as physical labour and inputs such as herbicides and fertilizers are needed to achieve full potential.

Access to credit is considered as a major constraint in adopting agricultural technologies. Lack of credit has been cited in several studies (Doss 2001; Doss *et al.,* 2003) as key constraints limiting access and adoption of improved seeds, planting materials and fertilizers. The second most important constraint to improved cassava variety adoption was cost of inputs. Lack of credit coupled with high cost of inputs limit farmers' accessibility of complementary inputs such as fertilizers and herbicides needed for the production of improved cassava varieties. This obviously has adverse effect on adoption of improved cassava varieties.

Table 5.24. Ranking of constraints to the production of improved cassava (N=450)

Constraints	Very high		High		Low		Very low		None		Total score	Overall rank
	Freq.	Score	Freq.	Score	Freq.	Score	Freq.	Score	Freq.	Score		
Planting material availability	201	1005	96	384	53	159	19	38	81	81	1667	3
Cost of input	318	1590	91	364	31	93	3	6	7	7	2060	2
Credit accessibility	358	1790	46	184	19	57	12	24	15	15	2070	1
Land accessibility	161	805	57	228	55	165	42	84	135	135	1417	6
Marketing of produce	140	700	171	684	51	153	22	44	66	66	1647	4
Extension contact	183	915	94	376	58	174	40	80	75	75	1620	5

Source; Farm level survey, 2011

The third most important constraint ranked by farmers was planting material availability. Farmers are unable to get access to planting materials of the improved varieties. The production of cassava depends on good quality stem cuttings. The multiplication rate of these vegetative planting materials is very low, compared to cereals and legumes, which are propagated by seeds. Unlike the cereals there are limited organised markets for cassava planting materials. The finding here renders support to the findings of Osei *et al*. (2008) and Owusu and Donkor (2012) that the major constraint to cassava production is accessibility of planting materials. Planting material unavailability has been reported to hamper technology transfer and according to David *et al.* (2002), it is a key constraint to adoption of improved crop varieties.

Cassava marketing was found to be the fourth most important constraint to improved cassava production. Most farmers find it difficult distributing their cassava output. Cassava is bulky and deteriorates fast. Transporting cassava from the production centres to markets is difficult due to poor road network. Matured cassava roots are sometimes left in soil in some areas where road networks are really bad. The state of road infrastructure is important in influencing the adoption of agricultural technologies as it implies access to markets and institutions (Langyintuo and Mungoma, 2008). Also, the cassava market chains are not well developed in Ghana. Only the fresh cassava market chain dominates even though other markets such as flour, chips and glue are known to exist (Kleih *et al*, 2013; Angelucci, 2013).

Extension access was also mentioned as the fifth constraint of cassava production as farmers find it difficult getting in touch with agricultural extension agents. The extension staff-to farmer ratio is estimated to be 1:1500 in Ghana (Duo and Bruening, 2007). They are therefore unable to reach most farmers especially those far away from the district capitals. Extension personnel are also limited by lack of resources, including lack of training, operational funds and low remunerations, thus making them ineffective in performing their roles. Nonetheless, they are considered as influencing adoption of improved cassava varieties (Udoh and Kormawa, 2009).

Land for cassava production was the last constraint mentioned by farmers. Though most of the farmers owned land, the land sizes were small as previously mentioned. Farmers practiced mixed cropping and so found it difficult trying out new crops on the already limited land resource. Farmers' risk aversion discourages them from trying new technologies on limited land where they have already planted known crops. Adoption of improved cassava varieties is therefore constrained due to limited land access.

5.5.3. The role of trait perception in the adoption of improved cassava varieties

Multicollinearity is a problem in regression analysis especially using cross sectional data, and results in parameters with incorrect signs and implausible magnitudes (Belsley *et al*., 1980; Greene, 2003). Various diagnostics are frequently employed to assess whether multicollinearity is indeed a problem. One of such tools is the determinant of the regressor correlation matrix (Johnston, 1984). A correlation matrix for a pair of independent variables is as presented in Table 5.25. The results revealed that age is positively correlated (r = 0.60) with experience. This implies that the older farmers tend to be more experienced. The perception that improved variety can be used for fufu is positively correlated (r = 0.63) with perception that improved variety is resistant to cassava mosaic virus disease. The perception that improved variety yields more is positively correlated (r

= 0.73) with the perception that improved variety can be used for fufu. In the remaining cases the correlation coefficients are low, most of them falling below 0.2. This finding suggests that the problem of multicollinearity is not serious.

Table 5.26 presents the estimation results of factors influencing adoption of improved cassava varieties.

Table 5.25. Correlation matrix of independent variables

	famage	eduyears	Gender	hhsize	farmsize	experi~e	mktdis~e	landte~e	Awaren~s	credit	extcont	nuextvis	fieldpa
famage	1.0000												
eduyears	-0.2594	1.0000											
Gender	0.1692	-0.2953	1.0000										
hhsize	0.3230	-0.1780	0.0670	1.0000									
farmsize	0.0359	0.1158	-0.1936	0.0510	1.0000								
experience	0.6067	-0.2511	0.1772	0.2254	0.0729	1.0000							
mktdistance	-0.0289	-0.0840	-0.0664	0.0320	0.2217	0.0101	1.0000						
landtenure	0.1453	0.0289	0.1258	-0.0001	0.0511	0.1287	-0.0663	1.0000					
Awareness	0.0362	0.0756	-0.0243	-0.0154	-0.0239	0.0617	-0.0432	0.1547	1.0000				
credit	0.0120	-0.0635	0.0582	0.0451	0.1051	0.0649	0.1514	-0.0608	-0.1887	1.0000			
extcont	-0.0063	0.0050	0.0269	0.0593	0.0006	0.0369	-0.0626	-0.0904	-0.0098	0.1196	1.0000		
nuextvis	0.0059	0.0789	-0.0298	-0.0021	0.0923	0.0529	0.0092	0.0315	0.0018	0.0116	0.4028	1.0000	
fieldpa	-0.0591	0.0405	-0.0370	0.0706	-0.0039	0.0225	0.0733	-0.0816	-0.0069	0.1190	0.3009	0.2548	1.0000
hiredlabour	0.0756	-0.0736	0.0084	-0.0075	-0.0073	0.0366	0.0132	0.0180	0.0699	0.0230	0.0070	-0.0635	-0.0408
diseaseR	-0.0198	0.0617	-0.0786	-0.0585	0.0656	-0.0643	0.0183	-0.1033	-0.1790	0.0752	0.0758	0.0693	0.0382
tuberuse	-0.0381	0.0976	-0.1201	-0.0396	0.0378	-0.0507	-0.0583	-0.0940	-0.1423	-0.0049	0.0196	0.0234	0.0441
Yield	-0.0716	0.0791	-0.1095	-0.0294	0.0520	-0.0765	0.0061	-0.1257	-0.1345	0.0760	0.0719	0.0830	0.0797
soilstore	-0.0528	0.0462	-0.0834	-0.0356	0.0491	-0.0642	-0.0073	-0.1131	-0.1620	0.1400	0.0868	0.1633	0.1445

	hiredl~r	diseaseR	tuberuse	Yield	soilst~e
hiredlabour	1.0000				
diseaseR	-0.1107	1.0000			
tuberuse	-0.1175	0.6397	1.0000		
Yield	-0.0713	0.8535	0.7394	1.0000	
soilstore	-0.0418	0.7967	0.6388	0.8064	1.0000

Table 5.26. Estimation results for factors influencing adoption of improved cassava varieties

Variable	Coefficient	Standard error
Age of farmer (years)	0.0145	0.0157
Gender of farmer (1=female)	-0.5518*	0.3427
Number of household members (count)	-0.0400	0.5527
Number of years in farming (years)	-0.0100	0.01530
Education in years of farmer (years)	0.0462	0.03562
Hired labour for cassava production (1=yes)	0.9068**	0.5271
Farm size (acres)	0.0339***	0.0145
Access to credit (1=yes)	0.4155	0.5101
Extension contact(1=yes)	0.0837	0.3396
Number of times of extension visit (count)	0.0457	0.0342
Participation in field day/demonstration (1=yes)	0.8127**	0.42890
Farmer own land (1=yes)	-0.4482	0.3065
Awareness of an improved cassava variety (1=yes)	3.2551***	0.8603
Distance to input and output market (km)	-0.2024	0.0265
If farm household head perceives that improved cassava is resistant to diseases and pest than local (1=yes)	-0.574	0.9228
If farmer perceives that improved cassava stores longer in soil than local (1=yes)	3.305***	0.6309
If farmer perceives that improved cassava yields more than local (1=yes)	1.4148	0.9018
If farmer perceives that improved cassava is good for fufu than local (1=yes)	0.1574***	0.0776
Constant	-6.3666***	1.264
Number of observations	450	
Likelihood ratio χ^2	191.50	
Pseudo R^2	0.37	
P value	0.000	

Source: Farm Household survey, 2011, Dependent variable = Growing improved cassava variety (1=yes, 0=no), **significant at 5%, ***significant at 1%

The coefficient on the gender variable takes the hypothesized negative sign and it is statistically significant at 10%. This means that male farmers are likely to adopt improved cassava varieties than females, pointing to decision making regarding resource allocation which are made mainly by males (Regasa, 2012). The finding is in contrast with the finding by Dankyi and Agyekum (2007), Abele *et al*. (2007) and Kavia *et al*. (2007), who found no significant effect of gender on adoption of improved cassava varieties in Ghana, Uganda and Tanzania respectively. However, Tarawali *et al*. (2012) and Nwakor *et al*.

(2011) found positive effect of gender on adoption of improved cassava varieties in Nigeria which is consistent with the findings of this study. Again, in Tanzania, Uganda and Ghana, Kavia *et al*. (2007), Abele *et al*. (2007) and Owusu and Donkor (2012) respectively found positive and significant effect of age on adoption of improved cassava varieties.

Number of household members (household size) has no effect on adoption of improved cassava varieties. This suggests that farm households with more family members are less inclined to improve cassava varieties. As postulated, those with larger household members might be involved more in off farm activities in an attempt to earn income to ease the consumption pressure imposed by a large family size. This is confirmed by the positive and significant relationship of hired labour and adoption of improved cassava varieties in this study. It means that instead of family labour, more labour is hired for cultivation of improved cassava varieties which involve other activities like row planting and fertilizer application. This finding contrasted findings by Udensi *et al*. (2011) who found negative and significant relationship of household size with adoption of improved cassava varieties and findings by Mohammend-Lawal *et al*. (2012) who found positive effect of household size on adoption of improved cassava varieties in Nigeria. Again, Abele *et al*. (2007) found positive influence of household size on adoption of improved cassava in Uganda and, in Ghana, Owusu and Donkor (2012) found that household size related positively to extent of adoption of improved cassava varieties, all contrasting the finding of this study.

As hypothesized, farm size had positive and statistically significant relationship with the adoption of improved cassava varieties. Farmers with larger farm holdings are more likely to adopt the improved cassava varieties as they can afford to devote part of their field to try out the new varieties. This finding is consistent with studies of improved maize in Ghana (Morris *et al*., 1999) whereby farmers with larger land holdings adopted the new varieties. Imoh and Essien (2006) and Kavia *et al*. (2007) all found positive and significant effect of farm size on adoption of improved cassava in Nigeria and Tanzania. As expected, credit access was positive though insignificant. This means that the adoption of improved cassava varieties will increase with increase access to credit. Farmers will be able to hire more labour and access other inputs and expand their land holdings.

Surprisingly, the number of years of education of the farm household head, though had the expected positive sign, had no effect on adoption contrary to earlier empirical evidence in agricultural adoption literature, which shows that farm households with more schooling tend to be more innovative and quick to accept new technologies. As pointed out by Rahm and Huffman (1984), education may have a negative effect on the adoption decision if the new technology is not economically feasible since non- adopting is the best option. Nevertheless, for this study, participation in cassava field day/ demonstration served as alternative for education which was positive and statistically significant at 5%. Farmers that participate in extension programmes are more likely to adopt improved technologies. The reduction of information asymmetry is evident as farmers attend and participate in field demonstrations of new technologies and have access to first-hand information. The result is consistent with studies by Dankyi and Agyekum (2007) who reported of participation in field days and demonstrations as being very influential in improved cassava adoption in southern Ghana.

Contrary to expectation, extension contact and number of times of extension agents' visit, though had the positive sign, had no effect on adoption of improved cassava varieties. This suggests that, though farmers receive extension agents, they may not discuss improved cassava varieties hence their insignificant effect on adoption of improved cassava varieties. As hypothesized, knowledge or awareness of the improved varieties was positive and statistically significant at 5%. Farmers' awareness about the improved cassava varieties is therefore important for adoption of the varieties. Farmers who know the improved cassava varieties probably have better information about the advantages of the varieties and are likely to adopt and allocate land to their production. This positive effect of farmer awareness variable is consistent with studies for pigeon pea varieties in Tanzania (Shiferaw *et al*., 2008), cowpea varieties in Nigeria (Kristjanson *et al*., 2005) and maize varieties in Tanzania (Kaliba *et al*., 2000).

The perception that the improved varieties yielded higher than the local varieties had no effect on adoption of improved cassava varieties. This finding contrasts the findings of studies conducted in West Africa by Korwawa *et al.* (2001) and Tumuhimbise *et al*. (2012) in Uganda where perception that improved cassava varieties were high yielding affected adoption. This result indicates that high yielding is not the main or only criterion for farmers. However, the perception that the improved cassava varieties can stay longer in the soil after maturity is positive and highly significant at 1%. The probability of farmers adopting cassava varieties with robust roots is therefore very high. This result lends support to previous findings of this study whereby *in-soil storage trait* was highly preferred and highly valued by farmers in the study area indicating that other criteria other than yield inform farmers decision to adopt. The perception that the improved variety can be used for 'fufu' is positive and significant. Thus, adoption of improved varieties will increase with increased poundability of varieties.

Table 5.27 presents results of the marginal effects from the multinomial logit of the effects of socioeconomic and institutional characteristics and technology characteristics on the decision to adopt a given improved cassava variety. As indicated earlier, the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable: estimates do not represent actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed. The base is adoption of traditional cassava varieties. The results revealed that farmers are mostly homogeneous in making decisions to adopt improved cassava varieties in the study area. Two of the varieties (*Abasafitaa and Afisiafi*) were introduced earlier in 1993 and, over a decade later in 2005, *Bankyehemaa* was introduced. The homogeneity in farmers' decision might be due to the differences in strategies during dissemination.

Table 5.27. Marginal effects from the multinomial logit on the choice of improved cassava varieties

Variable	*Bankyehemaa*		*Abasafitaa*		*Afisiafi*	
	δy/δχ	Std err	δy/δχ	Std err	δy/δχ	Std err
Age of farmer (years)	-0.004***	0.001	-0.005***	0.002	-0.0005	0.002
Gender of farmer (1=female)	-0.072**	0.034	0.027	0.022	-0.008	0.034
Number of household members (count)	0.002	0.004	-0.01***	0.004	0.007	0.005
Number of years in farming (years)	-0.003	0.001	-0.001	0.001	0.001	0.002
Education in years of farmer (years)	0.0002	0.003	0.002	0.002	0.002	0.003
Hired labour for cassava production (1=yes)	0.0105	0.035	0.009	0.031	0.115**	0.056
Farm size (ha)	0.0002	0.004	0.006	0.001	0.003***	0.001
Access to credit (1=yes)	0.0450	0.035	0.008	0.028	-0.081	0.056
Extension contact (1=yes)	-0.019	0.028	0.003	0.023	-0.015	0.034
Number of times of extension visit (count)	0.0049***	0.001	0.001	0.001	0.001	0.003
Participation in field day/demonstration (1=yes)	0.035	0.036	0.051**	0.027	-0.049	0.056
Farmer own land (1=yes)	-0.037	0.025	0.020	0.021	-0.015	0.031
Awareness (1=yes)	0.079	0.072	0.035	0.049	0.195**	0.106
Distance to input and output market (km)	-0.027*	0.004	-0.008	0.001	-0.002	0.003
If farmer perceives that improved cassava is more resistant to diseases and pest than local (1=yes)	0.100**	0.054	0.006**	0.002	0.112	0.080
If farmer perceives that improved cassava stays longer in the soil than local (1=yes)	0.015	0.052	0.134***	0.0318	0.170***	0.0612
If farmer perceives that improved cassava yields more than local (1=yes)	0.174***	0.069	-0.028	0.0407	-0.109	0.0856

Number of observations: 450; LR chi2 (57): 164.45; Prob > Chi2: 0.0000; Pseudo R2: 0.2156; Log likelihood: -299.217. ***: significant at 1% level; **: significant at 5 level; *: 10 level.

There is homogenous effect of the gender of the respondents on adoption decisions regarding the three improved cassava varieties. The gender variable was only negative and significant at 1% with the adoption of *Bankyehemaa*. Specifically, the results revealed that males are more likely to adopt *Bankyehemaa* than females. Some empirical studies (Nwakor *et al*., 2011; Tarawali *et al*., 2012) on improved cassava varieties in Nigeria have found that males adopt improved cassava varieties more than females, similar to findings in this study.

There is a negative and significant effect of age on the likelihood of adoption of *Abasafita*. This could suggest that younger farmers are more likely to try new cassava varieties. Owusu and Donkor (2012) found similar results in their study of improved cassava varieties adoption in Ghana. However, studies in Tanzania (Kavia *et al*., 2007) and Nigeria (Mohammend-Lawal *et al*., 2012) found positive effect of age on adoption of improved cassava varieties. The results also suggest the need for age targeting in dissemination of new cassava varieties, instead of blanket recommendations of varieties regardless of the characteristics of the farmers, to encourage adoption of cassava varieties.

The effect of hired labour on probability of adoption of *Afisiafi* is positive and significant at 1%. The implication is that the probability of adoption of *Afisiafi* will increase with the use of hired labour. This highlights the importance of labour availability to improved cassava adoption, consistent with findings by Anyaegbunam *et al*. (2012) that improved cassava adoption increased with labour accessibility in their study of cassava productivity among small holders in Nigeria. Again the probability of adoption of *Afisiafi* increases with farm size. The coefficient of farm size is positive and significant at 1% indicating its influence on adoption of *Afisiafi*. The positive influence of farm size on adoption of improved cassava varieties is found in many studies in Nigeria (Imoh and Essien, 2006;

Udensi *et al*., 2011; Mohammend-Lawal *et al*., 2012; Madu *et al*., 2008) and in Tanzania by Kavia *et al*., (2007) which is in line with this study.

Access to information on new technologies is important to creating awareness and forming attitudes towards the adoption of the new technology. In this study, though access to extension indicated by whether or not the farmer had contact with an extension agent, had no impact on the choice of any of the improved varieties, the number of times of extension visit impacted positively on the probability of choice of *Bankyehemaa* .This underscores the importance of regular visits of extension agents, consistent with findings by Dankyi and Agyekum (2007), Orebiyi *et al*. (2005) and Onyemauwa (2012).

Regular visits of extension agents give farmers access to enough information on innovations, their use and management. In this study number of times of extension visits impacted positively on the adoption of *Bankyehemaa*. In most cases, extension workers establish demonstration plots where farmers get hands-on training and can experiment with new farm technologies. Regarding the three varieties in this study, it was found that participation in field demonstrations impacted positively on the adoption of *Abasafita.* Farmers that participate in extension programmes are more likely to adopt improved technologies. In Nigeria, Orebiyi *et al*. (2005) and Onyemauwa (2012) found similar results in their studies of determinants of farmers' participation in improved cassava varieties.

Knowledge or awareness of the improved varieties is positive and significant at 1% on the probability of adoption of *Afisiafi*. This positive effect of farmer technology awareness variable is consistent with studies for pigeon pea varieties in Tanzania (Shiferaw *et al*., 2008), cowpea varieties in Nigeria (Kristjanson *et al*., 2005) and maize varieties in Tanzania (Kaliba *et al*., 2000).

Distance to output and input market is negative and significant at 5% with the adoption of *Bankyehemaa.* The implication is that the shorter the distance to a market the higher the likelihood of adoption of *Bankyehemaa*. Farmers farther away from an input and output market may be disadvantaged as they may be lacking market information and thus may incline more to subsistence production. As a result they may not be interested in participation in improved varieties so long as the traditional varieties provide subsistence level of output for the family (Langyintuo and Mekuria, 2008).

There is a heterogeneous effect of the perception of disease resistance regarding *Bankyehemaa* and *Abasafitaa.* The disease resistance variable is positive and significant at 5% with both varieties. Disease resistance assures farmers of stable yields and gives farmers the opportunity of realizing their dual objectives of consumption and sale. This finding supports studies conducted in West Africa (Korwawa *et. al.,* 2001) where perception that improved cassava varieties were high yielding affected adoption. The results also showed heterogeneous effect of in-soil storage regarding *Abasafitaa and Afisiafi* varieties. The coefficient is positive and significant at 1%. The probability of adoption of *Abasafitaa* and *Afisiafi* will increase with assurance of matured root remaining longer (at least a year or more) in the soil without rotting. This finding has confirmed the importance of *in-soil storage* in adoption of improved cassava varieties as indicated in previous results. The probability of adoption of *Bankyehemaa* and *Afisiafi* is jointly affected by the perception of poundability (ability to be used for fufu). Assurance that the improved varieties can be used for 'fufu' will increase their adoption. Many farmers in the study area were unsure of pounding ability of the improved cassava varieties.

5.6. Chapter summary

This chapter has presented and discussed the results of the study. It has provided a description of the demographic characteristics of respondents as well as farm and institutional characteristics of the study area, analysis of farmers' perception of cassava traits, empirical estimations of the farmers' preferences for cassava variety traits, farmers' willingness to pay for cassava variety traits, and empirical estimation of determinants of adoption of improved cassava varieties.

The next chapter summarizes the findings of the study, draws conclusions from them and considers the policy implications of the findings as well as suggestions for future research.

CHAPTER 6

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS FROM THE STUDY

6.1. Summary of findings

The aim of this study was to analyse cassava producers' decision-making behaviour towards cassava variety selection and to evaluate farmers' WTP for cassava variety traits. As a result of low adoption of improved cassava varieties in Ghana, the study was intended to contribute to the development and adoption of improved cassava varieties in the country. The main motivation for this study was the provision of information for cassava researchers regarding farmer preferences for different cassava variety traits. It was anticipated that the results from the study would improve understanding of farmers' preferences for cassava variety traits in order to include them in breeding programmes to enable a reasonable adoption of improved cassava varieties for increased yields in Ghana. The study further aimed to identify the factors that influence adoption of improved cassava varieties in order to provide feedback information on prospects of adoption of improved cassava varieties.

Data was collected by personal interviews from four hundred and fifty (450) cassava growing farmers in three cassava growing districts of Ghana: Atwima Nwabiagya District in the Ashanti Region, Techiman Municipal Area in the Brong Ahafo Region, and Fanteakwa District in the Eastern Region. The choice experiment method was applied to investigate farmer's preferences for cassava variety traits in order to ascertain the values that farmers place on different traits and to identify factors that influence preference of the farmers to serve as an input to both technology development and diffusion in Ghana. The choice experiment method used in this study is a good example of a bottom-up approach to research. It can be used to either fine-tune existing technologies or to generate information about farmers' preferences for new technologies such as the new improved cassava varieties. Sources of heterogeneity have been analyzed using the latent class model. Adoption determinants have been analysed using both logit and multinomial logit models.

Out of the 450 respondents interviewed, 60.9% were males and 39.1% were females. Putting the three districts together, 54.7% of the respondents were between 31 and 50 years of age. Indeed, 60.7%, 50.7% and 52.7% of the respondents from the Atwima Nwabiagya District, the Techiman Municipality and the Fanteakwa District respectively were in the 31-50 years age category. Farm sizes ranged from 3.2 hectares to 4.4 hectares. Farmers used mostly hired labour for crop production. There were available market places, however, transporting farm produce to market centres was difficult due to bad road network. The most important crops produced in the study area were cassava, maize, and plantain. Farmers depended principally on cassava production for income generation and for food security.

Farmers cultivated many local and few improved cassava varieties. Names of local varieties produced in the study area included *edebor, bensere, esiabaayaa, amodogo, tuaka,* and *bosomnsia.* These varieties were produced due to their early maturity, long storage in the soil after maturity, and ability to be used for ''fufu''. Improved varieties produced were *Afisiafi, Bankyehemaa* and *Abasafitaa.* Although the improved varieties were perceived by farmers to be high yielding, the perceived inability to be used for ''fufu'', the perceived fast deterioration in the soil after maturity and the perceived susceptibility to diseases and pests discouraged farmers from growing them.

Farmers had more utility towards *in-soil storage* attribute of cassava varieties. Farmers from all the study areas showed strong preferences for *in-soil storage* trait, thus confirming its importance in farmers' decision to use improved cassava varieties. Farmers were willing to pay ₵127.68, ₵69.83 and ₵35.50 for a year or more increase in the *in-soil storage* trait respectively at Atwima Nwabiagya District, Techiman Municipal Area and Fanteakwa District. Farmers were also willing to pay ₵12.85, ₵37.49 and ₵33.70 for an increase *in resistance to cassava mosaic virus disease* trait respectively at Atwima Nwabiagya District, Techiman Municipal Area and Fanteakwa District. Willingness to pay for the *multiple usage* trait was ₵34.34, ₵11.17 and ₵8.35 at Atwima Nwabiagya District, Techiman Municipality and Fanteakwa Districts respectively. Farmers' willingness to pay amounts for the *productivity* trait was very small in all the districts. Farmers were only willing to pay ₵1.04, ₵0.21 and ₵0.28 at Atwima Nwabiagya District, Techiman Municipality and Fanteakwa District respectively. Farmers were also heterogeneous in their preferences for cassava variety traits. Farmer specific characteristics and institutional factors that influenced preference for cassava attributes were gender, age, farm size, household size and experience. There were significant differences between males and females, the aged and the younger ones concerning the choice of cassava variety attributes. The males demanded more disease resistance trait whilst the females demanded multiple usage trait.

Adoption of improved cassava varieties is affected by hired labour, farm size, awareness, participation in cassava field day/demonstration and trait perceptions such as high resistance to diseases and pest, and longevity of tubers in the soil after maturity. Farmers that are aware of the improved technologies are more likely to adopt them. Also, farmers that have the opportunity to attend field days and participate in field demonstrations of improved cassava varieties are more likely to adopt them. The probability of adoption is also influenced by the perception that improved varieties can store longer in the soil after maturity and the perception that they can resist diseases.

6.2. Conclusions

This study has identified cassava varieties cultivated in the study area, assessed cassava farmers' perceptions towards cassava variety traits, empirically estimated farmers' preferences for cassava variety traits and determinants of adoption of improved cassava varieties. The conclusions are presented under three main sub-sections: preferences for cassava variety traits, willingness to pay for cassava traits and the role of trait perception in the adoption of improved cassava varieties.

6.2.1. Preferences for cassava variety traits

Examination of farmers' preferences for cassava variety traits using discrete choice models such as conditional logit and mixed logit models revealed that variety characteristics such as *in-soil storage, resistance to cassava mosaic virus disease* and *multiple tuber usage* were preferred. Willingness to pay estimates (WTP) also demonstrated strong preferences for *in-soil storage*, *disease resistance* and *multiple usage* than increased *productivity*. The *multiple usage attribute* was valued more in areas where cassava processing centres were available and where there were available markets than those areas with limited facilities.

Further assessment of preference heterogeneity amongst respondents for cassava variety traits considering farmers specific socio-demographic variables revealed that male farmers have more utility towards disease resistance than female farmers. Also, older farmers demanded *disease resistance, in-soil storage* and *multiple tuber usage* attributes. The more experienced respondents preferred *productivity, disease resistance, in-soil storage* and *multiple tuber usage attributes*. The latent class model revealed that males and younger farmers are more likely to participate in improved varieties that take into account in-soil storage and multiple usages.

6.2.2. Willingness to pay for cassava variety traits

The estimated willingness to pay amounts show that farmers are willing to pay more for a year or more increase in *in-soil storage* trait in cassava varieties, probably reinforcing their high preference for increased storage period of matured cassava tubers in the soil. Farmers cannot accept more yield per hectare with accompanying gluts and lowering of prices which make them worse off in the end. This is perhaps one major reason behind the low adoption of high yielding improved varieties, which are generally believed to deteriorate a few months after maturity in the soil. This result has important implication for breeding of cassava varieties and for subsequent adoption. It shows how important *in-soil storage* is in motivating farmers to participate in improved cassava varieties.

6.2.3. The role of trait perception in adoption of improved cassava varieties

The results revealed that only 25.5% of the total sample had adopted any of the improved cassava varieties. The most adopted improved variety was *Afisiafi*. Constraints to adoption were access to credit, high cost of inputs and planting materials availability. The logit model showed that the probability of adoption of improved cassava varieties will increase with increases in awareness, participation in field days, hired labour access, perception of longevity of matured roots in the soil and perception of poundability. The multinomial logit results revealed a homogenous effect with regards to factors that influence the adoption of improved cassava varieties. Whilst gender, number of times of extension visit, distance to market and perception of higher yield impacted on the probability of adoption of *Bankyehemaa,* age, field demonstrations and perception of disease resistance affected the probability of adoption of *Abasafitaa*. The probability of adoption of *Afisiafi* is influenced by hired labour, farm size, awareness, perception of disease resistance and perception of longer root storability in the soil after maturity.

These findings may explain the low adoption rates of high yielding improved cassava varieties in Ghana over the years, as breeders have only emphasized on productivity and disease resistant traits. The fact that farmers attach substantial weights to both in-soil storage and disease and pest resistant traits allude to the need for breeding varieties that have the ability to stay longer in the soil to serve as storage facility. The reason is that cassava market chains are not well developed except the fresh tuber market and farmers face challenges in distributing their produce.

To sum up, farmers have strong preference for cassava varieties that are resistant to cassava mosaic virus disease and can store longer in the soil after maturity. The adoption model also revealed that adoption of new cassava varieties by farmers is influenced by disease resistance, perception of disease resistance and perception of longevity. This study therefore comes to the conclusion that adoption of new cassava varieties is conditioned by farmer perception and preferences. The planning and implementation of the development of new varieties must therefore begin with in-depth study of farmer preferences before such varieties' adoption rates can be expected to increase.

6.3. Policy recommendations

This study has first of all demonstrated farmers' preferences for cassava variety traits and farmers valuation of these traits. Secondly, the study has found factors that influence adoption of improved cassava varieties. These results have important implications for breeding priority setting, and targeted diffusion of improved cassava varieties in Ghana.

The first policy implication is in the area of breeding priority setting. The results show that farmers attach greater importance to *in-soil storage* and *disease resistance* traits of cassava. The results also show that *in-soil storage* and *disease resistance* increase the probability of adoption of improved cassava varieties. Thus, for breeding priority setting, given that farmer's preferences for variety traits determine to a large extent their choice of a variety, breeding should satisfy the demand of farmers. The National Agricultural Research Systems (NARS) primarily dealing with crop breeding programmes in Ghana should therefore prioritize these attributes in their direct or supportive breeding programmes. Breeding should target the improvement of *in-soil storage* and *disease resistance* attributes of cassava. The implication is that intervention to develop new cassava varieties should not focus only on the often assumed desirable traits such as yield and disease resistance but should also pay attention to other non-market traits like *in-soil storage*. According to the results, the *productivity* attribute is less demanded by farmers. This probably suggests the importance of developing market chains and value chains for cassava. Farmers would not see the need to adopt more productive cassava varieties when constraints to marketing are not alleviated. Government and private sector intervention should therefore emphasize improving markets and value chains. The findings from the latent class model indicates the importance of considering heterogeneity within social classes as it offers a useful support for breeding policy interventions to particular farmer classes.

The second policy implication is in the area of technology adoption. The results showed that, though extension contact and education were insignificant in explaining adoption decisions, awareness, perception and participation in farmer field days/demonstrations were significant. These results make a convincing case for increased awareness education of the improved cassava varieties and organization of more farmer field schools and demonstrations to show farmers the yield advantage of improved varieties over local ones. Resources allocated to extension services should be increased to enable regular visits and on-farm demonstrations of improved cassava technologies. Such activities provide opportunities for farmers to interact effectively with breeders and extension agents. Farmers are able to avoid information asymmetry and obtain first-hand information concerning the technology being disseminated. The need for policy to strengthen and leverage research institutions and extension services to promote and create awareness about the existing improved cassava varieties is imperative. The government should play a leading role in technology promotion and dissemination. Awareness creation for improved varieties, in addition to increased availability of improved cassava varieties, can accelerate and expand adoption.

The results also pointed to credit access, cost of inputs and planting material acquisition as the main constraints militating against improved cassava production. The results have important implications for cassava variety adoption in Ghana. First, in order for farmers to use improved cassava varieties policy should target financial institutions to relax requirements and lower interest rates for agricultural loans. Secondly, cassava seed market should be more formalised like the cereals seed market. Cassava is vegetative propagated and farmers can use their own planting materials for several years. The private companies lack the incentive to participate in the enhanced delivery of seeds of such crops as the size of the market is small. Strengthening farmers' planting materials production system by improving farmers' skills in planting material multiplication can assist in increasing the supply of planting materials of improved varieties. The extension services division of the Ministry of Food and Agriculture can also be resourced to produce more planting materials for farmers.

6.4. Suggestions for future research

This study concentrated on few attributes of cassava such as disease resistance, productivity, in-soil storage and multiple usages. Other attributes such as canopy formation, height above ground and root colour are not considered in this study. Future studies regarding these attributes would be very interesting in providing a complete picture about the importance of the different cassava variety attributes.

Choice Experiment (CE) is an emerging methodology which has not been applied very much in the field of agriculture and this study is one of few studies that have applied CE to study farmers' preferences. This study only concentrated on cassava. There are other root and tuber crops such as yam, cocoyam and sweet potato which one can also easily apply CE and study farmers' preferences for variety attributes embedded in these crops that contribute to the food security of majority of Ghanaians. The results from such research activities would inform research and policy makers in the designing of breeding interventions towards each of these crops.

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APPENDICES

Appendix I: Farm level questionnaire

1.0. General Farmer information

1.1. Farmer identification

Question	Response
Questionnaire number	
Date	
Name of Village or Town	
District	
Region	
Name of enumerator	
Name of farmer	

1. 2 Personal characteristics of farmer

Table 1. Farmer characteristics

No	Question	Response
1.2.1	Age of farmer in years	
1.2.2	Sex of farmer 0= Male 1= Female	
1.2.3	Residence status 1= native 2= settler	
1.2.4	What is your level of education? 1= Primary 2= JHS/Middle 3= Secondary 4= Vocational/Technical 5= Tertiary 6= Other	
1.2.5	Marital Status :1= Single; 2= Married 3=Divorced 4= widowed	

1.3. Household characteristics of farmer

Table 2. Farmer household characteristics

No	Question	Response
1.3.1	Household size:	
1.3.2	Economically active household members (> 65).	
1.3.3	Adult males (16-65)	
1.3.4	Adult females (16-65)	
1.3.5 1.3.5.1 3.3.5.2	Children < 16 years Male child< 16 years Female child< 16 years	

2.0 Farmer's Income and Assets (Wealth) in 2010 production year

2.1. Farmer ownership of implements/tools

Table 3. Please complete the following table about your use of farm implements in 2010 production year.

	Tool /equipment	No owned at present	Unit price (₵)	Value of assets
2.1.1	Vehicles			
2.1.2	Motorcycle			
2.1.3	Bicycle			
3.1.4	Tractor			
2.1.5	Plough yoke			
2.1.6	Hoe			
2.1.7	Cutlass			
2.1.8	Sickle			
2.1.9	Axe			
2.1.10	Knapsack chemical sprayer			
2.1.11	Others(specify)			

2.2. Income from crops

Table 4. In the table below indicate the major crops you grew in 2010, how much was Consumed, sold and the value

No	Crop	No of acres	Total yield per acre (local unit)	Total sale (local Unit)	Value of sale (₵)	Total consumed (local units)
2.2.1						
2.2.2						
2.2.3						
2.2.4						
2.2.5						
2.2.6						
2.2.7						

2.3.1 Do you own livestock? 1=yes 0=no2.3 Income from livestock

If yes proceed to table 5 and if no proceed to 2.4

Table 5. Livestock ownership and value in 2010 production season

Livestock	Quantity owned	Quantity Sold	Unit Price(₵)
Sheep			
Goat			
Cattle			
Chicken			
Duck			
Donkey			
Pigs			
Other (specify)			

2.4. Non-farm employment

2.4.1. Off-farm wage employment

Table 6. Please indicate in the table below your other income generating activities in the 2010 production season

No	Question	Response
2.4.1.1	Were you involved in any off/non-farm activity in 2010?1=yes 0=no	
2.4.1.2	If yes, what activity were you involved in? Casual Labour.=1 ,Self-employment=2, Skilled labour =3, Salaried employment =4, Petty trading .=5 7= others (specify)	
2.4.1.3	Average no of months or days per year engaged in this activity?	
2.4.1.4	Average income per Month or day did you receive?	

2.4.2. Non-labour income

Table 7 Non –labour income

	Question	Response
2.4.2.1	Did you receive any non-labour income such as remittances, gifts etc. in 2010? 1=yes 0=no	
2.4.2.2	If yes was it in cash or in kind? 1. In-cash 2. In-kind	
2.4.2.3	If in-cash, how much did you receive (₵)?	
2.4.2.4	If in-kind, what is its value (₵)?	

3.0 Plot characteristics

3.1. How much total agricultural land do you owe?

3.3 How many years have you been farming?

3.4 Please complete the following table for the three largest farm plots in 2010 production season.

Table 8. Three largest farm plots in 2010

		Plot number		
		1	2	3
3.4.1	Size of plots (acres)			
3.4.2	What is the land tenure arrangement? 1 = Own 2 = sharecrop 3 = rent 4 = others (specify)			
3.4.3	Type of vegetation 1=forest, 2=transition ,3=savannah			
3.4.4	The type of soil that you cultivated? 1=sandy, 2=loamy , 3=clayey, 4= specify			
3.4.5	Soil fertility 1= very fertile, 2=fertile, 3=poor			
3.4.6	slope of your plots 1=flat ,2=hilly, 3=valley bottom			
3.4.7	Distance of field from the village (km)			
3.4.8	Distance of field from the main road(km)			
3.4.9	Do you have access to market 1= yes 0=no			
3.4.10	Distance of nearest food crop market from your village (km)			

4.0 Cassava production

4.1. How much of your farm is under cassava production? (   ) Acres

4.2. Are you growing improved cassava variety in your farm? 1 = Yes 0 = No

If the answer to question 4.2 is 'yes', go to question 4.3 if 'no' proceed to question 4.9

4.3. Please complete the table below about your adoption of improved cassava varieties

Table 9. Years of adoption of improved cassava varieties

No.	Cassava variety	Number of years of adoption		
		Plot1	Plot 2	Plot 3
1	Plot size (acres)			
2	1= Afisiafi			
2	2=Bankyehemaa			
3	3= tekbankye			
4	4= Abasafitaa			
5	5= Essam Bankye			
6	6= Dokuduade			
7	7=agblefia			
8	8= Fillindiakong			
9	9= Eskamaye			
10	10= Nyerikobya			
11	11=others specify			
12	How did you get to know about improved cassava varieties? 1 = Extension services (MOFA) 2 = Research 3 = Radio (multimedia) 4 = other farmer 5= Other (specify)			
13	Source of planting material 1=Previous harvest, 2= Purchased, 3=borrowed 4=Gift , 5=Other (Specify)			
14	Main intercrop 1=none,2=maize,3=plantain,4=cocoyam 5=cowpea, 6= groundnut, 7=others(specify)			

4.4. Why did you decide to grow improved cassava? (Rank in order of importance)

1 = Observation of their performance on demonstration trials on other farmers field

2 = Motivation by extension staff 3 = Motivation by researchers

4 = Influence by neighbours 5 = other (specify)

4.5 Which of the following recommended management practices of the improved cassava varieties do you follow?

Table 10. Management of improved cassava varieties

	Recommended management practice		
4.5.1	Fertilizer application		
4.5.2	Mulching		
4.5.3	Line planting		
4.5.4	Spacing		
4.5.5	Use of healthy planting material		
4.5.6	Regular weeding		
		<u>Codes</u> 1=yes 0=no	If no, why not? <u>codes</u> 1 = Labour intensive 2 = Lack of money 3 = Not aware 4 = Not beneficial 5=other(specify)

4.6. In the table below indicate the differences you have found between producing improved cassava varieties and local cassava varieties:

Table 11. Differences between improved and local cassava varieties

No		Pest and disease susceptibility Lower = 0 Higher =1	Poundability Lower=0 Higher=1	Yield Lower=0 Higher=1	Soils storage Lower=0 Higher=1
4.6.1	Improved variety				
4.6.2	Local variety				

4.7. Since you started growing improved cassava varieties has there been any change in any of the following household livelihood outcomes?

1 = Increased production 1=Yes 0= No

2 = Extra income 1=Yes 0= No

3 = More food for the household 1=Yes   0= No

If the answer to question 4.7 is 2 go to question 4.8 otherwise proceed to question 4.9

4.8. Which are the four major household expenses (in order of importance) is the extra income from cassava in your household used for?

1. Education 2. Food   3. Household items 4. Clothing   5. Health

6. Investment 7. Saving

4.9. Why are you not growing improved cassava variety? (*Indicate the three main reasons)*

1 = Planting material not available 2 = A lot of labour is required 3 = a lot of fertiliser is required   4= Never heard about them   5 = other (specify)

4.9.1 Please complete the table below about the local varieties that you grow

Table 12 Years of cultivation of local variety

No.	Cassava variety	Number of years of cultivation		
		Plot1	Plot 2	Plot 3
	Plot size (acres)			
1				
2				
3				
4				
5				
6				
7				

5.0 Access to credit

5.0.1	Did you have access to credit for your farming activities in 2010 production season? 1= Yes 0= No	
5.0.2	If yes, what was the source of the credit? 1=government programme 2=commercial/ rural bank 3=family member 4=money lender 5=other (specify	
5.0.3	What was the volume of the credit received (₵)?	

5.1 Extension contact

5.1.1	Were you ever visited by an agricultural extension agent in 2010? 1= yes 0=no	
5.1.2	If yes, during the 2010 production season how many times did an agricultural agent visit your farm?	
5.1.3	Have you ever participated in cassava field day or cassava extension programme before? 1= yes 0= no	
5.1.4	If yes, what kind of extension service (s) did you receive in 2010?	

5.2. Constraints to cassava production

Please indicate with respect to the following your level of constraint to the production of cassava

	Constraint	Very High	High	Low	Very Low	None
5.2.1	Lack of planting materials					
5.2.2	High prices of inputs					
5.2.3	Lack of access to credit					
5.2.4	Land accessibility					
5.2.5	Marketing of produce					
5.2.6	Lack of access to Extension services					
5.2.7	Other (Specify!)					

Appendix II: Choice experiment questionnaire

Use the choice cards provided in the file. Each farmer is to answer profiles 1-6

Scenario: For **each choice task**, ask the respondent to assume that he wants to buy cassava planting material. Explain the traits of each type of planting material and show them the advantages and disadvantages of each, from the pictures in the file. Then tick the appropriate box for the choice the farmer has made for each task.

Choice task 1

1.1	Cassava variety 1	Cassava variety 2	Cassava variety 3
Productivity	15 tons per hectare	30 tons per hectare	30 tons per hectare
Disease and pest resistance	Not resistant	Resistant	Not resistant
In-soil storage	Less than 12 months	12 months or more	12 months or more
Multiple usage	Dough and gari	Gari, fufu and dough	Fufu and gari
Purchase price	₵15	₵15	₵45
I would prefer to buy …..	☐	☐	☐

Choice task 2

1.2	Cassava variety 4	Cassava variety 5	Cassava variety 6
Productivity	60 tons per hectare	60 tons per hectare	15 tons per hectare
Disease and pest resistance	Not resistant	Resistant	Resistant
In-soil storage	12 months or more	12 months or more	Less than 12 months
Multiple usage	Fufu and gari	Fufu and gari	Gari and dough
Purchase price	₵15	₵30	₵15
I would prefer to buy	☐	☐	☐

Choice task 3

1.3	Cassava variety 7	Cassava variety 8	Cassava variety 9
Productivity	30 tons per hectare	15 tons per hectare	60 tons per hectare
Disease and pest resistance	Resistant	Resistant	Resistant
In-soil storage	Less than 12 months	12 months or more	Less than 12 months
Multiple usage	Dough and gari	Fufu and gari	Gari and dough
Purchase price	₵30	₵45	₵30
I would prefer to buy	☐	☐	☐

Choice task 4

1.4	Cassava variety 10	Cassava variety 11	Cassava variety 12
Productivity	60 tons per hectare	60 tons per hectare	30 tons per hectare
Disease and pest resistance	Not resistant	Resistant	Not resistant
In-soil storage	12 months or more	12 months or more	12 months or more
Multiple usage	Fufu and gari	Gari and dough	Fufu, gari and dough
Purchase price	₵45	₵15	₵30
I would prefer to buy	☐	☐	☐

Choice task 5

1.5	Cassava variety 13	Cassava variety 14	Cassava variety 15
Productivity	60 tons per hectare	15 tons per hectare	30 tons per hectare
Disease and pest resistance	Resistant	Not resistant	Resistant
In-soil storage	12 months or more	12 months or more	Less than 12 months
Multiple usage	Dough and gari	Dough and gari	Dough and gari
Purchase price	₵45	₵30	₵45
I would prefer to buy	☐	☐	☐

Choice task 6

1.6	Cassava variety 16	Cassava variety 17	Cassava variety 18
Productivity	15 tons per hectare	15 tons per hectare	30 tons per hectare
Disease and pest resistance	Resistant	Resistant	Resistant
In-soil storage	12 months or more	12 months or more	Less than 12 months
Multiple usage	Fufu and gari	Fufu and gari	Fufu and gari
Purchase price	₵30	₵45	₵15
I would prefer to buy	☐	☐	☐