Tanzanian Economic Review, Vol. 13 No. 1, June, 2023: 104–128

Adoption of Improved Cassava Varieties in Uganda: What Does Agricultural Extension Do?

Vincent Ssajjabbi,[*] John Sseruyange[‡] & John D. Ssentamu[§]

Abstract

Agricultural production, especially by smallholder farmers, is often hampered by insufficient knowledge about better farm inputs or farming practices, low adoption to improved agricultural technologies, or low diffusion of agricultural innovations by the inventing institutions. This paper examines the role of agricultural extension to the adoption of improved cassava varieties in Uganda. We indicate for agricultural extension using the farmers' reported accessibility to agricultural extension from extension workers about such improved varieties. We use probit with selection equation on data collected from eight (8) districts in Northern Uganda. Our main results indicate a higher probability of adopting improved cassava varieties when farmers access agricultural extension services; and also document farmers' distrust to improved cassava varieties as a crop enterprise that can guarantee their households with food security. From a policy perspective, our results suggest that the design and content of agricultural extension services are important to leverage the extent of the adoption of modern agricultural technologies. Specifically, improving the performance of the cassava crop enterprise requires enhanced investment in diffusing innovations in the enterprise.

Keywords: agricultural extension, improved cassava varieties, adoption, Uganda

JEL Classification: O12, O13, O33, Q16

1. Introduction

Agricultural technology is a key ingredient to the development of agriculture and poverty eradication. Nonetheless, its contribution to the growth of the sector and reducing poverty lies on the extent of its diffusion and adoption by farmers (Meinzen-Dick et al., 2004). In more specificity, the gains from new agricultural technologies are better achieved when inventors diffuse such technologies and when farmers adopt to them (ibid.). Diffusion in itself can be quite simple, especially if the innovating firm or the funding institution has the interest and resources necessary to diffuse. On the side of farmers, the adoption of a new technology is explained by a number of factors. First, is the attributes of the new technology and the perceived benefits if such technology is adopted. Second, some farmers are driven by market forces and socio-cultural factors (Nwawuisi et al., 2007), while others compare the uncertainty regarding the benefits of the new technology against the uncertain costs of adoption (Uaiene, 2011). Third, Kaliba et al. (2018) attributes the adoption of a new technology to resource accessibility among which land, capital, subsidies are observed as the key influencers for the

[*]School of Economics, Makerere University: ssajjabbi.v@gmail.com
[‡]School of Economics, Makerere University: johnsseruyange@gmail.com
[§]School of Economics, Makerere University: jddumba@yahoo.com

 ♦ **https://doi.org/10.56279/ter.v13i1.107**

decision of farmers to adopt. Forth, the changing environment, institutional arrangements and the changing perceptions of households toward farming also influence adoptiion (Kabunga et al., 2012).

Although agricultural technology adoption has received considerable attention in literature (Kaliba et al., 2018; Kabunga et al., 2012; Mwangi et al., 2015; Nwawuisi et al., 2007; Pamuk et al., 2014; Sunding & Zilberman, 2001; Uaiene, 2011), and more so in explaining the determinants of adoption; literature on the adoption of improved agricultural technology, especially in the context of Uganda, has remained scanty. Existing studies are mainly focused on the effects of agricultural technology (Diiro & Sam, 2015; Kassie et al., 2011; Kinuthia & Mabaya, 2017; Pan et al., 2018); and few studies explain the determinants of agricultural technology adoption. To be more specific, Kassie et al. (2011) finds a positive and significant impact of agricultural technology (improved groundnut varieties) to household income, as well as rural poverty. This is supported by Kinuthia and Mabaya (2017), which finds adoption to agricultural technology to positively impact on household welfare. According to Kinuthia and Mabaya (2017), improved seeds have a potential of helping rural households to improve their welfare, and also reduce their poverty levels. Kinuthia and Mabaya (2017) indicate for household welfare using consumption of foodstuffs, energy, clothing, paying of medical bills, education and other social contributions.

Turning to the determinants of agricultural technology adoption by farmers in Uganda, Mwaura (2014) addresses farmer group membership. According to the study, group membership influences farmers' decisions to adopt. For instance, the study shows that farmers who are members to farmer groups are less likely to adopt inorganic fertilisers and improved seeds compared to non-group members.[1] Campenhout, (2021) attributes agricultural technology adoption to information accessibility. Using field experiments, the study provides technical information on the use of modern inputs and farming practices, and also information aimed at changing farmers' perceptions on expected returns. Further, the study reports increased intensification of rice-growing, though this was realised after accounting for the possibility of interference between farmers. Moreover, Omotilewa et al. (2019) finds subsidization of improved technology to significantly influence uptake while Pan et al. (2018) finds information accessibility and agricultural extention training that was implemented in a large-scale agricultural extension program to positively influence farmers' adoption of better but basic farming techniques. In this study, we extend the analysis in Pan et al. (2018), but concentrate on examining the impact of agricultural extension to adoption of improved cassava varieties.

A quite related study was conducted in Nigeria (see, Ojo & Ogunyemi, 2014). But, the diversity of agro-ecological zones in Africa requires a deeper understanding of such determinants in other agro-ecological zones, e.g., in low-humid forest zones,

[1] Mwaura (2014) also shows significantly higher maize and banana yields from group members compared to non-group members, though yields of beans and cassava are not significantly different between group and non-group members.

which mostly characterise Uganda. Moreover, the conclusions in Ojo and Ogunyemi (ibid.) are based on descriptive statistics, probit models and budget analysis, which may not adequately address endogeneity issues that may arise from directional causality. For instance, Ojo and Ogunyemi (ibid.) finds a significant difference between adopters and non-adopters in terms of farmers' experience. Per se, adopters had more experience in the growing of cassava. By implication, the longer a farmer takes while growing a particular crop (farming experience), the higher the likelihood of adopting other improved varieties. In a similar way, adopting a given technology/ crop variety can also impact on farmer's experience in using that technology or growing that particular crop, which raises directional causality concerns. In this paper, access to agricultural extension is modelled separately in the form of a selection equation; and then applies the adoption equation (details are provided in section 3). Using this estimation technique helps address potential endogeneity problems that commonly arise from selection bias and directional causality.

Understanding the factors affecting the adoption of improved cassava varieties is necessary especially to generators, disseminators and researchers with interest in understanding food security and the overall economic outcomes of farm households. Specifically, over the years the government of Uganda (GoU), through the National Agricultural Research Organisation (NARO), has continuously invested in research and development to boost the performance of the cassava subsector. For instance, in the National Development Plan III (NDPIII 2020/21–2024/25), the government allocated UGX33.2bn to the Integrated Cassava Industry Development Program (ICIDP), with UGX392m earmarked for the distribution of cassava cuttings to farmers (NPA, 2020).

With such interventions from the government, a number of cassava varieties have been developed by the NARO. Data obtained from the NARO indicates that twenty-one (21) improved cassava varieties have been invented and distributed since year 1991. Some of these include NASE 1, 2, 3 and 4 introduced between 1991 and 1994. These varieties are quite resistant to cassava mosaic, which had by then greatly affected cassava production in various parts of the country. Additionally, NASE 5,6,7,8, 9 and 11 were developed between 1994 and 2012 following complaints against the taste of NASE 1, 2, 3 and 4.[2]

Although there has been a remarkable effort in enhancing the performance of the cassava subsector in the country, annual production has been oscillating around a linear production trend,[3] with production remaining below the sector potential that stands at 3.5mn MT (UBOS, 2019). One possible explanation for such a discrepancy between technology developments and the production capacity of the subsector is the low adoption of the improved technology, which can be attributed to either weak diffusion efforts by the disseminating institutions, or farmers' weak attributes toward such technology.

[2] For details of cassava varieties invented by the NARO and their attributes, see to Table A1.

[3] See Figure A1 which portrays the trend in cassava production and harvested land area.

Efforts to boost cassava production require specific interventions that may include adopting improved varieties, practicing good agronomic practices, and taking better investment decisions by those intending to adopt. Viewed in line with this, understanding the factors that influence farmers' decision to adopt improved cassava varieties is vital if the sector is to operate at its full capacity. Thus, the objective of this paper is to unfold the role of agricultural extension to the adoption of improved cassava varieties in Uganda; while also documenting other determinants. Specifically, we try to understand whether access to information by farmers through agricultural extension influences their decisions to adopt improved cassava varieties. We follow Uaiene (2011), who studied agricultural technology adoption in Mozambique. We consider cassava rather than many other agricultural crops due to the huge investments that the government of Uganda has injected into the cassava subsector, and the relevance of cassava in supporting food security in areas where it is a staple food.[4] Cassava also provides income (UBOS, 2020), starch, livestock feeds and industrial raw material (Nuwamanya et al., 2015). Basing on the aforementioned contributions of cassava on the welfare of households and the nation at large, one would expect high adoption rates of improved varieties by farmers, and possibly high production rates. However, production has still remained below the country's potential.

The reminder of the paper is as follows. In section 2, we present literature related to adoption of agricultural technology and also, literature relating agricultural extension to technological adoption. In section 3, we develop the theoretical and empirical framework used to unveil how agricultural extension impacts on adoption of improved cassava varieties. In section 4, we present data and the sampling strategy while section 5 contains the empirical results. Conclusions are presented in section 6.

2. Adoption of Agricultural Technology

A voluminous body of literature on the adoption of agricultural technology exists, but it has placed more focus on improved production techniques and practices (Jain et al., 2009); and crop varieties and management regimes (Loevinsohn et al., 2013).[5] Also, more literature has focused on the impact of such agricultural technologies on farm production (Chandio et al., 2021; Evenson & Gollin, 2003; Kariyasa & Dewi, 2013; Minten & Barrett, 2008; Nin et al., 2003; Ojo & Ogunyemi, 2014; Tibamanya et al., 2021; Uaiene, 2011). For instance, Kariyasa and Dewi, (2013); Minten and Barrett (2008), and Nin et al. (2003) maintain that the adoption of agricultural technologies can increase food production, household earnings and employment opportunities for rural individuals, as well as the socio-economic development of the entire country. Indeed Minten and Barrett (2008) reveal higher yields and lower levels of food insecurity in Madagascar following the adoption of

[4] Cassava is mainly grown by smallholder farmers on 1 to 2 acres, mainly for food security and income generation (UBOS, 2020)

[5] E.g., soil as well as soil fertility management, weed and pest management, irrigation and water management schemes.

new agricultural technology. In a similar way, Evenson and Gollin (2003) found high rates of adoption of improved varieties of wheat and rice to have resulted into increased productivity in Asia. On their part, Chandio et al. (2021), and Tibamanya et al. (2021), document a positive relationship between the adoption of new agricultural technologies and farmers' economic gains.

Agricultural technologies include all kinds of improved techniques and practices that affect an increase in agricultural output (Jain et al., 2009), and takes different features that dictate the pace of adoption (Rogers, 1995). Individual decision to adopt a technology largely depend on its ability to satisfy one's needs (ibig.). This is an indication that the adoption of technology is not static but involves collecting information, learning how the technology works, and seeking experiences (Jabbar, 2003). Udimal et al. (2017) documents the factors that influence the adoption of a new rice variety (Nerica) in the rice-growing districts of Northern Ghana. The study highlights, among other factors, age, social status, farm size, farming experience, credit access to be the influencers of adoption. Bandiera and Rasul (2006), Feder et al. (1985), Sunding and Zilberman (2001): all identify social networks to be the key determinants of technology adoption. Specifically, Bandiera and Rasul (2006) used a dataset on the adoption of a new technology (sunflower) in presence of social networks. The study concludes that the adoption of new technologies is truly influenced by social network effects, especially networks with few people.[6]

The issue of networks in influencing adoption speaks to a broader body of theories. The social network theory illustrates the role of social relationships in transmitting information, channelling personal influence, and also the change of behaviour (see, Beaman et al., 2021). Since the adoption of new agricultural technology requires interpersonal dependence, some farmers can choose to adopt or not to adopt because of peer influences, which are normally strengthened through social networks. When a specific technology performs to the expectations of the adopters, the non-adopters finds it easy to learn from their peers, and thus adopt. In a similar way, in case of failure, the non-adopters can choose alternative technology basing on the returns registered by their peers. The social network theory is supported by the Bronfenbrenner's social ecological theory, which asserts that human behaviour is influenced by the characteristics (e.g., family, peer and neighbourhood) of the system in which individuals live as well as their reciprocal relationships with persons in their systems (McCart et al., 2011). By implication, the theory seems to suggest that social networks, defined by peer relationships between farmers, can play a remarkable role in causing a behavioural change among farmers toward a specific technology.

Turning to the drivers of adoption, Uaiene et al. (2009) find access to extension services and credit to be the key driving factors that infuence farmers to adopt new technologies, while Feder et al. (1985), Kohli and Singh (1989), and

[6] Networks with few people are associated with a higher and positive effect of increased adoption if a neighbour adopts to a technology.

Akudugu et al. (2012) identify economic, social and institutional factors to be the influencing factors of technology adoption. Specifically, Feder et al. (1985), Foster and Rosenzweig (2010), and Sunding and Zilberman (2001) point to expected profits, farm size, labour availability, credit constraints, land tenure, and access to input and output markets to be the main drivers of agricultural technological adoption. Asfaw et al. (2012) attributes the adoption of agricultural technology to its availability and accessibility, combined with a training on how to use such technology.

Further, Fernandez-Cornejo et al. (2007), and Keelan et al. (2010) conclude that the adoption of agricultural technologies depends on human capital, measured by farmer's education, age, gender, and household size. In quite a dissimilar way, Khanna (2001), and Samiee et al. (2009) find education to negatively impact on the adoption of new technologies, especially for genetically modified crops. This result can potentially be explained by highly educated farmers associating genetically modified crops with environmental destruction and health hazards. Bonabana-Wabbi (2002) observes unreliable, inconsistent and inaccurate information to negatively impact on technology adoption. According to this study, when farmers access a lot of information, they develop a wider information gap which can negatively change their attitudes toward adoption.

Although technological adoption is a decision mainly taken at a household level, Tegengne (2017) observes that adoption can be a community realism. Tegengne (ibid.) documents that the adoption of a new technology can vary from one community to another; and that farmers in each community can dictate the extent of using a particular technology. Such farmers are mainly influenced by information availability, sustainability of the technology, and their interest which can make adoption gradual (Brown et al., 2017).

2.1 Agricultural Extension and Technological Adoption

The relationship between agricultural extension and technological adoption is widely documented (Asfaw et al., 2012, Maffioli et al., 2013, Takahashi et al., 2020); but the existing literature is mainly focused on accessibility of agricultural extension services and its impact on technological adoption. While examining the impact of agricultural extension on the adoption of new improved technologies (i.e., laser levelling, rice and wheat varieties), Ali and Rahut (2013) report a disproportionate accessibility to agricultural extension among farmers mainly driven by farm size. The study found large scale farmers to benefit more from agricultural extension compared to small scale farmers. This is supported by Bonye et al. (2012), who found varying rates of technological adoption among farmers.

According to Bonye et al. (ibid.) extension services increase awareness among farmers about new technologies, and thus the speed of adoption depends on how fast farmers perceive the expected benefits of the new technologies; which can in turn be attributed to limited information accessibility from extension workers (Asfaw et al., 2012a, 2012b; Khonje et al., 2015; Villano et al., 2015). Too, Shiferaw et al. (2015) found farmers with limited technological information from extension workers to be associated with low adoption rates of improved groundnuts in Uganda. On their part, Murari et al. (2017) found a 24% higher chance of adopting new technology by farmers' who participated in extension programs. Moreover, Ali (2013) and Genius et al. (2014) find access to extension services to positively impact on technological adoption. However, it should be noted that extension services go beyond technology transfer to farmers towards strengthening social capital development, and skills and knowledge exchanges, which can influence processing, market accessibility and the formation of farmer groups (Christoplos & Kidd, 2000; Swanson, 2008). Kilpatrick and Johns (2003) observes that farmers learn to change their business operations through accessing information from extension workers; while Anderson and Feder (2007) add that extension workers can also assist farmers to access marketing information.

3. Theoretical Framework and Empirical Strategy

It is a common practice for inventors and policy makers to assume that the introduction of agricultural technologies will boost production and improve welfare, but often forget that the intended outcomes depend on the adoption of such technologies. In some instances, intended communities may not participate at ideal rates, intensity and required length of time (Parvan, (2011). Per se, the introduction of agricultural technologies may fail to improve the welfare of the intended households unless farmers adopt to such varieties.

Following Udimal et al. (2017)—in which a simple model on adoption of improved rice varieties is presented—we try to model the factors that influence farmers' adoption of improved cassava varieties in Uganda, but under conditions of agricultural extension accessibility on such improved varieties.

Udimal et al. (2017) models a binary (1/0) dependent variable based on either the respondent adopted ($Y = 1$) or did not adopt ($Y = 0$). In the Udimal et al. (ibid.), a number of factors are assumed to influence adoption. These are represented in vector x.

$$Pr(Y = 1 \,|X) = F(x, \sigma)$$
$$Pr(Y = 0 \,|X) = 1 - F(x, \sigma) \qquad (1)$$

The set of parameters σ reflects the impact of change in x on the probability. Vector x contains age, farm size, education, off-farm income, family labor, access to extension, access to credit, among others (ibid.). Equation (1) is further simplified as:

$$y = E[Y|X] + (y - E[Y|X]) = x'\sigma + \varepsilon \qquad (2)$$

since $E[Y|X] = F(x, \sigma)$.

Although Udimal et al. (ibid.) run both probit and logit models, including access to extension services in vector x, the problem with such a model lies on two facts. One is observed in the study itself: the heterogeneous nature of the error term. The second is the possible endogeneity problem that might result from selection bias (i.e., selection to adopt to a new variety and/or in accessing extension services). Precisely, choosing to adopt to a new variety and/or to access extension services depends on specific factors that non-adopters may not have access to. For instance, an individual may choose to adopt because s/he has access to capital, while access to extension services may depend on the proximity between an extension worker and an intending adopter.

To overcome the aforementioned problems, we modify equation (1)—in which the probability of adoption is influenced by the variables in vector x—by removing access to extension services from x, and modelling it independently in the form of a selection equation, i.e.,

$$Pr(Y = 1 \,|X) = F(x - a, \sigma)$$
$$Pr(Y = 0 \,|X) = 1 - F(x - a, \sigma) \qquad (3)$$

where a is access to information through extension workers.

In our model, the attainment of equation (3) is conditional to a selection equation (4):

$$Pr(a = 1 \,|Z) = F(z, \sigma) \qquad (4)$$

where vector z contains a number of factors that influence the probability of accessing information from extension workers. Vector z can also contain some information that influences adoption i.e. some variables that influence equation (3).

Equations (3) and (4) can jointly be estimated using a probit model with a selection equation (Freedman & Sekhon, 2010). This approach is strong enough to address endogeneity concerns in binary choice models with issues of selection bias (ibid.).

In more specificity, we design our study in the form of a quasi-experiment using access to agricultural extension as a treatment arm. Precisely, by creating a treatment arm and a reference group (control group—farmers that did not have access to agricultural extension), we are capable of addressing endogeneity problems[7] which are normally common with survey data. The two equations are: First, the selection equation of the form:

$$\varphi_i = 1 \; if \; \alpha_0 + \alpha_1 Z_i + \varepsilon_i > 0, \text{ otherwise, } \varphi_i = 0 \qquad (5)$$

Where $\varphi_i = 1$ implies that subject i self-selected into the treatment arm (accessed agricultural extension on improved cassava varieties provided by extension workers).

[7] Endogeneity problems may result from two sources. First, the selection bias resulting from non-randomness of adopters who may have unique attributes (e.g., family size, land size, marital status and market accessibility) compared to non-adopters. By implication, the adoption of improved cassava varieties is not exogenously determined. Second, access to agricultural extension from extension workers is also influenced by specific factors, e.g., the proximity of the adopter to extension workers. Arguably, the selection of our subjects into our treatment arm against their counterparts in the control may also present a threat of non-randomness.

The variables that influence agricultural extension accessibility are given in vector Z_i. Second, the household's choice to adopt to new cassava varieties is determined using:

$$Y_i = 1 \; if \; \theta_0 + \theta_1\varphi_i + \theta_2 X_i + \theta_3 Z_i + v_i > 0, \text{ Otherwise, } Y_i = 0 \quad (6)$$

Equation (6) is estimated by fitting an expanded model of the form:

$$P(Y_i = 1|\varphi_i, X_i, Z_i = \gamma(\theta_0 + \theta_1\varphi_i + \theta_2 X_i + \theta_3 Z_i + \mu_i) \quad (7)$$

Where

$$\mu_i = \varphi_i \frac{\gamma(\theta_0 + \theta_1 X_i)}{\gamma(\theta_0 + \theta_1 X_i)} - (1 - \varphi_i) \frac{\gamma(\theta_0 + \theta_1 X_i)}{1 - \gamma(\theta_0 + \theta_1 X_i)} \quad (8)$$

From equation (8), θ_0 and θ_1 would be unknown, but are replaced by maximum likelihood estimates from equation (5); while γ is normally distributed. X_i represents other factors for individual i that influence the adoption of new cassava varieties, but not specified in Z_i. The error terms are represented by v_i and μ_i.

4. Data and Sampling Procedure

For purposes of examining the impact of agricultural extension on the adoption of improved cassava varieties, and also exploring the other determinants of adoption, we use data obtained from the National Agricultural Advisory Services (NAADS) secretariat. The NAADS is a statutory semi-autonomous body under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) of Uganda, mandated to manage the distribution of agricultural inputs to farmers for sustainable household food security and incomes.

Data were collected from eight (8) districts of Uganda, i.e., Arua and Nebbi districts in West Nile sub-region; Apac, Oyam and Lira in Lango sub-region; Gulu in Acholi sub-region; Kibuku in Bukedi sub-region; and Masindi in Bunyoro sub-region. Data were collected from March, 2020 to June, 2020. The choice of the districts was based on: 1) the quantity of cassava produced in those districts; 2) the volume of trade in cassava and cassava-related products in those districts; and 3) the amount of consumed cassava in those districts as cassava is one of the staple foods in those areas. Figure 1 presents the sub-regional comparison of cassava production.[8]

Back to the sample, a total of 348 respondents were interviewed; including 241 cassava farmers/producers, 64 agro-input dealers, 8 district agricultural officers, 16 agro-processors, 16 extension workers and 3 officers (1 from NAADS secretariat, 1 from the Ministry of Agricultural Animal Industry and Fisheries (MAAIF), and 1 from the Operation Wealth Creation (OWC).

[8] The amount of consumed cassava in season 2 of 2019 is shown in Table A3.

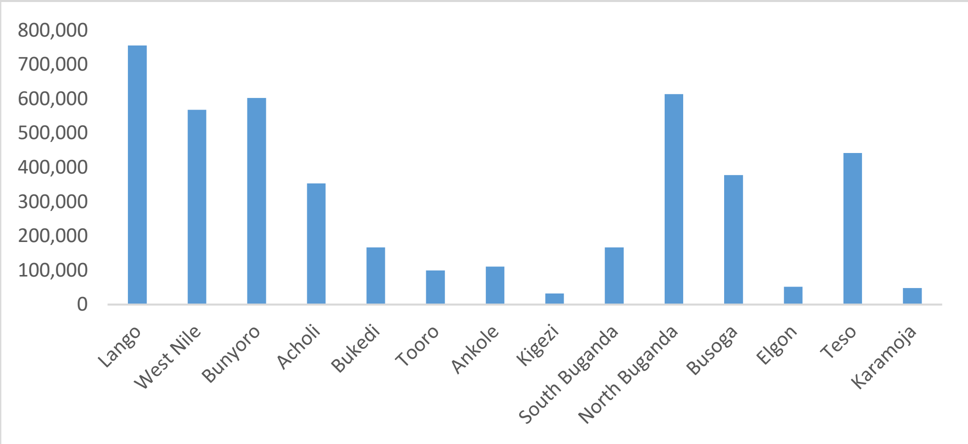

Figure 1: Total Cassava Production by Sub-region (*in Mmt*).
Source: Constructed from data extracted from Annual Agricultural Survey, 2018 provided by Uganda Bureau of Statistics.

The dataset contains different modules with information on demographic characteristics of farmers, their household attributes, cassava varieties, input use, cassava storage and market information, financial accessibility sources, group membership, knowledge on agronomical trainings, information on processing and value addition, and information on the roles of the central and local governments in the cassava value-chain.

For the purposes of addressing the objectives of the study, we used data collected from the 241 farmers. However, two subjects were dropped due to missing information on key variables. Specifically, we used data on demographic characteristics, cassava varieties, input use, group membership and information accessibility through agricultural extension workers. The adoption of cassava varieties is indicated by a constructed dummy that takes 1 if a farm household adopted at least an improved cassava variety, and 0 otherwise. Table 1 presents the summary statistics for the variables.[9]

On average, the respondents were 46 years old, and the majority of them were married and employed in farming. In relation to family size, the data suggests large families were with at least 8 persons per household, though only 18 percent of the household heads had completed secondary level of education. Moreover, the data also suggests that households had at least 19 years of experience in farming; with over 85 percent of the households being headed by males. Over 60 percent of the households adopted to new cassava varieties; and 68 percent received information on improved cassava varieties from extension workers. The results also show that, on average, over 97 percent of the households grow cassava as a food security crop.

[9] Variable names and their descriptions are presented in Table A4.

Table 1: Summary Statistics of the Variables

Variables	Obs.	Mean	S.D
Adoption =1	239	0.603	0.490
Agric_Extension =1	239	0.677	0.468
Age	239	46.054	12.756
HH_Male	239	0.854	0.354
Marital_status	239	0.904	0.296
Education	239	0.180	0.385
Occupation	239	0.879	0.327
Household_size	239	8.326	4.641
Experience	239	19.289	12.763
Group_membership	239	0.565	0.497
Input costs	239	1770801	1610000
Food security	239	0.971	0.169
Financial	239	0.782	0.413
Easy_cook	239	0.360	0.481
Easy_grow	239	0.310	0.463
Drout_resist	239	0.360	0.481

Other reasons cited as to why households engage in cassava growing included: desire to earn income (78 percent), easy to cook and being a drought resistant crop (over 36 percent). It is observed that, on average, over 56 percent of the households were in one or more farming membership groups with a community; and incurred an input cost amounting to UGX1,770,801.

5. Empirical Results and Discussion

Before presenting the study results in a regression framework—in which we detail the role of agricultural extension in the adoption of improved cassava varieties, and also report other determinants of adoption—we first demonstrate the reasons for the adopting of improved cassava varieties in the form of a histogram.

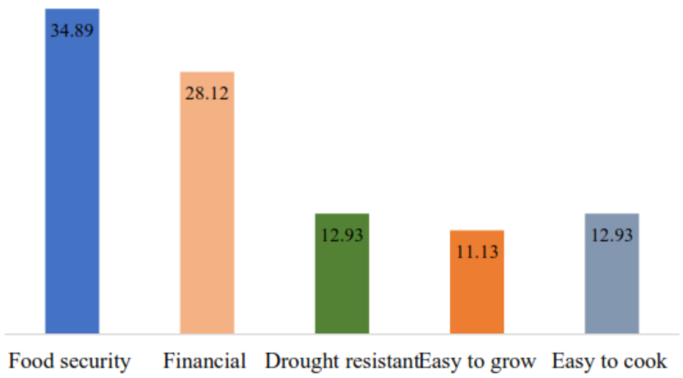

Figure 2: Reasons for Adopting New Cassava Varieties (*Calculated as percentage of adopters*)

Notes: Statistics in this figure are calculated from the participants' responses on the main reason why at least an improved cassava variety was adopted.

Figure 2 suggests that farmers adopt to improved cassava varieties for five reasons. Many adopters (34.9%) adopt improved cassava varieties because they believe in high harvests that can assure them of food security. This result is supported by Nweke (2004) and Parmar et al. (2017), who show that cassava is a good crop for food security. 28.1% of the improved cassava variety adopters are driven by the desire to sell or market. The implication here is that farmers expect more yields from the improved varieties compared to the local varieties. This result is still supported by Nweke (2004) and Parmar et al. (2017). 12.9% of the adopters grew improved varieties because they were considered drought-resistant; while some adopters believed cassava from the improved varieties take less time to cook and thus, considered them as consuming less biomass-energy. Lastly, 11.1% of the adopters believed that the improved varieties were easy to grow given that some take about six months to mature.

5.1 Determinants of Adoption of Improved Cassava Varieties

Using a regression framework explained in section 3.0, we first report results from the selection equation (equation 5), i.e., the factors that influence access to agricultural extension. The results are presented in Table 2.

Table 2: Factors Influencing Agricultural Extension Accessibility

Variables	Access to Information	
	Co-efficient	Standard Errors
Age	0.002	0.009
HH_Male	1.04	0.279***
Education	0.021	0.270
Occupation	-0.033	0.328
Household_size	-0.019	0.023
Experience	-0.010	0.009
Group_membership	0.782	0.203***
Food security	1.201	0.520**
Financial	0.031	0.267
Easy_cook	0.460	0.240*
Easy_grow	-0.513	0.229**
Drout_resist	-0.661	0.212**
Constant	-2.9608	0.919***

Notes: Results are estimated odds ratio using probit model with selection technique. ***p < 0.01 ***p<0.05 and *p < 0.1

Positive coefficients in the selection model imply a higher likelihood of farmers to adopt improved cassava varieties when they access agricultural extension services related to such varieties. Precisely, the results show that male subjects, and those who are members of at least a farmers' group, are more likely to access agricultural extension services. These results are not strange in the sense that farmers tend to learn and change their behaviours through their peers, or through government extension workers. In trying to understand how farmers lean to manage their businesses, especially in changing their strategic and tactical knowledge, Kilpatrick amd Johns (2003) observed that farmers learn to change their business operations through accessing information from extension workers and individuals. The study further indicates that through such learning approach, farmers assess information through a one-to-one basis, and most frequently from experts and from individuals. In a similar way, membership to social groups positively influenced farmers' attitude towards adapting to climate change (Zamasiya et al., 2017). The results in Table 2 also show that when farmers receive information that improved cassava varieties are associated with improved food security in their households, that they are easy to grow and to cook, and that they are drought resistant, the chances of adopting the varieties increase.

5.2 Agricultural Extension Accessibility and Improved Cassava Adoption

Next, we analyse how accessibility to agricultural extension affects the adoption of improved cassava varieties. To capture this effect, first, we estimate equation (7) using the switch_probit command;[10] and second, apply the predict command to obtain the effect of agricultural extension accessibility on the adoption of improved cassava varieties (see, Lokshin & Sajaia, 2011). The results are presented in Table 3.

Table 3: Showing Proportion of Farmers Who Adopt New Cassava Varieties

Variable	Observation	Mean	SD
Adoption =1	162	0.458	0.277

Notes: MTE is the marginal treatment effect which is the effect of the treatment on individuals given observable and unobservable characteristics.

The results in Table 3 show that farmers who received agricultural extension from extension workers about the improved varieties are 45.8 percentage points more likely to adopt those varieties. Precisely, after receiving the relevant information about the improved cassava varieties, then the likelihood of adopting such varieties increases. Extension workers provided information to farmers relating to each new (improved) cassava variety introduced by the NARO, its attributes (resistance to either disease or drought, maturity period, expected yields, etc.), best farming practices for each variety, among others. The information was normally shared through farmer groups and, at times, directly to farmers. The results in Table 3 supports Zamasiya et al. (2017). who find a positive effect of access to extension services to climate technology adoption. Too, Ali, (2013) and Genius et al. (2014) find access to extension services to positively impact on technological adoption and its diffusion (Genius et al., 2014).

5.3 Other Factors Influencing Adoption

Access to agricultural extension alone may not fully explain the choices made by farmers to adopt improved cassava varieties. Table 4 presents other factors that influence improved cassava adoption. These are results from equation (6) estimated when access to agricultural extension is considered as a treatment arm in the selection equation.[11]

[10] The switch_probit command implements a maximum likelihood method and simultaneously estimate the binary selection and the binary outcome parts of the model to yield consistent standard errors of the estimates (Lokshin & Sajaia 2011).

[11] Other factors that non-adoption even if after accessing agricultural extension services are presented in Table A5.

Table 4: Other Factors Influencing the Adoption of Improved Cassava Varieties With Access to Agricultural Extension

Variables	Adopters
	Coefficient
Age	0.011
	(0.011)
HH_Male	0.513
	(0.335)*
Marital_status	0.085
	(0.414)
Educ	0.404
	(0.294)
Occupation	0.184
	(0.329)
Household_size	-0.030
	(0.023)
Experience	-0.008
	(0.011)
Group_membership	1.286
	(0.219)***
Input_costs	4.64e-09
	(7.38e-09)
Food security	-4.471
	(0.972)***
Financial	-0.238
	(0.282)
Easy_cook	0.989
	(0.278)***
Easy_grow	-0.454
	(0.269)*
Drout_resist	0.163
	(0.255)

Notes: Results are estimated odd ratios using the probit estimation with selection technique. ***p < 0.01 ***p<0.05 and *p < 0. In the parenthesis are standard errors

The results show that the probability of adopting improved cassava varieties increases when the household head is male. These gendered differences are normally attributed to access to complementary inputs such as land, labour, and extension services (Doss & Morris, 2000). Polar et al. (2017) attributes to access to productive resources and access to information.

Further, being a member to any farmer group raises the probability of adopting improved varieties. The possible explanation for this rests on the sharing of knowledge and experiences among peers. Peer to peer learning provides a useful avenue for sharing information and experiences (David, 2014). Still, peer learning motivates people to learn (Núñez-Andrés et al, 2021); and can shorten the decision-taking period to adopt. Using data on agricultural technologies and farm performance from Burundi, Democratic Republic of Congo and Rwanda, Ainembabazi et al. (2017) demonstrated a shorter adoption period for households that were members to a farmers' group. Further, Etwire et al. (2013) and Tolno et al. (2015) also report that farmers' groups increase the chances of farmers' interaction with extension workers, and their decision to adopt to improved technologies.

Still, the results in Table 4 demonstrate that when farmers receive information about the benefits of adopting improved cassava varieties, they are likely to adopt those varieties especially if the agricultural extension content contains information on the luxury of reducing the effort of preparing a meal (when the variety is easy to cook). Contrariwise, if farmers are told that improved cassava varieties can raise the extent of food security in their house, and that the varieties are easy to grow, their chances of adopting reduce. This can be explained by the farmers' perception on imporved varieties. Through lobbying, many farmers seem to hold a perception that improved varieties are costlier than local varieties on the grounds that: (1) they are easily attacked by pests, and hence attract pest prevention costs; and (2) such varieties cannot withstand delayed weeding compared to local varieties. In relation to food security, some farmers believe that since improved varieties take less time to maturity (some varieties take six to nine months), they are also less likely to last longer in the ground before getting spoilt. This forces them to stick to the local varieties which can last for over 2 years in the ground before harvest.

Turning to food security, results in Table 4 show that there is a significant negative relationship between adoption and food security. This means that farmers are less likely to adopt to new cassava varieties. The possible explanation for this result is that farmers are more secure when they continue growing their local varieties, which are assumed to be long-lasting, easy to keep and store in the ground, among others. In most cases farmers do not see a reason why they should change from their already grown varieties to new improved varieties (Wale, 2012). However, in their study about the effect of variety attributes on the adoption of improved sorghum varieties in Kenya, Timu et al. (2014) noted that farmers decide to take on a new variety for reasons like taste, drought tolerance, yield, easy for cooking, and a variety's ability to raise their income[12]. Quite similar factors seem to influence the adoption of sweet potato varieties by farmers (see, Danso-Abbeam, 2021).

6. Conclusions and Policy Implication

Increasing agricultural productivity and improving the livelihood of farmers depends on the extent of the interventions invested by policy makers in supporting agricultural innovations, their adoption and diffusion. This is driven by the fact that registering significant gains from new agricultural technologies is better achieved when the inventors diffuse such technologies, and when farmers adopt them (Meinzen-Dick et al., 2004). The use of various agricultural technologies—

12 Timu et al. (2014) documents the determinants of new variety adoption taking a case of sorghum while, for adoption of improved cassava varieties, see Osewe, M. L. (2021).

such as improved seeds, agro-chemical inputs, and machinery—has for long been at the forefront of many country's development agendas. This is evidenced by the huge investments directed to this effect.

In the context of Uganda—and more specifically for the cassava subsector—the government allocated UGX33.2bn to the ICIDP with UGX392m earmarked for distributing of cassava cuttings to farmers for a period of five years preceding 2020 (NPA, 2020). This is a supplement to many other interventions that have been implemented to support the subsector. Other interventions include agricultural extension services, agro-industrialisation for value addition, etc. However, even with such interventions in place, the rate of improved cassava adoption is still low in the country. The key question that remains unanswered, especially from the policy perspective, is whether the investment in agricultural extension is impacting on adoption of such improved cassava varieties.

This paper aimed to examine the role of agricultural extension in the adoption of improved cassava varieties, and also expose other determinants of adoption. It used probit with selection equation to estimate the effect of agricultural extension in the adoption of improved cassava varieties in Uganda. Consistent with theory, we find evidence that access to agricultural extension services influences farmers' decisions to adopt such varieties. Putting that aside, we also document farmers' distrust to improved cassava varieties as a crop enterprise that can guarantee their households with food security. Some farmers believe that improved varieties are also less likely to last for a longer period before harvest. This forces them to stick to their local varieties, which can last for over two (2) years in the ground before harvest.

References

Akudugu, M. A., Guo, E. & Dadzie, S. K. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions?

Ainembabazi, J. H., van Asten, P., Vanlauwe, B., Ouma, E., Blomme, G., Birachi, E. A. & Manyong, V. M. (2017). Improving the speed of adoption of agricultural technologies and farm performance through farmer groups: Evidence from the Great Lakes region of Africa. *Agricultural Economics*, 48(2): 241–259.

Anderson, J. R. & Feder, G. (2007). *Agricultural extension: Handbook of agricultural economics*, 3: 2343–2378.

Alcon, F. S.-P. (2014). *Forecasting deficit irrigation adoption using a mixed stakeholder assessment methodology*. (Vol. 83). Technological Forecasting and Social Change.

Asfaw, S., Shiferaw, B., Simtowe, F. & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, 37(3): 283–295.

Azikiwe A. I., Monde, N. Obi, A. & Sunday, O. A. 2013. Quality of extension services: A case study of farmers in amathole. *Journal of Agricultural Science* 5(2): doi: 10.5539/ jas.v5n2p204.

Bakshi, A. (2003). Potential adverse health effects of genetically modified crops. Part B, *Journal of Toxicology and Environmental Health*, 6(3).

Bandiera, O. & Rasul, I. (2006). Social networks and technology adoption in northern Mozambique. *The Economic Journal,* 116*(*514*):* 869–902.

Beaman, L., BenYishay, A., Magruder, J. & Mobarak, A. M. (2021). Can network theory-based targeting increase technology adoption? *American Economic Review,* 111*(*6*):* 1918–43.

Bonabana-Wabbi J. (2002). Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District. Msc. Thesis Eastern Uganda.

Brown, B., Nuberg, I. & Llewellyn, R. (2017). Stepwise frameworks for understanding the utilisation of conservation agriculture in Africa. *Agricultural Systems*, 153: 11–22.

Cafer, A. A. (2018). Adoption of new technologies by smallholder farmers: The contributions of extension, research institutes, cooperatives, and access to cash for improving Tef production in Ethiopia. *Agriculture and Human Values*.

Campenhout, B. V. (2021). The role of information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda. *Economic Development and Cultural Change*, 69(3): 1239–1272.

Chandio, A. A., Jiang, Y., Akram, W., Adeel, S., Irfan, M. & Jan, I. (2021). Addressing the effect of climate change in the framework of financial and technological development on cereal production in Pakistan. *Journal of Cleaner Production*, 288: 125637.

Danso-Abbeam, G. B. (2021). Food security impacts of smallholder farmers' adoption of dual-purpose sweetpotato varieties in Rwanda. *Food Sec.* 13: 653–668. https: //doi.org/ 10.1007/s12571-020-01119-7.

de Ven, W. V. (1981). The demand for deductibles in private health insurance: a probit model with sample selection. *Journal of Econometrics*, 17: 229–252.

Diiro, G. M. & Sam, A. G. (2015). Agricultural technology adoption and nonfarm earnings in Uganda: A Semiparametric analysis. *The Journal of Developing Areas*, 145–162.

Doss, C. R. & Morris, M. L. (2000). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25(1): 27–39.

Doss, C. R. (2000). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25(1): 27–39.

Etwire: M., Dogbe, W., Wiredu, A. N., Martey, E., Etwire, E. & Robert, K. (2013). Factors influencing farmer's participation in agricultural projects the case of the agricultural value chain mentorship project in the northern region of Ghana.

Evenson, R. E. & Gollin, D. (2003). Crop variety improvement and its effect on productivity the impact of international agricultural research. In: Cabi FAO. (2016). *The State of Food and Agriculture.*

Feder, G. R. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, 33: 255–298.

Fernandez-Cornejo, J., Mishra, A. K., Nehring, R. F., Hendricks, C., Southern, M. & Gregory, A. (2007). Off-farm income, technology adoption, and farm economic performance (No. 1477-2016-121070). *Economic Research Report Number* 36.

Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annual Review of Economics*, 2.

Freedman, D. A. & Sekhon, J. S. (2010). Endogeneity in probit response models. *Political Analysis*, 18(2): 138–150.

Gebrehiwot, T. (2009). Determinants of food security in rural households of the Tigray region. MPhil thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Gebre, G. G., Isoda, H., Amekawa, Y. & Nomura, H. (2019, September). Gender differences in the adoption of agricultural technology: The case of improved maize varieties in southern Ethiopia. In: *Women's studies International Forum* (76: 102264). Pergamon.

Heckman, J. J. (1978). Dummy endogenous variables in a simultaneous equation system. Econometrica 46: 931–959.

Jabbar, A. (2003). Role of knowledge in the adoption of new agricultural technologies: An approach and application. *International Journal of Agricultural Resources*, *Governance and Ecology*, 2: 312–327.

Jain, R., Arora, A. & Raju, S. (2009). A novel adoption index of selected agricultural technologies: Linkages with infrastructure and productivity. *Agricultural Economics Research Review*, 22: 109–120.

Kabunga, N. D. (2012a). Yield effects of tissue culture bananas in Kenya: Accounting for selection bias and the role of complementary inputs. *Journal of Agricultural Economics* 63: 444–464.

Kaliba, A. R., Mazvimavi, K., Gregory, T. L., Mgonja, F. M. & Mgonja, M. (2018). Factors affecting adoption of improved sorghum varieties in Tanzania under information and capital constraints. *Agricultural and Food Economics*, 6(1): 1–21.

Kariyasa, K., Dewi, A. (2011). analysis of factors affecting adoption of integrated crop management farmer field school (ICM-FFS) in swampy areas. *International Journal of Food and Agricultural Economics,* 1(2): 29–38.

Kassie, M. N. (2014). What determines gender inequality in household food security in kenya? Application of exogenous switching treatment regression. *World Development*, 56: 153–171.

Kassie, M., Shiferaw, B. & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, 39(10): 1784–1795.

Kinuthia, B. K. & Mabaya, E. (2017). The impact of agricultural technology adoption on farmer welfare in Uganda and Tanzania. Pep Policy Brief, *Partnership for Economic Policy, Number* 163

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: A double selectivity model. *American Journal of Agricultural Economics,* 83(1): 35-51.

Knowler, D. M. (2015). Farmer adoption of conservation agriculture: A review and update. In: *Conservation Agriculture*, 621–642. Springer International Publishing, Springerlink https: //link.springer.com/chapter/10.1007/978–3–319–1.

Kohli, I. & Singh, N. (1989). Exports and growth: Critical minimum effort and diminishing returns. *Journal of Development Economics*, 30(2): 391–400.

Lin, T., Ko, A. P., Than, M. M., Catacutan, D. C., Finlayson, R. F. & Isaac, M. E. (2021). Farmer social networks: The role of advice ties and organizational leadership in agroforestry adoption. *Plos one*, 16(8): e0255987.

Loevinsohn, M., Sumberg, J., Diagne, A. & Whitfield, S. (2013). Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? A systematic review. *Institute of Development Studies.*

Malla S, T. D. (2015). Household food insecurity and associated factors in West Abaya district, Southern Ethiopia. *Agriculture & Food Security*, 6(1): 2.

McCart, M. R., Henggeler, S. W. & Hales, S. (2011). Multisystemic therapy. *Encyclopedia of Adolescence,* 202–209. doi:10.1016/b978-0-12-373951-3.00121-6.

Meinzen-Dick, R. A. (2004). *Science and poverty: An interdisciplinary assessment of the impact of agricultural research.* Food policy report, International Food Policy Research Institute. Washington DC. http: //ageconsearch.umn.edu/bitstream/ 42566/2/ pr16.pdf.

Minten, B., & Barrett, C. (2008). Agricultural technology, productivity, and poverty in Madagascar. *World Development.* https: //doi.org/10. 1016/j.worlddev. 2007.05.004*,* 36(5): 797–822.

Mtunda, K. J. (2002). Current status of cassava brown streak disease in Tanzania. Past, present and future. In: James P. Legg and Rory J. Hillocks (eds.), *Proceeding of an International Workshop*, October 2002.

Mwangi, M. & Kariuki, S.(2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development,* 6(5).

Mwaura, F. (2014). Effect of farmer group membership on agricultural technology adoption and crop productivity in Uganda. *African Crop Science Journal*, 22: 917–927.

Nakabonge, G. S. (2018). Local varieties of cassava: Conservation, cultivation and use in Uganda. *Environment, Development and Sustainability,* 20(6): 2427–2445.

Namonje-Kapembwa, T. & Thelma, A. (2016). Improved agricultural technology adoption in Zambia: Are women farmers being left behind? Indaba Agricultural Policy Research Institute (IAPRI) Working Paper 106 (No. 1093-2016-87913).

Nicoletti, C. & Peracchi, F. (2001, July). Two-step estimation of binary response models with sample selection. Paper presented in the first British Household Panel Survey Research Conference held in Colchester, July Citeseer.

Nin, A., Arndt, C. & Preckel: V. (2003). Is agricultural productivity in developing countries really shrinking? New evidence using a modified nonparametric approach. *Journal of Development Economics,* 71(2): 395–415.

Nuwamanya, E., Baguma, Y., Atwijukire, E., Acheng, S. & Alicai, T. (2015), Effect of cassava brown streak disease (CBSD) on cassava (Manihot esculenta Crantz) root storage components, starch quantities and starch quality properties. *Int. J. Plant Physiol. Biochem.*, 7: 12–22.

Nwawuisi, J. U., Okoye, B. C and Odaji, C. O. 2007. Adoption of improved cassava varieties (TMS). Proceedings of the 41st Conference of the Agricultural Society of Nigeria, Samaru, (pp. pp. 527–53).

Nweke, F. I. (2004). New challenges in the cassava transformation in Nigeria and Ghana. *Intl Food Policy Res Inst.*, 118.

Ojo, S. O. & Ogunyemi, A. I. (2014). Analysis of factors influencing the adoption of improved cassava production technology in Ekiti State, Nigeria. *International Journal of Agricultural Sciences and Natural Resources*, 1(3): 40–44.

Omotilewa, O. J., Ricker-Gilbert, J., & Ainembabazi, J. H. (2019). Subsidies for agricultural technology adoption: Evidence from a randomized experiment with improved grain storage bags in Uganda. *American Journal of Agricultural Economics*, 101(3): 753–772.

Ornetsmüller, C. J. (2018). A multiscale gaming approach to understand farmer's decision making in the boom of maize cultivation in Laos. *Ecology and Society*, 23: 35.

Osewe, M. L. (2021). Variety traits and sustainable food security: the role of improved cassava varieties in Kenya. *Chemical Engineering Transactions*, 89: 355–360.

Ovwigho, B. O. (2013). A framework for measuring adoption of innovations: Improved cassava varieties in Delta State Nigeria. *Extension Farming Systems Journal,* 9: 171–177.

Pamuk, H., Bulte, E. & Adekunle, A. A. (2014). Do decentralized innovation systems promote agricultural technology adoption? Experimental evidence from Africa. *Food Policy*, 44: 227–236.

Pan, Y., Smith, S. C. & Sulaiman, M. (2018). Agricultural extension and technology adoption for food security: Evidence from Uganda. *American Journal of Agricultural Economics*, 100(4): 1012–1031.

Parmar, A., Sturm, B. & Hensel, O. (2017). Crops that feed the world: Production and improvement of cassava for food, feed, and industrial uses. *Food Security* 9(5): 907–927.

Parvan, A. (2011). Agricultural technology adoption: Issues for consideration when scaling-up. *The Cornell Policy Review,* 1(1): 5–32.

Polar, V., Babini, C., Velasco, C., Flores, P. & Fonseca, C. (2017). Technology is not gender neutral: Factors that influence the potential adoption of agricultural technology by men and women. International Potato Center, La Paz – Bolivia. 41 pp.

Rogers, E. M. (1995). *Communication of innovation: A Cross-cultural approach.* (Second Edition). Free Press, New York. 450pp.

Rogers, E. M. (2003). *Diffusion of innovations (*5th ed.*).* New York: Free Press.

Samiee, A., Rezvanfar, A., Faham, E. (2009). Factors affecting adoption of integrated pest management by wheat growers in Varamin County, Iran. *African Journal of Agricultural Research*, 4(5): 491–497.

Sunding, D. & Zilberman, D. (2001). The agricultural innovation process: research and technology adoption in a changing agricultural sector. *Handbook of Agricultural Economics,* 1: 207–261.

Tanellari, E., Kostandini, G., Bonabana-Wabbi, J. & Murray, A. (2014). Gender impacts on adoption of new technologies: The case of improved groundnut varieties in Uganda. *African Journal of Agricultural and Resource Economics*, 9(311–2016–5619): 300–308.

Tegengne, Y. (2017). Factors affecting adoption of legume technologies and its impact on income of farmers: The Case of Sinana and Ginir Woredas of Bale Zone. MSc. dissertation in Agricultural Economics, Haramaya University, Haramaya.

Theis, S., Lefore, N., Meinzen-Dick, R. & Bryan, E. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agriculture and Human Values*, 35: 671–684.

Tibamanya, F. Y. (2021). Drivers of and barriers to adoption of improved sunflower varieties amongst smallholder farmers in Singida, Tanzania: The double-hurdle approach. IFRO Working Paper, No. 2021/03, University of Cop.

Timu, A. G., Mulwa, R., Okello, J. & Kamau, M. (2014). The role of varietal attributes on adoption of improved seed varieties: The case of sorghum in Kenya. *Agriculture & Food Security*, 3(1): 1–7.

Tolno, E. K. (2015). Economic analysis of the role of farmer organisations in enhancing smallholder potato farmers' income in middle Guinea. *Journal of Agricultural Science,* 7(3): 123. Doi: http: //dx.do.

Uaiene, R. N. (2011). Determinants of agricultural technology adoption in Mozambique. In 10th African Crop Science Conference Proceedings, Maputo, Mozambique, 10–13 October 2011. African Crop Science Conference.

UBoS. (2020). *Annual Agricultural Survey* 2019 *Report. Kampala, Uganda.* https: //www.ubos.org/wp-content/uploads/publications/04_2022AAS2019 _Report. pdf.

Udimal, T. B., Jincai, Z., Mensah, O. S. & Caesar, A. E. (2017). Factors influencing the agricultural technology adoption: The case of improved rice varieties (Nerica) in the Northern Region, Ghana. *Journal of Economics and Sustainable Development,* 8*(*8*):* 137–148.

Uganda Bureau of Statistics (UBoS). (2019). *Statistical abstract*. Uganda Bureau of Statistics.

Wale, E. (2012). Farmers' Perceptions on replacement and loss of traditional crop varieties: Examples from Ethiopia and implications. *In:* Edilegnaw Wale, Adam G. Drucker & Kerstin K. Zander (eds.) *The Economics of Managing Crop Diversity On-farm: Case studies from the genetic resources policy initiative*. Routledge. (pp. 65-89).

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.

Appendices

Table A1: Cassava Varieties Invented by NARO and their Attributes

Variety name	Year of Release	Reaction to CMD	Reaction to CBSD	Yield (t/ha)
Nase 1	1993	Tolerant	Tolerant	25.4–43.5
Nase 2	1993	Tolerant	Susceptible	31.7–37
Nase 3	1993	Tolerant	Tolerant	20 –35.5
Nase 4	1999	High resistant	Susceptible	35–50
Nase 5	1999	Tolerant	Obsolete	28–40
Nase 6	1999	Tolerant	Obsolete	25–35
Nase 7	1999	Tolerant	Obsolete	30 –45
Nase 8	1999	Resistant	Tolerant	30–40
Nase 9	2003	Tolerant	Susceptible	20.2–38
Nase 10	2003	Highly resistant	Susceptible	36–42
Nase 11	2003	Tolerant	Susceptible	28.7–37.8
Nase 12	2003	Highly resistant	Susceptible	33–35.8
Nase 13	2011	Resistant	Tolerant	20–30
Nase 14	2011	Resistant	Tolerant	20–35
Nase 15	2011	Resistant	Tolerant	20–35
Nase 16	2011	Resistant	Tolerant	20–30
Nase 17	2011	Resistant	Tolerant	20–30
Nase 18	2011	Resistant	Tolerant	20–35
Nase 19	2013	Resistant	Tolerant	20–35
NAROCASS 1	2015	Resistant	Tolerant	20–35
NAROCASS 2	2015	Resistant	Tolerant	20–35

Notes: 1) CMD = Cassava mosaic Disease. 2) CBSD= Cassava Brown Strake Disease
Source: National Agricultural Research Organisation

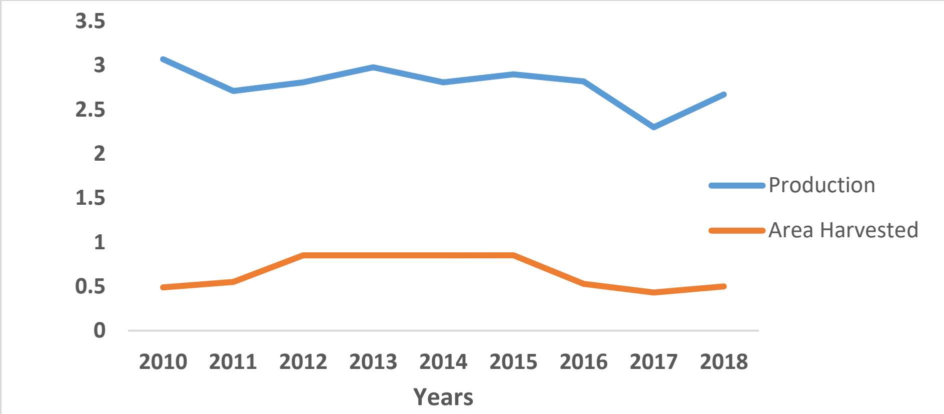

Figure A1: Annual Cassava Production (million MT) and Harvested Land Area in Hectares

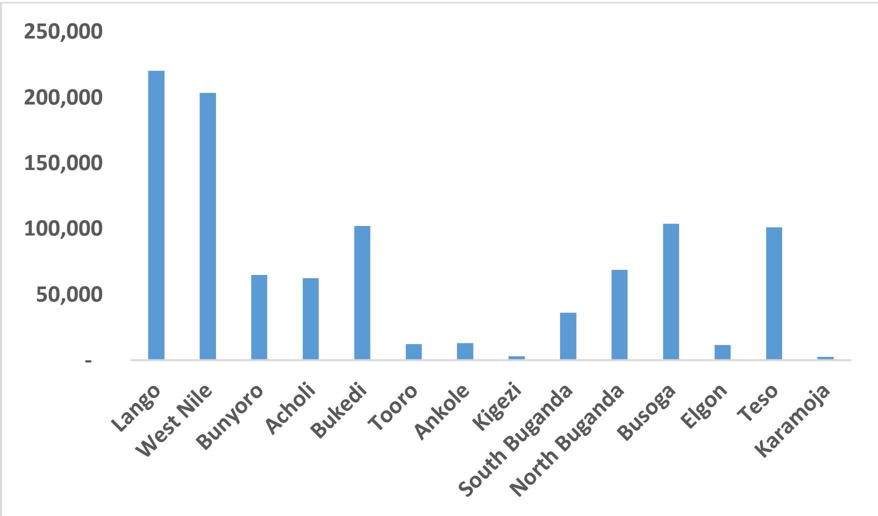

Figure A2: Total Amount Cassava Consumed in Season 2 of 2019 (*Million Tonnes*)

Table A4: Variable Names and their Descriptions

Variables	Definition
Age	Age of household head in complete years
HH_Male	1 if the household head is a male, 0 otherwise
Adoption=1	1 if a household adopts to at least a new variety, 0 otherwise
Agric_Extension=1	1 if the household accessed agricultural extension workers
Marital_status	1 if the household head is married/engaged, 0 otherwise
Education	1 if a household head completed advanced secondary level, 0 otherwise
Occupation	1 if a household considers farming as the main activity, 0 otherwise
Household_size	Average number of household habitats
Experience	Number of years in farming
Group_membership	1 if a household belongs to a cooperative, 0 otherwise
Input costs	Average cost of inputs required to grow cassava
Food security	1 if a household adopts to at least an improved cassava variety for purposes of food security, 0 otherwise
Financial	1 if a household adopts to at least an improved cassava variety for purposes of market/sale, 0 otherwise
Easy_cook	1 if a household adopts to at least an improved cassava variety because it is easy to cook, 0 otherwise
Easy_grow	1if a household adopts to at least an improved cassava variety because it is easy to grow, 0 otherwise
Drout_resist	1 if an improved cassava variety is drought resistant, 0 otherwise

Table A5: Other Factors That Influence Non-Adoption of Improved Cassava Varieties After Access Agricultural Extension

Variables	Non-adopters
	Coefficient
Age	-0.005
	(0.016)
HH_Male	-0.070
	(0.457)*
Marital_status	0.109
	(0.454)
Educ	1.177
	(0.886)
Occupation	-0.612
	(0.640)
Household_size	0.088
	(0.066)
Experience	0.006
	(0.018)
Group_membership	0.340
	(0.570)
Input_costs	1.89e-08
	(2.71e-08)
Food security	-2.333
	(0.977)**
Financial[13]	0.471
	(0.592)
Easy_cook	0.268
	(0.591)
Easy_grow	-0.665
	(0.704)
Drout_resist	1.079
	(0.418)**

[13] The authors are fully aware that willingness for farmers to sale their cassava produce can be influenced by other factors like market availability, market accessibility and price variability. However, due to absence of data, we fail to control for them in the regression framework.