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Variety Traits and Sustainable Food Security: The Role of Improved Cassava Varieties in Kenya

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Sustainable food and nutrition security is a critical issue on the changing climatic conditions and rapidly increasing population growth. Improved and sustainable agricultural practices are the key to sustaining and feeding the growing population. Cassava has been proposed as one of the mitigations to feed the future because its drought resistance and varietal improvement is vital for food security in Sub-Saharan Africa. The varietal improvements are particularly essential in Kisumu where cassava is produced more than any other county, but yields are low. This article aims to analyse the role of variety attributes on the adoption and farmers awareness of improved cassava varieties in Kisumu County, Kenya. A multivariate probit model involving four adoption equations using data set from a sample of 418 respondents was estimated. The results show that about 93.8 %, 72.6 %, and 70.4 % were aware of TMS 30572, TM/14, and MH93/OVA improved varieties. The local variety, *Selele,* was at 98 %. In addition, about 41.7 %, 32.9 %, and 25.8 % adopted TMS 30572, TM/14, and MH93/OVA improved cassava varieties, while 45.8 % were still growing local varieties, *Selele*. Awareness of production attributes, yield, maturity period, pest and disease resistance, and drought tolerance induced the adoption of improved cassava varieties. In contrast, local varieties were grown due to desirable consumption traits, taste, and ease of cooking. The findings of the model demonstrate the existence of correlation in the farmers' adoption decisions. Yield, early maturing, resistance to pests and diseases, and tolerance to drought positively and significantly influence the adoption of improved varieties, while taste and ease of cooking negatively affect the same adoption. The findings envision that more sustainable approaches to cassava production could offer tangible environmental benefits since it is a subsistence crop that is cultivated over a large cropland proportion. This approach will enable cassava breeders to focus on enhancing production attributes and consumption traits that address farmers' different needs in adoption.

1. Introduction

Changes in technology are essential for agricultural productivity, food security, and poverty alleviation in developing countries, particularly in sub-Saharan Africa (Mwaura, 2014). It is common knowledge that smallholder farmers benefit from the improved crop seed varieties and corresponding farming practices (Osewe et al., 2020). Their development and dissemination is essential for smallholder growth and development. Nonetheless, the empirical studies highlight that improved farming technologies does not necessarily help the smallholder farmers alleviate poverty because most of them are inhibited by structural challenges that make the practices inaccessible and non-profitable (Abdoulaye et al., 2018). Therefore, it is fundamental to understand why and how smallholder farmers approve the enhanced varieties and their subsequent effects on sustainable food security outcomes for an operative pro-poor expertise policy dissemination.

There is extensive research that highlights the beneficial factors of cassava globally demonstrating its effects on food security, industrial use, and value addition (Ikeogu et al., 2017). Cassava crops can obtain maximum average production in smallholder farms without using inputs such as fertilizers. The varieties are suited to grow in marginal lands with low requirements making them ideal for sustainable modern agriculture. As it is grown mostly among the smallholder farmers in rural areas, it is essential for supporting overgrowing food demand and issues related to environmental sustainability. Cassava is also, effectively used in the baking and

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confectionery industry. In sub-Saharan Africa, the Nigerian government initiated and launched cassava varieties that augmented their production vehemently, attaining the first millennium development goal by halving the starving population. Unlike Nigeria, cassava potentials have not been realized in Kenya. Its production has been affected by several challenges ranging from low-yielding varieties to inefficient extension service delivery. The average cassava yield in Kenya is estimated between 7.5 t/ha to 10 t/ha. Still, it can be as high as 25 t/ha with efficient and improved varieties targeting disease and climate resistance and yields (Opondo et al., 2020). Kenya has the potential to produce more than two million Mg of cassava annually. This overall yield has not been achieved because the current cassava production is dominated by smallholder farmers unaware of the new varietal traits, improved farming practices, and resource constraints.

The international institute of tropical agriculture and the Kenyan government, through Kenya agricultural and livestock research organization, initiated and produced new cassava varieties with desirable traits to supplement and complement sustainable food security, poverty alleviation, early maturity, environmentally sustainable, and disease resistance (Opondo et al., 2020). The varieties produced include, among others, TMS 30572, MH93/OVA, and TM/14. On the other hand, the literature on improved cassava varieties has concentrated on the socio-economic attributes (Wossen et al., 2017), policy, and institutional aspects that enhance their adoption (Adekunle et al., 2016). The studies have assumed that the features and asset base of the farmers (adopters and non-adopters) contains similar effects on the outcome variables. Most of the research has focused on rice, wheat, maize, pigeon peas, and potatoes (Abdoulaye et al., 2018). Wossen et al. (2017) documented that the multiplication and disbursement of clean cassava planting resources generated an increased rate of return in Malawi and Nigeria. The authors, however, did not outline the contributions and the awareness of individual planting resources among the farmers. The research by Christinck et al. (2017) observed that improved maize varieties enhanced household crop yields, food security, and expenditure. The authors presented a single focus on maize farming but did not outline how the varieties affect environmental sustainability and quantify the varietal awareness. Abdoulaye et al. (2018) concluded that factors determining the adoption of intensive high yielding maize differed among the poorly-endowed and well-endowed households. The adoption of varietal traits positively influences the income and food security of the households.

Considering the literature, none of the studies focused on the determined effects of varietal attributes on sustainable food security, the case of improved cassava varieties, a gap this current research sought to bridge. Various researches addressed the factors determining the adoption of cassava variety attributes using either Logit and Probit regression models. In this study, multivariate probit model is applied to solve the problem of generalization. The previous models ignore the interdependencies of the decision-making process among the households leading to biased and inconsistent results. Besides, the multivariate probit model explains the probable correlation in the case of the alternative variety adoptions. This means that the model can highlight which varietal combinations are influenced by a set of factors compared to other models such as logit/probit that generalize on the factors influencing a single technological adoption.

Therefore, this article evaluates the awareness and the role of improved cassava variety traits on sustainable food security, well-being, and poverty alleviation among the rural farmers in Kenya. There has been considerable investment in the growth and diffusion of better-quality cassava varieties by international research agencies, development institutions, and national research institutes. As part of the long-term climate change mitigation effort, the national institutions, in collaboration with other international agencies, have initiated research to develop climate adaptive, disease-resistant, and nutritious varieties. Coupled with other traits that include lodging resistance, high yield, high dry matter, and root quality. This research adds to the literature by outlining the relationship between the adoption of various cassava varieties and the preferred varieties combination that offer significantly higher yields.

2. Methods and materials

2.1 Data collection and sampling

The data used in this research was conducted in the Western circuit of Kenya in 2019 and employed a multi-stage random sampling design to test the hypothesis. First, Kisumu County was purposively selected because the region experienced an intensive promotion of the improved cassava varieties. Second, three sub-counties were listed and randomly selected from the list of available sub-counties found at the regional ministry of agriculture, livestock, and fisheries. Twenty locations were randomly selected and used the distributed list of the cassava farmers to make a final sample size. Finally, a random number generator was used to determine a sample of 418 farmers for this study. Also, interviews were conducted using semi-structured questionnaires to determine the farmers' perceptions, characteristics and preferences. The authors selected the cassava varieties because of the benefits in terms of household welfare and environmental sustainability. The improved varieties are capable of maturing earlier, resistant to pests and diseases, and can tolerate soil

infertility as well as drought. Most of the smallholder farmers in the rural (Kisumu County) prefer such crops compared to other cereals that cannot withstand invariable rainfall and pests.

2.2 Empirical model specification

This research applied a multivariate probit regression model as various researchers have endorsed it (Asrat et al., 2010). The model accounts for simultaneity in adopting multiple crop varieties and possible correlations among the farmers' uptake decisions. Therefore, the model is specified as Eq (1) and (2);

$$Y_{im}^{*} = \beta_{im} X_{im} + \varepsilon_{im} \quad (1)$$

$$Y_{im} = 1, \text{ if } Y_{im}^{*} > 0 \text{ and 0 otherwise} \quad (2)$$

Y^{*}_{im} indicates the unobservable latent variable of improved varieties, X_{im} indicates the observable socioeconomic, institutions, and cassava varieties attributes, β_{im} represents an estimation parameter, and ε_{im} represents the random error term. Further, the authors expanded equation 1 to a system of *m* equations and specified as Eq(3);

$$\left.\begin{array}{l} Y_1^{*} = X_1\beta_1 + \varepsilon_1 Y_1 = 1 \; if \; Y_1^{*} > 0, Y_1 = 0 \; otherwise \\ Y_2^{*} = X_2\beta_2 + \varepsilon_2 Y_2 = 2 \; if \; Y_2^{*} > 0, Y_2 = 0 \; otherwise \\ Y_3^{*} = X_3\beta_3 + \varepsilon_3 Y_3 = 3 \; if \; Y_3^{*} > 0, Y_3 = 0 \; otherwise \\ Y_4^{*} = X_4\beta_4 + \varepsilon_4 Y_4 = 4 \; if \; Y_4^{*} > 0, \; Y_4 = 0 \; otherwise \end{array}\right\} \quad (3)$$

This research estimated the simulated maximum likelihood method and a pair-wise correlation of the error term to justify using a multivariate probit regression model and the robustness of the results (Abdoulaye et al., 2018).

3. Results and discussion

3.1 Household attributes of cassava farmers

The socioeconomic attributes of the cassava farmers are presented in Table 1, and it illustrates that the average age of the household head for the adopters (improved cassava varieties) is 43.8 years compared with the non-adopters 45.2 years. The mean household size for the adopters is five compared to four for the non-adopters. This statistic is consistent with the projections of the Kenya National Bureau of Statistics. Also, 48.7 % of the adopters' households were headed by men compared to 48.1 % of the non-adopting households. Adopting farmers were more educated compared to the non-adopting farmers with a mean land size of 2.3 ha. Most households at least owned a mobile phone with a mean income of 6,257.6 shillings for the adopters. Further, the authors also presented the significant differences among the household characteristics.

Table 1: Socioeconomic attributes of the cassava farmers

	Cassava Farmers		
Variables	Adopters	Non-adopters	t-value
Household head age	43.812	45.225	0.765
Household size	5.045	4.031	2.876**
Male-headed HH	48.704	48.109	0.056
Education (post-pri.)	23.734	19.546	0.012
Land size	2.328	1.925	4.023***
Phones owned	1.801	0.716	2.017**
HH income	6,257.641	3,678.521	3.076***
Farmers' groups	54.832	44.340	0.674
Mkt info access	94.709	68.941	1.896
Ext serv access	42.912	34.818	6.765**

Note: ***, ** denotes 1 % and 5 % significance levels.

3.2 Households' awareness and uptake of improved cassava varieties

The authors presented the households' awareness and uptake of improved cassava varieties in Kisumu county in Table 2. The results indicated that apart from the new types introduced in the region, the farmers also cultivated a local variety, Selele. Most farmers were aware of TMS 30572 improved variety of cassava compared to the other varieties leading to 41.7 % of the households adopting it. Farmers noted that this variety is higher-yielding and environmentally proactive resulting in its higher adoption rate. This finding conforms with the results of Wossen et al. (2018) that TMS 30572 was the most preferred improved cassava variety in Nigeria. Even more, about 35.2 % of the farmers still farmed the local variety, Selele.

Subsequently, the authors analyzed the case-by-case analysis of the households' awareness and adoption of the improved varieties. As illustrated in Table 3, the improved varieties were considered more yielding compared to the local variety.

Table 2: Awareness and adoption of improved cassava varieties

Cassava Varieties	Farmers awareness (%)	Farmers adopted varieties (%)
Selele	98.300	45.800
MH93/OVA	70.400	25.800
TMS 30572	93.800	41.700
TM/14	72.600	32.900

Table 3: Awareness and adoption regarding varietal attributes

Variety Attributes	Selele (%)		TM/14 (%)		TMS 30572 (%)		MH93/OVA (%)	
	Aware	Adopt	Aware	Adopt	Aware	Adopt	Aware	Adopt
Yield potential	10.300	1.900	62.700	4.800	93.700	19.500	65.900	4.900
Maturity period	4.200	0.300	88.300	16.700	96.600	7.300	61.200	10.400
Resist drought	67.800	5.300	62.900	3.900	83.900	2.900	74.600	3.600
Pest and diseases	36.100	0.500	59.100	8.100	81.300	6.800	48.400	9.500
Taste	80.100	29.400	24.800	0.800	20.300	0.200	16.100	0.200
Cooking status	65.900	16.500	13.700	0.500	25.700	0.700	18.900	0.400

TMS 30572 was the most preferred variety in terms of yield potential. TM/14 and TMS 30572 varieties had the shortest maturity period. However, the farmers expressed that all the cassava varieties were drought and pests, disease-resistant, and improved the environment. Nonetheless, a small number of farmers were concerned about the improved varieties' ease of cooking and taste compared to the local variety, Selele. Hence, most of the adopting farmers considered the production attributes of the improved varieties compared to the local type that was considered because of its consumption traits.

3.3 Factors influencing the adoption of improved cassava varieties

In Table 4, the authors computed the pair-wise correlation coefficient between the cassava varieties cultivated in Kisumu county. The error term coefficients were significant, indicating that residuals are associated. Further, the improved varieties exhibited a positive association among themselves compared to a negative one with the local variety. The authors concluded that the improved varieties showed a complementarity compared to the substitutability aspect with the local variety. Farmers prefer more than one new variety to achieve their production and consumption desires. The uptake of cassava varieties is mutually exclusive among the households, a factor that qualifies the use of the multivariate probit regression model.

Table 4: Pair-wise correlation coefficients between cassava varieties

	TM/14	TMS 30572	Selele	MH93/OVA
TM/14	1.000	1.379 (0.001)	-0.654 (0.002)	1.287 (0.001)
TMS 30572	1.379 (0.001)	1.000	-0.925 (0.002)	0.897 (0.000)
Selele	-0.654 (0.002)	-0.925 (0.002)	1.000	-0.276 (0.001)
MH93/OVA	1.287 (0.001)	0.897 (0.000)	-0.276 (0.000)	1.000

The Wald test statistic in Table 5 illustrates that the whole model is significant rejecting the null hypothesis of conjoint nullity regarding the estimation variable coefficients. The likelihood ratio test is also significant at a p-value of 0.000, implying that the data fits the model specification. Table 5 illustrates the variables that influence the uptake of the improved varieties of cassava and the local variety. For instance, the age of the household head exhibited a negative vector though significantly influence the uptake of MH93/OVA. A unit increase in the age of the household head enhances a 1.2 % adaptation of MH93/OVA, ceteris paribus. However, the local variety's uptake is significantly influenced by the age household head. This is similar to other researchers' resolutions that old farmers are risk-averse and prefer less risky technologies (Osewe et al., 2021). Similarly, the size of the household members significantly and positively influenced the uptake of all the researched cassava varieties. It implies that larger households can pool and consolidate their resources and offer the required family labor necessary for the effective production of the cassava varieties. For instance, a unit increase in the household size could influence the adoption of TMS 50572 by 3.5 %. Besides,

the positive vector of influence on adopting the local variety of cassava indicates that larger families prefer consumption traits over other factors (Waswa et al., 2009).
Consequently, a unit increase in the land size (Osewe et al., 2020) significantly enhanced the uptake of TMS 30572 cassava variety by 2.2 %. This projected the competitiveness of TMS 30572 over other types in terms of land cultivation percentage. Therefore, farmers with larger parcels of land are likely to allocate larger chunks for growing this variety. Yet, this is a challenge because the land size in the study area is approximately 2.0 hectares per household on average. Also, access to extension services was significant in improving the cassava varieties' adoption. For instance, a unit increase in the provision of extension services increases TMS 30572 uptake by 3.1 %. However, access to extension services reduced the local variety adoption by 6 %. It implies that the extension officers advise farmers on the benefits of accepting and adopting improved technologies compared to the traditional methods. This is similar to Adekunle et al. (2016), who noted the positive and significant influence of extension officers regarding agricultural technology adoptions.

Table 5: Factors influencing the uptake of improved cassava varieties

Varieties/	Selele		TM/14		TMS 30572		MH93/OVA	
Variables	ME	Sig	ME	Sig	ME	Sig	ME	Sig
HH age	0.010	0.006***	0.003	0.614	0.010	0.211	-0.017	0.021**
HH size	0.081	0.021**	0.017	0.002***	0.035	0.057**	0.028	0.039**
HH education	0.073	0.267	0.042	0.187	0.018	0.316	0.054	0.192
Variety Yield	-0.062	0.001***	0.010	0.087*	0.043	0.002***	0.063	0.001***
Land Size	0.009	0.428	-0.045	0.214	0.022	0.071*	0.032	0.218
Variety Maturity	-0.072	0.532	0.058	0.003***	0.041	0.021**	0.701	0.425
Group Membership	0.047	0.023**	0.026	0.025**	0.076	0.231	-0.072	0.564
Extension access	-0.060	0.017**	0.216	0.037**	0.031	0.000***	0.009	0.018**
Mkt Info Access	0.025	0.216	0.034	0.653	0.046	0.428	0.083	0.537
Drought Tolerance	0.156	0.732	0.018	0.156	0.053	0.025**	0.159	0.058**
Variety Taste	0.118	0.001***	-0.021	0.006***	-0.021	0.005***	-0.051	0.020**
Ease of Cooking	0.021	0.041**	-0.026	0.050**	0.435	0.161	-0.074	0.001***
Pest and Disease Tol	-0.010	0.872	0.039	0.001***	0.068	0.001***	0.316	0.031**
Constant	0.108	0.431	1.365	0.432	0.376	0.781	0.872	0.217
Observations = 418								
Wald Chi2 = 187.226; Prob > Chi2 = 0.000								
Pseudo Log Likelihood = -196.567								

Note: ME (Marginal Effects), ***, **, * denotes significance at 1 %, 5 %, and 10 %.

Becoming a farmers' group member influenced the uptake of two varieties: TM/14 and Selele. There are two reasons to complement this finding. First, the farmers who adopted the improved variety, TM/14, could be because the information or inputs were shared in the individual groups. However, farmers usually share local seeds with others in the local breed as a sign of oneness (Mwaura, 2014). The varietal productivity attribute significantly and positively influenced the uptake of the improved varieties, but significantly reduced the adoption of the local breed (Wossen et al., 2018). Farmers prefer varieties that offer them a surplus in the market. Moreover, the uptake of the two varieties was significantly enhanced by the maturity status aspect. Farmers expressed a positive outlook on the maturity period of the TM/14 and TMS 30572 varieties.
The results also indicated that farmers opted to consider adopting cassava varieties depending on their response to the existence of drought calamities. Through the literature (Woldeyohanes et al., 2016), cassava is a drought-resistant crop; however, farmers are not taking any aspect to chance. For example, they preferred to adopt TMS 30572 and MH93/OVA because of their drought endurance compared to the other varieties. The local variety is prone to pests and diseases, and farmers incur costs to prevent or treat these abiotic factors (Wossen et al., 2017). In addition, farmers adopted varieties that provided better taste and ease of cooking. Statistically, this aspect influenced the adoption of the improved varieties negatively.

4. Conclusion and policy implications

Relying on cassava varieties as affordable subsistence food for the smallholder farmers and as a source of their livelihood extensively depends on how better it is promoted to create awareness in a safe and attractive manner compared to other food crops. This article aimed to determine the smallholder farmers' awareness and the role of varietal attributes on sustainable food security, a case of improved cassava varieties using a multivariate probit model. The overall goal is to provide the policymakers with options to promote the uptake of

the improved cassava varieties to curb the increasing food and nutrition insecurity among the rural Kisumu County. The findings indicate that farmers cultivated both the local and improved breeds depending on various perceptions.

The farmers who adopted the improved varieties preferred the production attributes such as high yields, tolerance to drought, early maturity period, and resistance to pests and diseases. Other farmers preferred the consumption traits such as the taste and ease of cooking. Therefore, it is significant to understand farmers' preferences before innovating new agricultural technologies that can curb and sustainably handle food security. Also, varietal breeders should understand the production and consumption matrix that influences the smallholder farmers' decision to adopt. Equally, other household attributes such as age, household size, access to extension services, size of the land, and group membership also influenced the farmers to uptake the improved cassava varieties.

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