



Determinants of Food Security Status amongst Smallholder Farmers Utilizing Different Maize Varieties in OR Tambo District, South Africa

Ardinesh Kambanje

Department of Agricultural Economics and Extension, Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa

Amon Taruvinga

Department of Agricultural Economics and Extension, Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa

Abbyssinia Mushunje

Department of Agricultural Economics and Extension, Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa

Charles Mutengwa

Department of Agronomy, Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa

Saul Ngarava*

Risk and Vulnerability Science Center, Faculty of Science and Agriculture, University of Fort Hare, Alice, South Africa

Abstract

Maize is an important staple crop for poverty reduction and global food security in Sub Saharan Africa. Food insecurity can be combated through adoption of productivity improving technologies, which include improved maize varieties. In that endeavour, South Africa has promoted various improved maize varieties which include open pollinated varieties (OPVs), hybrids, and genetically modified (GM) varieties. Despite this, the traditional landrace varieties have also been dominating in the country. However, the household food insecurity problem in the Eastern Cape Province of South Africa may signify a mis-match between maize varieties being promoted amongst smallholder farmers' and their needs. It therefore necessitates a scrutiny of the food security status among users of different maize varieties, and the determinants of such food security. A cross sectional survey was conducted in Port St Johns, Mqanduli and Flagstaff in the Eastern Cape Province, South Africa. Data was purposively collected from a sample of 650 smallholder farmers using a structured questionnaire. Descriptive statistics, Household Food Insecurity Access Score and ordinal logistic regression model were employed to characterize, examine the household food insecurity status and the determinants, respectively. Fifty-six percent of the respondents were utilizing land race maize varieties, whilst 29% GMs, 10% combining GMs and landrace, 4% improved OPVs and 1% convectional hybrids. The average land area under maize was 1.09 hectares with average yields (t/ha) of 1.9, 0.5, 1.7 and 1.6 for GM, landrace, conventional hybrids and improved OPVs respectively. Fifty-five percent of households utilizing GM varieties and 61% of those combining maize varieties were food secure. The regression model showed that maize variety had significant influence on food security. The study found that GM maize, improved OPV, white maize and combination effects of GM maize was associated with reduction of household food insecurity. From the study, it can be put into perspective that use of white and improved maize varieties reduces household food insecurity. Therefore, to address household food insecurity, the study recommended targeting white maize varieties, especially GM white maize varieties which are highly productive and a positive influence on household food security.

Keywords: Food security; GM maize; Smallholder farmers; South Africa; Ordinal logistic regression model.



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1. Introduction

Food security debate has been a hotbed in Sub-Sahara Africa, where 30% of the population lives in chronic hunger (Westengen *et al.*, 2014b). It is multi-dimensional, mainly defined along the lines of accessibility, stability, utilization and availability (Faber and Drimie, 2016). It has also been spatial-specific, where food security at the national scale does not necessarily translate into food security at the individual or household scale. Within the same household even, there exist differentiated food security circumstances. Contextually, food accessibility as a measure of food security refers to the ability (of a region, country, household or individual) to acquire enough food through either own production, purchasing, food aid, loan, gifts and bartering (Sakyi, 2012).

In contrast, maize (*Zea mays*), is an important staple crop for poverty reduction and global food security (Zalkuwi *et al.*, 2010). It is widely grown by smallholder farmers, being a staple to over 50% of the populations in Africa and the third most significant global crop (Khonje *et al.*, 2015). It is a staple crop in South Africa, providing food to the country's majority, having a multiplier in the economy through provision of raw material in downstream industries and a market for upstream industries (Maize, 2014). Food insecurity can be combated through adoption of productivity improving technologies (Bezu *et al.*, 2014). This is envisaged through multiplier concerning improved food production, food price reduction, non-farm sector growth and commercialisation (Gouse *et al.*, 2005). In that

*Corresponding Author

endeavour, various improved maize varieties have been promoted including improved open pollinated varieties (OPVs), hybrids developed through conventional methods and genetically modified organisms (GMOs) (Westengen *et al.*, 2014a). However, landraces have also remained in practice. An increase in maize production in South Africa has been attributed to improved maize variety utilization (Mbofung, 2009). The most recent technologies have concerned use of Genetically Modified (GM) maize and hybrid maize, with the country occupying 9th position globally in terms of biotech production (James, 2014). South Africa is the only country having small-scale farmers producing GMs in the past decade, with land area under GM maize increasing by 72% from 1999 to 2011, to 85% in 2014, with small scale farmers cultivating about 350 000 to 500 000 hectares of improved maize varieties (IMVs) (Global Harvest Initiative, 2017). However, these figures are very low in comparison with commercial farmers producing IMVs (Van Den, 2013), as South Africa's economy benefited R6.179 billion in utilising biotech crop production from 1998 to 2010 (Abidoeye and Mabaya, 2013).

Becerril and Abdulai (2010), identified that most welfare impact studies of agricultural technology have been difficult, focusing more at the macro scale. Nonetheless, there have been a plethora of studies on agricultural technology adoption, especially of factors that affect this adoption (Fisher *et al.*, 2015). There have also been a number of studies that have focused on the factors affecting food security, while others have concentrated on the impact of IMV adoption on food security (Bezu *et al.*, 2014). Notwithstanding, few studies have attempted to zero-in on the factors that determine food security comparing the utilisation of many IMVs (Gitonga and De Groote, 2016). The argument here being that on its own, technology adoption is a poor measure of impact, but nevertheless, entangled in a web of determinants having a bearing on the impact. The question then being what determines the welfare impact of technology adoption? Hence this study seeks to illuminate on the determinants of food security status amongst smallholder farmers utilising different maize seed varieties.

2. Material and Method

2.1. Study Area

The study covered three local municipalities in the O. R Tambo District Municipality of Eastern Cape Province, South Africa namely Port St John's, King Sabata Dalindyebo and Ingquza Hill. Low maize yields albeit abundant arable land, favorable climatic conditions, input and financial support programs, plagues smallholder maize farming in Eastern Cape Province. Low production witnessed in the province may be due to the maize varieties being used by smallholder farmers and signifies that there might be a "mis-match" between the maize varieties being promoted and the smallholder farming systems. Low maize productivity, further results in low profitability of the smallholder farmers, leading to low income, food insecurity and rapid exit of people to other non-farm activities. Literature highlights the need to further question productivity of different maize varieties under various cropping systems common in rural areas (Munz *et al.*, 2014). Need therefore arises to query the productivity of various improved maize varieties currently promoted for smallholder farmers against OPV's (landraces) year on year variation in food availability, to inspire future maize breeding efforts and government maize support programmes that may improve household food security.

2.2. Study Design

From the three given local municipalities, one area was selected for data collection, namely, Port St Johns, Mqanduli and Flagstaff respectively. The study used a cross sectional, descriptive and quantitative survey of smallholder maize producers. For the purpose of capturing a well-represented sample of the smallholder farmers in the study area, purposive sampling was used as the sampling technique targeting 650 respondents.

2.3. Data Analysis

Household Food Insecurity Access Scale (HFIAS) was used to measure the food insecurity levels of the various households (Coates *et al.*, 2007). The method assumes that a household's experience of food insecurity has predictable reactions and responses can be captured and quantified through a survey and summarized in a scale (Sakyi, 2012). It is made up of two types of questions which are related to the occurrence and frequency of occurrence of a food insecure condition that took place during the previous month (30 days) which is used to compute the score (Shisanya, 2008). The HFIAS is computed as:

$$\text{HFIAS (0 - 27)} = Q_{1a} + Q_{2a} + Q_{3a} + Q_{4a} + Q_{5a} + Q_{6a} + Q_{7a} + Q_{8a} + Q_{9a} \quad (1)$$

Where Q = the occurrence question

The expected least score is 0 and the highest is 27, meaning that the higher the score the higher the probability of a household being vulnerable to food insecurity (Maziya *et al.*, 2017). HFIAS was preferred because it encompasses the three domains of food access namely, anxiety, insufficient quality and quantity of food supplied (Mango *et al.*, 2014). Since there is no universally accepted approach in setting up cut-off points so as to categorize households (Coates *et al.*, 2007), the study used a six-point cut-off as outlined below:

HFIAS 0 – 6: Food Secure; HFIAS 7 – 13: Mildly Food Insecure; HFIAS 14 – 20: Moderately Food Insecure; HFIAS 21 – 27: Severely Food Insecure. These four categories were then used in the ordinal regression model.

An ordinal regression model was used to determine association among variable of interests. An ordinal regression model entails that a dependent variable has categories which have a meaningful sequential order (Grilli and Rampichini, 2014). In that respect consider an individual drawn from the joint distribution of (Y; X) where Y is the ordinal response, the HFIAS amongst n alternatives, from n=1 (HFIAS: 0-6) to n=4 (HFIAS: 21-27) and X= X₁, ..., X_n is the independent variables (Kim, 2004). The probability p₀ = (p₁(Y), p₂(Y), ..., p_k(Y) for each

category $j=1, \dots, n$ at value $Y_0 = Y_1, Y_2, \dots, Y_n$ for a set of explanatory variables X_1, X_2, \dots, X_k is of particular importance to the predictor X . Thus, the ordered logit model in the form of a proportional odds model was used and is outlined below:

$$\text{Logit}(p_1 + p_2 + \dots + p_k) \equiv \log \frac{p_1 + p_2 + \dots + p_k}{1 - p_1 - p_2 - \dots - p_k} = \alpha_k + \beta X' \tag{2}$$

3. Results and Discussions

3.1. Descriptive Results

The average age of the total respondents was 57 years, lower in Flagstaff and Mqanduli (56) and higher in Port St John’s (59). There was a lower age range for the respondents in Mqanduli (59) relative to Port St John’s (62 years) and Flagstaff (72 years). Across all the three study areas, most of the maize producers were predominantly female, with primary education, with those in Flagstaff being single relative to married in Port St John’s and Mqanduli. On average, collectively, the dependency ratio of the respondents was 1.9, with Flagstaff and Port St John’s individually having dependency ratios of 1.57 and 2.44. Most of the respondents were unemployed, who were dependent on social grants, with an average monthly household income of between R1001 – R2000. With an overall average area of 1.09 ha under maize, land allocated to maize was higher in Mqanduli (1.1 Ha) with Port St Johns and Flagstaff having 0.85 ha and 0.78 ha respectively, with white maize common in Port St Johns and Mqanduli and yellow in Flagstaff. Across all the three study sites, four maize varieties were identified, namely, GM, landrace, conventional hybrids and improved OPVs, with yields of 1.9t/ha, 0.5t/ha, 1.7t/ha and 1.6t/ha respectively.

Table-1. Association between food security and maize variety

		HFIAS CATEGORY (Score)				Total
		Food Secure (0 – 6)	Mildly Food insecure (7 – 13)	Moderately Food Insecure (14 – 20)	Severely Food Insecure (21 – 27)	
Maize Variety Used	Landrace	199 (55)	79 (21)	71 (20)	13 (4)	362
	GM	118 (63)	66 (35)	3 (1.5)	1 (0.5)	188
	Conv. Hybrid	0 (0)	4 (50)	3 (37.5)	1 (12.5)	8
	Imp. OPV	14 (54)	7 (27)	5 (19)	0 (0)	26
	Combination	40 (60.5)	23 (35)	2 (3)	1 (1.5)	66
Total		371 (57)	179 (28)	84 (13)	16 (2)	650
CHI SQUARED TEST						
Variables		Chi Square Value	Asymptotic Significance (2-sided)			
Food security and GM		60.6	0.000***			
Food security and Landrace		77.3	0.000***			
Food security and Improved OPV		0.63	0.89			
Food security and Con. Hybrids		10.56	0.014*			
Food security and Combination		7.42	0.060*			

In terms of maize varietal use, results in [Table 1](#) shows that 56% of the respondents were using landrace maize varieties, 29% GMs, 10% a combination of landrace and GMs, 4% improved OPVs and 1% conventional hybrid. The results also generally show that, 55% of households using landrace maize seeds, 63% using GMs, 54% using improved OPVs were food secure and for those using a combination of maize varieties 61% were food secure. These findings suggest that GM maize varieties are more associated with household food security than any other variety followed by landrace and conventional hybrids as shown by the significant chi-square. Results further indicate that, a combination of landrace and GMs has a significant association with household food security.

In that respect, the aim of the study here was to outline possible contributors to the association between household food security and choice of maize variety using logical interpretation. In this study food security was defined and estimated by household food in-access score which measured the prevalence of food insecurity in the last 30 days. In essence, anything that affects access to food, for example technology (maize variety), system (farming or cropping system) or institutional factors (cropping program or markets) that addresses access to better yield (food) at household level was believed to be a critical factor in explaining the inferred association. Thus, anxiety about lack of food, insufficient quality and quantity supplied are the main domains in HFIAS Mango et al which then affects accessibility of food.

It therefore follows that, accessibility implied also affordability and preferences that enable people to effectively translate their hunger into demand that is satisfied. Meaning that food security in these households was partially explained by the choice of maize variety in the sense that, agriculture was not practiced to its full potential, rather emphasis was on incomes and social networks that are used in accessing food ([Ziervogel and Ericksen, 2010](#)). Thus, a significant association is therefore suggested between household food security and a combinational use, landrace and GM maize varieties grown worth probing further with regression models for purposes of understanding the direction of influence.

3.2. Empirical Results

An ordinal logistic regression was done to establish strength and direction of the association between food security and maize varieties used along with cropping systems. Determinants of household food security are outlined in Table 2.

Table-2. Relationship between household food security and maize variety

Variable	B	Std. Error	Wald	Sig.
GM	-1.875	0.539	12.087	0.001**
Landrace	-0.846	0.526	2.593	0.107
Improved OPV	-1.219	0.624	3.816	0.051*
CombiVar	2.010	0.828	5.890	0.015**
MonoCrop	0.321	1.153	0.078	0.780
MixedCrop	0.023	1.155	0.000	0.984
CombiCrop	-0.227	1.276	0.032	0.859
Yellow	-0.462	0.581	0.634	0.426
White	-0.947	0.571	2.752	0.097*
GM*White	-0.603	0.218	7.660	0.006**
GM*Yellow	-0.461	0.174	7.000	0.008**
Improved OPV*White	0.023	0.591	0.002	0.969
Improved OPV*Yellow	0.019	0.369	0.003	0.959
Model Summary				
Chi-square (df) (Sig)	35.28 (9) (***)			
(-2) Log Likelihood	219.88			
Nagelkerke R ²	0.061			

Note: ***, ** and * indicate the level of significance at 1, 5 and 10 percent respectively. Results for conventional hybrids was not included in the model due to a very low sample (N=14). Meaningful conclusions cannot be obtained when the sample size is below 30

Based on the thirteen predictor variables fitted into the regression model as shown in Table 2, six variables (GM maize variety, improved OPV maize variety, white maize, combinational variety use, combination of GM and white maize as well as GM and yellow maize) had a significant impact in influencing the household food insecurity level. Whereas, seven variables (landrace maize variety, mono-cropping, mixed-cropping, combination of cropping system, yellow maize, combination of improved OPV) were not significant, implying that they had no impact in influencing the household food insecurity level.

Furthermore, it is important to note that, out of the six significant variables in Table 2, one had positive sign (combinational variety use). This implies that an increase in this variable would be associated with a unit increase in the response variable by its respective regression coefficient in the ordered log-odds scale while, the other variables in the model are held constant. The other five variables (GM maize variety, improved OPV maize variety, white maize, combination of GM with white and yellow maize) had negative signs meaning a unit increase in the coefficient of an independent variable is associated with a unit decrease in the response variable level by its respective regression coefficient in the ordered log-odds scale while the other variables in the model are held constant.

In that respect, results indicate a negative and significant association ($p\text{-value}=0.001$) between GM maize varieties and household food insecurity. The ordered logit for GM maize variety users being in a higher food insecure category was -1.875 less than non-GM maize variety users when the other variables in the model are held constant. These findings suggest that households who use GM maize varieties were more likely to be food-secure compared to their counterparts not using GM maize varieties. Several reasons explain this association, ranging from: improved productivity (higher yields = 1.9 ton/Ha), reduction in operational costs (low labour use, thus unlocking cash for other household needs) to low labour use associated with GM maize varieties. These findings are in-line with previous studies which highlights the positive contribution of GM maize varieties on household food security mainly because of high yield (Gouse, 2006; Mandikiana, 2011), decrease in the expense for pesticide and increase in profit (Klümper and Qaim, 2014). In contrast, Kaphengst *et al.* (2011) argued that there is no conclusive evidence to show that gross margins are higher for GM maize when compared with other maize varieties due to overall financial risk for GM adopters, which tend to affect their income and food security. Therefore, as farmers use GM maize along with the required input mix, they can obtain a higher yield than other maize varieties. The only challenge is the cost of the seed, which is exorbitantly higher for the reach of these smallholder farmers. However, with the help of the government subsidy, most of the farmers in this study were able to grow and have substantial amount of yield.

Improved OPV was investigated on the premise that, food insecurity can be combated through adoption of productivity improving technologies (Bezu *et al.*, 2014). This is envisaged through multiplier concerning improved food production, food price reduction, non-farm sector growth and commercialisation (Gouse *et al.*, 2005). In that endeavour, the results indicate a negative and significant ($p\text{-value}=0.051$) association between improved OPV and household food insecurity. The ordered logit for improved OPV maize variety users being in a higher food insecure category was -1.219 less than non-users when the other variables in the model are held constant. These findings

suggest that households who used improved OPV maize varieties were more likely to be food-secure compared to their counterparts who were not using improved OPV maize varieties. Several reasons explain this association, ranging from adaptability, cheap and readily available seed to recycling seed. These findings concur with previous studies which highlights that food security increase substantially for smallholder farmer if they adopt improved maize varieties, (including improved OPVs as well) with an average probability of being food surplus decreasing by 2.7% if one does not adopt improved maize varieties (Jaleta *et al.*, 2015). Similarly, Kassie *et al.* (2014) postulated that chronic and transitory food insecurity can be reduced from 0.7 and 1.2% to 1.1 and 1.7% respectively with an increase in area allocated to improved maize varieties.

Closely related to improved OPV maize variety, was the colour of the maize, which was investigated on the notion that it was used by farmers in the study area to identify their maize varieties, without necessarily knowing the actual variety they are growing. Results indicate a negative and significant association ($p\text{-value}=0.097$) meaning as the use of white maize increase, the food insecurity at household level decreases. The ordered logit for white maize use for a household being in a higher food insecure category was -0.947 less than yellow maize use when the other variables in the model are held constant. A change in the use of maize colour at household level, from yellow to white, results in a 0.947 decrease in the log-odds of food insecurity holding other independent variables constant. This means that use of white maize contributed to household food security. This might be due to the fact that white maize was preferred mostly for various dishes, thus directly linked to household food security, unlike yellow maize which was mostly used for livestock feed and consumed as secondary maize in livestock meat. As these farmers select maize variety for growing, white is usually preferred due to its readily available market as well as the individual farmer's perception of white being better than yellow maize. It would be logical therefore to accept the fact that with the wide selection of maize varieties available to these farmers, and some form of income to purchase them, the farmers pay little attention to type of maize variety that they are using. By just knowing the colour of the seed, they prefer varieties that have done well to their counterparts. Furthermore, colour of maize varieties seems to be chosen based on utility, that is, whether the farmer is going to derive more satisfaction from consuming it or from livestock meat (as livestock feed which is highly associated with yellow maize). Such findings are in line with previous studies which highlights that the decision on the choice of maize varieties is affected by local availability, information on seed performance, agricultural extension to support farmers and social norms, with off farm income being the most significant (Waldman *et al.*, 2016).

With respect to the combination effects of variety and colour: white GM maize was negative and significant ($p\text{-value} = 0.006$) meaning the promotion of white GM maize has more impact in reducing household food insecurity. The model results indicate that, a one-unit increase in the use of a white GM maize variety resulted in a 0.603 unit decrease in the ordered log-odds of being in a higher food insecure category while the other variables in the model are held constant. These results can be explained by the fact that white maize varieties have a more direct food security implication (consumption and sales) than yellow varieties (more grown for livestock feed). Such findings are in line with previous studies by Gwartz and Garcia-Casal (2014) who postulated that white maize is highly preferred for consumption though this depends highly on the region or food use. Likewise, Efremidze *et al.* (2017) suggested that more than 50% production of white maize is highly attributed to perception whereby yellow maize is for animal consumption while white maize is for human consumption. Likewise, yellow GM maize was negative and significant ($p\text{-value} = 0.008$) meaning that the promotion of yellow GM maize had impact in reducing household food insecurity. The results outline that, a unit increase in the use of yellow GM maize variety resulted in a 0.461 unit decrease in the ordered log-odds of being in a higher food insecure category while the other variables in the model are held constant. These results can be explained by the fact that yellow maize is mainly grown for livestock consumption, hence it's consumed as secondary maize in livestock products (meat and milk). Furthermore, the regression analysis highlighted that white GM maize had the largest coefficient magnitude than that of yellow GM maize, showing a more direct effect towards household food security than yellow maize.

The use of a combination of maize varieties was investigated against a background that, increased productivity through the use of the best combination of varieties can add to household food security (Ghimire *et al.*, 2016). However, contrary to logic, the results indicate that, a one-unit increase in combinational maize variety use resulted in a 2.01 unit increase in the ordered log-odds of being in a higher food insecurity category while the other variables in the model are held constant. These results suggest that the use of a combination maize varieties leads to household food insecurity. These results may be explained by the negative cross pollination effects of combining GM maize and landraces which may lead to contamination.

4. Conclusion and Recommendations

Based on the results above, the study sought to examine determinants of food security status amongst smallholder farmers utilising different maize varieties within O. R Tambo District Municipality in the Eastern Cape Province of South Africa. The ordinal logistic regression model was used to attain the desired objective. The results of the study revealed that, 55% of households using landrace maize seeds were food secure, 63% of households using GMs were food secure, 54% of households using improved OPVs were food secure and for those using a combination of maize varieties 61% were food secure. These findings suggest that GM maize varieties were associated with household food security than any other variety followed by improved OPVs. Results further indicate that, a combination of landrace and GMs has a significant association with household food insecurity. Combining maize varieties (GM and landraces) though popular, empirical evidence suggests a positive effect on household food insecurity possibly as a result of suppression of GM hybrid vigour through cross pollination with landrace varieties especially if inappropriate field separation guidelines are followed between the two varieties generic in most rural

areas where arable land is limited. However, the production of white maize varieties has a positive effect on household food security more specifically if combined with GM varieties. White maize varieties enjoy a dual direct positive effect on household food security (consumption and cash sales) compared to yellow varieties (hence, the low coefficient magnitude). Yellow maize is mostly consumed in as secondary maize via livestock products. The study recommends addressing household food security targeting white maize varieties. Empirical evidence suggests that white maize varieties have a more direct positive influence on household food security especially for GM maize compared to yellow varieties. The study therefore argues that for well-resourced smallholder farmers (who can produce without external support) who can produce higher yields and target maize sales as their enterprise, GM maize varieties may be prioritised as food security strategy. However, for resource poor smallholder farmers who produce maize for consumption and sale of surplus accommodating other food crops, improved OPVs may be prioritised as a food security strategy. In that respect, depending on a region's climatic, farming and economic conditions, the role of maize is different. Secondly, there is need to articulate the structure, conduct and performance of the GM maize industry in South Africa. This will go a long way in cementing the importance of GM maize farming as a variety to solve both food insecurity and reduce poverty, especially its contribution towards agriculture and national GDP.

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