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Determinants of adoption and use intensity of organic fertilizer

A case of smallholder potato farmers in KwaZulu-Natal, South Africa

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Abstract: This study evaluates the determinants of adoption and use intensity of organic fertilizer among smallholder potato farmers using primary data collected from 189 smallholder farmers in three municipal areas in KwaZulu-Natal Province, South Africa, using a multi-stage sampling technique. The analytical framework incorporates descriptive statistics and Cragg's double-hurdle model. Empirical results indicate that household head gender, household size, access to credit, access to extension services, knowledge of organic fertilizer usage, land ownership, livestock size, and access to social grants significantly influence organic fertilizer adoption, while age of farmer, knowledge of organic fertilizer usage, farm size, and size of livestock holding significantly influence the use intensity of organic fertilizer. This study supports the development of appropriate options for farmers with low livestock holdings, and suggests that there is a need to enhance smallholder farmers' access to extension support and facilitate the dissemination of technical information and knowledge of organic fertilizer usage. There is also a need for improvement and development of policies that encourage the redistribution of land ownership rights among smallholder farmers.

Key words: adoption, Cragg's double-hurdle model, organic fertilizer, smallholder farmers, use intensity

JEL classification: C3, O1, Q12

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1 Introduction

Potatoes are a widely produced tuber crop, grown in over 100 countries around the world, and are the fourth most important crop after rice, wheat, and maize (DeFauw et al. 2012). Potatoes are regarded as an essential food security crop, consumed daily by over a billion people—the majority in developing countries, where people depend on them for survival (FAO 2008).

In South Africa, potatoes are produced in all nine provinces. The potato industry comprises few commercial farmers, the majority being smallholder farmers; however, most of the potatoes produced are from the commercial sector (NAMC 2012). The potato industry contributes to the livelihoods of many individuals in the country by creating jobs and generating income for potato producers, subsequently contributing to poverty alleviation and ensuring food security (PSA 2012). However, potato cultivation usually involves intensive soil tillage throughout the cropping season, which often results in soil degradation, erosion, and leaching of nitrates. Nutrient replenishment is required to maintain soil productivity (FAO 2004, 2005).

Land degradation has become one of the world's greatest environmental threats, as it poses a severe challenge to agricultural productivity—mostly in developing countries, where agriculture contributes substantially to the economy (Ketema and Bauer 2011). During intensive farming, organic matter and nutrients are depleted from soils. Nutrient replenishment is required to achieve sustainable and optimal yields of crops (Adediran et al. 2005). As a result, the adoption of fertility- or productivity-improving technologies (e.g. organic or inorganic fertilizers) is essential, especially for smallholder farmers, as this will improve long-term soil fertility, increase crop yield, and improve productivity, thereby enhancing their ability to become self-sufficient and depend less on food purchased in the market (Terefe and Ahmed 2016). It will also improve household income generated through sales from excess produce. Consequently, soil fertility improvement among smallholder farmers is believed to be critical for mitigating the consequences of food insecurity and poverty.

Despite the benefits of fertilizers in enhancing agricultural productivity, their use in Sub-Saharan Africa (SSA) countries continues to be low compared with other developing countries, where agricultural intensification is marked by a notable increase in fertilizer application (Diiro et al. 2015). Specifically, Sinyolo and Mudhara (2018) report that the use of inorganic (chemical) fertilizers by smallholder farmers in South Africa is very low, and is not adequate for maintaining soil fertility and crop sustainability. The main reason for the restricted use of chemical fertilizers is their high cost, while smallholder farmers are characterized by low purchasing power and uncertain returns during dry seasons (Cedric and Nelson 2014). In addition, chemical fertilizers as a soil ameliorant are notorious for causing soil degradation and environmental pollution, and they must be applied every season (Baiphethi and Jacobs 2009; Cedric and Nelson 2014; Roberts 2009).

A number of authors (Baiphethi and Jacobs 2009; Cedric and Nelson 2014; Roberts 2009; Sinyolo and Mudhara 2018) argue that one way to boost productivity without degrading the environment is to adopt a more sustainable, low-cost, and efficient integrated nutrient management system, which also better suits the socio-economic status of smallholder farmers. Hence, the adoption of organic fertilizer/manure is advocated.

Although there is sufficient advocacy for the adoption of sustainable agricultural inputs such as organic fertilizer, the economic linkage between farmers' socio-economic status and adoption has not been adequately explored. The aim of this study is to determine the factors influencing adoption and use intensity (level of adoption) of organic fertilizer or manure by smallholder potato farmers in KwaZulu-Natal (KZN).

2 Adoption of agricultural technologies

Agricultural technology generally refers to tools developed specifically to improve production in an agricultural activity (Gelgo et al. 2016). In practice, agricultural technologies are all those practices and techniques that influence agricultural output growth (Mwangi and Kariuki 2015). Attempts to reduce levels of poverty and enhance food security require an improved agricultural sector, and this can be achieved through the adoption of agricultural technologies designed to ensure the sustainability of agricultural productivity (Gelgo et al. 2016). Agricultural technologies are regarded as the most important tool for eliminating poverty in developing countries. However, these countries are characterized by low adoption of these technologies (Hailu et al. 2014; Mwangi and Kariuki 2015).

According to Gelgo et al. (2016), producers are rational in their technology adoption decisions. Consequently, the adoption of agricultural technologies may not be automatic, as farmers must observe the performance of such technologies adopted by others before they adopt them themselves. Barnard and Nix (1979), cited by Mahama et al. (2018), argued that farmers might choose to adopt new agricultural technologies (or inputs) given that they will accrue positive net returns or their associated costs (both direct and transaction costs) per unit will be lower and/or the associated benefits higher in comparison with existing inputs. Consequently, if producers believe that the costs associated with a new agricultural technology are high, they will be discouraged from adopting it and need to be made aware of the benefits before they will choose an input resource that is more favourable than the existing resource that must be discarded (Mahama et al. 2018).

3 Research methods and procedures

3.1 Study area description

This study was conducted in the Msinga, uMshwathi, and Umzumbe municipalities of KZN Province, South Africa. In terms of population size, KZN is the country's second largest province, covering some 94,360 km^2, with an estimated 11.3 million people (about 19.2 per cent of the national population), and it consists of 43 municipalities (Stats SA 2019). Msinga has an estimated population of 189,578 and an area of 2,500 km^2, uMshwathi 111,645 people in an area of about 1,811 km^2, and Umzumbe 160,005 people in a mostly rural area of about 1,183 km^2 (Media 2018). Figure 1 illustrates the location of the study areas (indicated by red triangles).

According to the WWF (2019), there are about about 35,000 commercial farmers in South Africa, compared with 2 million small-scale farmers who depend on the land to feed their families and also sell surplus produce to informal markets. Potatoes South Africa (PSA) records show that there are more than 1,000 active smallholder farmers growing potatoes compared with about 635 commercial potato producers (PSA 2014). Even though most smallholder farmers rely on agriculture to acquire extra food, they are still marginalized; and detailed, reliable data on smallholder farming sector in South Africa is limited (Cousins 2016; Okunlola et al. 2016).

Figure 1: KwaZulu-Natal Province map, showing the study areas

Source: author's illustration based on a map by HtonI on Wikimedia Commons.[1]

3.2 Data collection and sampling methods

This study employed the multi-stage random sampling technique to select respondents. The first stage involved a purposive selection of smallholder farmers involved in potato production in Msinga, uMshwathi, and Umzumbe, regardless of whether they were using or not using organic manure/fertilizer. The second stage employed a simple random sampling technique to select sub-samples of 63 smallholder farmers from each of the three selected municipal areas to constitute a total sample size of 189 smallholder potato farmers. The main potato production varieties of the sampled potato farmers were Mondial and BP1. The respondents were asked to participate in a survey. They were assured of the privacy, anonymity, and confidentiality of the data collected from them.

Ten randomly selected smallholder potato farmers from each of the three municipalities concerned were first interviewed in a pilot survey to evaluate the feasibility, time, and cost of the project and to test the structured questionnaire for any ambiguities. From their responses, ambiguous questions were modified, and possible responses that were not included in the closed-ended questions were added.

The questionnaires were administered by trained enumerators who understood data collection methods and the questionnaire content before performing the survey. The training involved reviewing the questionnaire and asking the enumerators how they would ask the questions in

[1] The map is under a Creative Commons Attribution-ShareAlike 3.0 Unported license (CC BY-SA 3.0). Available at https://commons.wikimedia.org/wiki/File:Map_of_KwaZulu-Natal_with_municipalities_named_and_districts_shaded_(2016).svg (accessed 7 September 2020).

isiZulu, since most of the respondents do not understand English. This was done to establish a common understanding of the type of data required by each question and to ensure that the enumerators collected the correct data.

Data were collected on smallholder potato farmers' socio-economic characteristics and household demographics such as gender, age, marital status, farming experience, household size, and education level. The questionnaire also included measures of adoption and use intensity of organic fertilizer, livestock and asset ownership, and off-farm income and expenditure patterns. Furthermore, the questionnaire captured data on capital assets (human, natural, financial, physical, social, and psychological), government support, access to social grants (such as pension, child support grant, and disability grant), and access to credit. At the end of each interview with the respondents, questionnaires were checked to ensure that all the information was captured comprehensively and correctly. The same set of questions was used across the study areas to ensure that the data collected was consistent across the sampled smallholder potato farmers.

4 Theoretical and conceptual framework

To examine the factors influencing the adoption and use intensity of organic fertilizer by smallholder potato farmers, the study employed the random utility framework model. Random utility theory assumes that, since the main aim or objective of a decision-maker is to maximize utility, decision-makers will choose an option that will maximize their utility (Danso-Abbeam and Baiyegunhi 2017). This model therefore assumes that a farmer's decision to adopt organic fertilizer is based on its expected utility function. Thus, a farmer decides to adopt organic fertilizer provided that the expected utility (yield) resulting from organic fertilizer adoption (U_i^O) is greater than that of non-adoption (U_i^N). In other words, a farmer chooses to adopt organic fertilizer if the expected net utility (net yield) (U_i^O -U_i^N) is greater than zero. Following previous research (Ali et al. 2018; Danso-Abbeam and Baiyegunhi 2017; Diiro et al. 2015; Gelgo et al. 2016; Kassie et al. 2009), the unobserved net utility can be expressed as a function of observable elements in the following latent variable model:

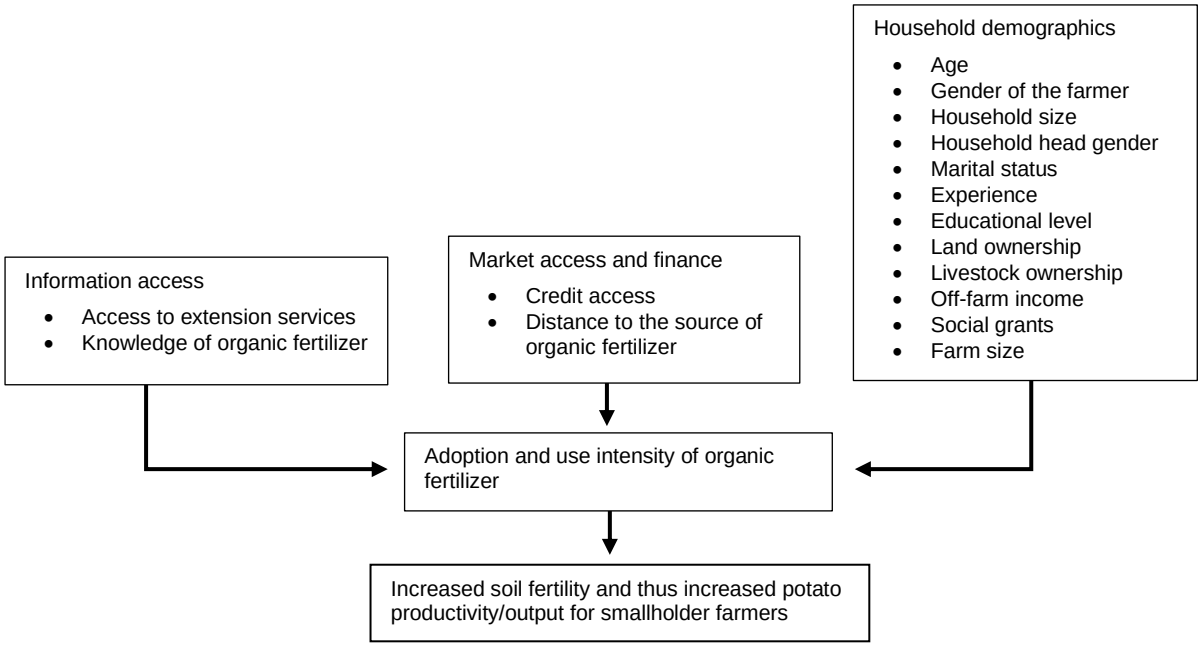
$$U_i^* = \beta Z_i + \varepsilon_i; \; U_i = 1 \text{ if } U_i^* > 0 \tag{1}$$

where U_i is a binary variable which equals 1 for the ith farmer in the case of organic fertilizer adoption and 0 otherwise; β is a vector of parameters to be estimated; Z_i is a vector of farmer and farm characteristics, and ε_i is an error term. The outcome variables considered were the decision to use organic fertilizer and the amount used. The amount of fertilizer used applies to the adopters only, as the non-adopters do not have these figures. The farmer's performance indicator is the total yield, measured by the number of 10 kg bags of potatoes harvested in the previous cropping season (12 months before the survey).

The dependent variable is a binary indicator of whether a farmer adopts organic fertilizer or not. Households' socio-economic characteristics and other institutional support variables that are included in the model as explanatory variables are based on empirical evidence from literature related to factors influencing adoption of agricultural technologies (Ajewole 2010; Farid et al. 2015; Gelgo et al. 2016; Ketema and Bauer 2011; Melesse 2018; Mwangi and Kariuki 2015). These variables include details of household demographics, socio-economic characteristics (age, gender, educational level, etc.), wealth and asset endowment (farm size, land ownership, livestock size, off-income, etc.), access to support services (extension, credit, training, information, etc.), and infrastructural and/institutional support (distance to the source of organic fertilizer). The

interaction between these variables and the dependent variables is illustrated diagrammatically in Figure 2.

Figure 2: Factors influencing the use and adoption of organic fertilizer



Source: author's illustration.

Various studies have been conducted by several authors to determine the factors influencing the adoption of agricultural technologies (Ajewole 2010; Farid et al. 2015; Gelgo et al. 2016; Ketema and Bauer 2011; Melesse 2018; Mwangi and Kariuki 2015). Adoption of farm practices or agricultural technologies may be affected by various factors, including the characteristics of the farm practice, the characteristics of the (non-)adopters and the change agent (extension agent or professional, etc.), and the socio-economic, biological, and environmental factors the technology is to improve (Farid et al. 2015). The attitude of farmers towards change, land, sources of information, educational level, farm income, experience, social status, and resource endowments are essential socio-economic factors affecting the adoption of farm innovations or technologies (Ajewole 2010; Farid et al. 2015). A farmer's age, level of education, income level, household size, and access to credit, among other factors, are believed to positively influence adoption (Farid et al. 2015; Martey et al. 2014).

It is also important to note that factors influencing the adoption of agricultural technologies do not always have a similar outcome on adoption; the effect of these determinants differs with the type of technology being introduced (Mwangi and Kariuki 2015). Uaiene and Rafael (2009), cited by Gelgo et al. (2016), noted that advanced or enhanced diffusion of information through extension support services positively influences agricultural technology adoption decisions (see also Ali et al. 2018; Eba and Bashargo 2014; Nazziwa-Nviiri et al. 2017). Farmers with a better network may possess superior information about agricultural technologies. Thus, improved access to these information sources positively influences the adoption of organic fertilizer. Additionally, Ajewole (2010) noted that the objectives of a new technology or innovation—as well as its characteristics, advantages relative to the existing technology, profitability, compatibility, and complexity—also play a significant role in the decision (not) to adopt.

For this study, it was hypothesized that the above-mentioned factors influence the adoption and use intensity of organic fertilizer. Increased age, extension support, farm size, off-farm income,

household size, size of livestock holding, farming experience, and knowledge of organic fertilizer usage were hypothesized to positively influence both adoption and use intensity, whereas distance to the source of organic fertilizer was expected to negatively affect adoption and use intensity.

Household size is the measure of labour availability; as a result, the larger the household, the greater the likelihood of a farmer adopting organic fertilizer (Ketema and Bauer 2011; Mwangi and Kariuki 2015). Since organic fertilizer is labour intensive, a larger household means that there is enough labour for the preparation and application of organic fertilizer.

Large livestock holding and land ownership are also expected to increase the likelihood of organic fertilizer adoption because smallholder farmers can easily collect livestock manure from the kraal, while land ownership ensures security of tenure and thus increases farmers' incentive to invest in soil fertility to increase crop productivity (Gelgo et al. 2016; Hailu et al. 2014). Livestock holding was measured in tropical livestock units (TLU), which provide different weights for several types of livestock. According to Ghirotti (1993), the TLU conversion weights for cattle, goats/sheep, pigs, and poultry are 0.7, 0.2, 0.1, and 0.01, respectively. However, farmers in the study area reported that during composting, they use only kraal manure (cow dung). Hence, livestock size was measured by the number of cattle that the smallholder farmer owns times 0.7 units.

Extension services are the primary source of information for farmers (Gelgo et al. 2016). Extension is defined as a systematic process that involves working with farmers to enable them to gain relevant and helpful agriculture-related knowledge and skills to enhance farm productivity, competitiveness, and sustainability (NDA 2005). In South Africa, extension services may be rendered by either governmental organizations (National Department of Agriculture, Department of Rural Development, etc.) or non-governmental organizations (e.g., agricultural co-operatives, commodity organizations, private companies) (Koch and Terblanche 2013).

4.1 Variable specification

The dependent variables and predictor variables hypothesized to influence the adoption and use intensity of organic fertilizer and employed in the analysis are defined and presented in Table 1.

Table 1: Definition of variables used in the empirical models and their expected direction

Variable	Definition	Measurement	Expectation
Dependent:			
ADOPTION	Selection variable	Dummy; 1 if adopted organic fertilizer; 0 if otherwise	
USE INTENSITY	Outcome variable	Kg/ha	
Explanatory:			
AGE_OF	Age of farmer	Years	Positive
HH_GENDER	Gender of household head	Dummy; 1 if farmer is male; 0 if otherwise	Positive
F_EXPER	Years of experience	Number of years farmer had been involved in farming	Positive
ACC_CREDIT	Access to credit	Dummy; 1 if farmer has access to credit; 0 if otherwise	Positive
EDU_LEVEL	Level of education	Number of years farmer spent in school	Positive
ACC_EXT	Extension support	Dummy; 1 if farmer has access to extension support; 0 if otherwise	Positive
FAR_SIZE	Farm size	Hectares (ha)	Positive
KNW_UOF	Knowledge	Dummy; 1 if farmer has knowledge of organic fertilizer; 0 if otherwise	
HH_SIZE	Household size	Number of household members	Positive
LSTOCK_SIZE	Cattle ownership	Number of livestock owned	Positive
OWN_LAND	Land ownership	Dummy; 1 if farmer has land ownership rights; 0 if otherwise	Positive
OFF_INCOME	Off-farm income	Total monthly off-farm income	Positive

DIST_FARM	Distance from farm to fertilizer market	Measured in kilometres (km)	Negative
SOC_GRANT	Access to social grants	Dummy; 1 if farmer has access to social grants; 0 if otherwise	Positive
M_STATUS	Marital status	Dummy; 1 if farmer is married; 0 if otherwise	Pos./neg.

Source: author's construction.

4.2 Empirical models

To estimate the factors influencing the adoption and use intensity of organic fertilizer, this study employed the double-hurdle (DH) model proposed by Cragg (1971). According to Cragg (1971), the household head's decision to adopt and the use intensity of a given technology are independent and sequential. The DH model therefore assumes that there is no selectivity bias and solves the problem of dual endogeneity and heteroscedasticity between the decision to adopt and the use intensity of organic fertilizer (Gelgo et al. 2016).

Since not all farmers will adopt a given technology, it is likely that this decision process will generate zero values for the quantity of organic fertilizer used in the case of farmers who decide not to adopt fertilizer. According to Tobin (1958), cited by Nazziwa-Nviiri et al. (2017), and Solomon et al. (2014), in such cases, where observations are clustered at a censoring point, a suitable model to use is a standard Tobit model. However, the Tobit model makes an assumption that the decision to adopt a particular technology and the amount adopted are determined by the same process; which essentially means that the size of the coefficient estimates for adoption and use intensity is assumed to be one and the same (Nazziwa-Nviiri et al. 2017). Thus, this model seems to be constrictive since it requires that zeros and positive values are generated by a similar process. In a scenario when the technology adoption decision and the level of adoption are separate, the double-hurdle model is more appropriate because it considers the probability that the factors that influence the decision to adopt a certain technology and those influencing the use intensity may be separate (Obuobisa-Darko 2015).

Given the two separate decisions, the initial stage of the DH model deals with the decision of adoption, which can be expressed by the following function:

$$d_i^* = \alpha_i x_i + u_i \tag{2}$$

where d_i^* is the latent (unobservable) variable for the choice of the decision to adopt technology, x_i is a vector of coefficient estimates for explanatory variables that were hypothesized to influence the decision to adopt organic fertilizer, and u_i is an error term (random and normally distributed with a zero mean and constant variance). Equation 2 is a probit model that examines the probability that the ith smallholder farmer would decide to adopt organic fertilizer. Since d_i^* is unobservable, then the observable decision to adopt organic fertilizer is:

$$\text{If } d_i^* > 0 \text{ then } D_i = 1 \text{ and } d_i^* \leq 0 \text{ then } D_i = 0 \tag{3}$$

where D_i is the observable decision made by the ith smallholder farmer to adopt organic fertilizer. Therefore, $D_i = 1$ if the respondent has adopted organic fertilizer and $D_i = 0$ if otherwise.

The second stage of the DH model applies a truncated model to estimate the use intensity of organic fertilizer. This stage is essential for determining the level or extent of organic fertilizer use by those respondents who reported using it.

The use intensity equation can be expressed as follows:

Let $y_i^* = \alpha_1 z_i + \varepsilon_i$ (4)

where $y_i = Y_i^* \geq \mu$ if $D_i = 1$ and

$Y_i^* \leq 0$ when $D_i = 0$ (5)

Y_i shows the observed use intensity of organic fertilizer by the ith smallholder farmer, Y_i^* is the latent variable of use intensity, μ is the threshold for the minimum organic fertilizer use considered as optimum in the study area, z_i is a vector of coefficient estimates for household characteristics that are hypothesized to influence the extent or level of using organic fertilizer, and ε_i is the error term.

According to Cragg (1971), assuming that the error terms are independent, the log-likelihood for the DH model is given by the following expression:

$$LogL = \sum_{0} \ln\left[1 - \Phi\left(\alpha X_i^{'}\right)\left(\frac{\beta Z_i^{'}}{\sigma}\right)\right] \sum_{+} \ln\left[\Phi\left(\alpha X_i^{'}\right)\frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X_i^{'}}{\sigma}\right)\right] \quad (6)$$

where Φ is the standard normal cumulative distribution function, and Ø is the density function. The log-likelihood function has two parts: the first part is for the probit, while the second part is for the truncated regression with the truncation of zero.

Initially, a farmer's household chooses whether to adopt a certain new practice or technology and secondly, depending on the farmer's adoption decision, the level or the intensity of adoption is determined (Nazziwa-Nviiri et al. 2017). For example, in the case of adopting organic fertilizer, farmers first decide to use organic fertilizer or otherwise; then, conditional on their decision to use organic fertilizer, the extent or quantity of organic fertilizer (measured in kilograms per hectare) used is determined at the second stage.

To substantiate the choice of using the DH model, the log-likelihood values generated from an individual estimation of the Tobit, probit, and truncated regression models were used to conduct a restriction test using the likelihood ratio test statistic shown in equation 7.

$$\lambda = 2(LL_{Probit} + LL_{Truncated} - LL_{Tobit}) \quad (7)$$

If the likelihood ratio test statistic (λ) is greater than the suitable chi-square critical value, the Tobit model is rejected (Martey et al. 2014) and the DH model is appropriate. Had there been sample selection bias, the Heckman selection model would have been suitable. To address this problem, the Heckman initially estimates the selection equation using the probit model and then adds the correction factor (Inverse Mills Ratio (IMR) calculated from the probit model) into a second stage of the Ordinary Least Squares (OLS) regression (Baiyegunhi and Oppong 2016; Chipfupa and Wale 2018). However, the results from the Heckman selection model for this study revealed that the IMR was statistically insignificant, suggesting that there was no sample selection bias. Hence, the Heckman selection model was inappropriate.

4.3 Empirical results

Descriptive statistics

The descriptive analysis for the household demographics and socio-economic characteristics of the sampled smallholder potato farmers by adoption levels for both continuous and dummy variables is reported in Table 2.

Among the sampled smallholder potato farmers, about 65 per cent are adopters and 35 per cent non-adopters of organic fertilizer. This shows that, even though there is a high rate of organic fertilizer adoption among the sampled smallholder potato farmers, there is still a significantly large number of smallholder farmers who are not using organic fertilizer in their farm production.

The t-statistic results show that there are statistically significant differences between adopters and non-adopters of organic fertilizer in terms of age, household size, household head gender, livestock holding, off-farm income, distance to the source of organic fertilizer, extension support, knowledge of organic fertilizer usage, access to credit, and access to social grants.

Table 2: Household demographics and socio-economic characteristics of sampled potato farmers by adoption levels (n=189)

Variable	Adopters [n=123]		Non-adopters [n=66]		t -value
	Mean	SD	Mean	SD	
Age (years)	43.53	13.51	40.36	14.47	4.34***
Household size	6.45	3.80	3.34	2.11	6.14***
Household head gender	0.40	0.04	0.27	0.05	1.83*
Marital status	0.62	0.04	0.92	0.48	0.85
Experience (years)	17.91	12.96	14.69	12.71	1.63
Educational level (years)	4.10	4.57	4.06	4.51	0.064
Farm size (hectares)	0.06	0.01	0.05	0.2	0.48
Livestock size (TLU)	16.44	1.49	0.23	0.13	7.93***
Off-farm income (rands)	2182.07	1283.07	1825.76	1355.63	1.78*
Distance (km)	2.58	3.59	8.40	4.04	10.13***
Extension support	0.79	0.04	0.03	0.02	14.69***
Knowledge	0.93	0.02	0.69	0.06	4.608***
Land ownership	0.65	0.04	0.62	0.06	0.39
Credit access	0.43	0.04	0.64	0.06	2.73***
Social grants access	0.90	0.03	0.74	0.05	2.96***

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels of significance, respectively.

Source: author's construction.

Age: The average age for adopters and non-adopters of organic fertilizer is about 44 and 40 years, respectively. This suggests that smallholder potato farmers who adopt organic fertilizer are generally slightly older than non-adopters.

Household size: The average household size for adopters and non-adopters is about 7 and 3 people, respectively. This shows that adopters have relatively large households.

Household head gender: About 40 per cent of adopters and 27 per cent of non-adopters are from male-headed households, indicating that male-headed households are more likely to adopt organic fertilizer.

Livestock holding: The average livestock size for the adopters of organic fertilizer is about 16.44 (TLU), compared with an average of 0.23 TLU for non-adopters. This implies that smallholder farmers who adopt organic fertilizer have larger livestock holdings than non-adopters.

Off-farm income: The average off-farm income for adopters and non-adopters is R2182.07 and R1825.76 per month, respectively, suggesting a connection between higher off-farm income and adoption of organic fertilizer.

Distance: The average distance travelled to the source of organic fertilizer by adopters and non-adopters is 2.58 km and 8.40 km, respectively. In general, a high percentage of the smallholder farmers who did not adopt organic fertilizer were located farther away from the nearest source of organic fertilizer than adopters.

Extension services: About 79 per cent and 3 per cent of adopters and non-adopters of organic fertilizer have access to extension services. This implies that most smallholder potato farmers who adopt organic fertilizer have access to extension services, while few non-adopters have access to such services.

Knowledge of organic fertilizer usage: There are about 93 per cent and 62 per cent of adopters and non-adopters with knowledge of organic fertilizer usage, suggesting an association between knowledge and adoption.

Access to credit: The average percentage of adopters and non-adopters of organic fertilizer who have access to credit is about 43 per cent and 64 per cent, respectively. This implies that smallholder farmers with access to credit are less likely to adopt organic fertilizer.

Social grants: The majority of smallholder potato farmers are beneficiaries of social grants, and on average, the percentages of smallholder farmers with access to social grants were 90 per cent and 74 per cent for adopters and non-adopters, respectively. This indicates a correlation between access to social grants and adoption of organic fertilizer.

Cragg's double-hurdle model results

To test for the possibility of multicollinearity—a perfect linear association between the predictor variables—this study used the variance inflation factor (VIF). According to Gujarati and Porter (2009), if the VIF is greater than the critical value of 10, then multicollinearity is a major problem. The mean VIF was 1.62, indicating that multicollinearity was not a concern. The Breusch-Pagan-Godfrey test was also conducted for the outcome equation to test for possible heteroscedasticity in the model. The Chi-square test statistic for the test was statistically significant at the 1 per cent level, which indicates that the outcome equation might be biased. To correct for the presence of heteroscedasticity, the outcome equation was estimated with robust standard errors.

The results of the selection regression (Cragg's DH model), which involves the probit analysis of the adoption decision of organic fertilizer and the results of the underlying truncated regression that establishes the determinants of the use intensity of organic fertilizer, are estimated jointly and are presented in Table 3.

To explain the differential effect of explanatory variables on the dependent variable, the coefficient estimates, as well as the marginal effects of the probit model estimates, are presented in Table 3. The DH model fits the data well, as 96.3 per cent of organic fertilizer adoption decision outcomes were correctly classified. Additionally, the Likelihood Ratio and Wald tests of the hypothesis that all the regression coefficient estimates are jointly equal to 0 is rejected at the 1 per cent level of significance. This implies that all explanatory variables included in the probit and truncated regression models explain the variations in the smallholder farmers' probability of adopting and intensifying the use of organic fertilizer.

Table 3: Results of Cragg's DH model for the factors influencing adoption and use intensity of organic fertilizer

	Probit model: first stage			Truncated model: second stage	
Variables	**Coefficient**	**Std. err.**	**Marginal effect**	**Coefficient**	**Robust std. err.**
AGE_OF	0.0310	0.0295	0.0017	-1.7681*	1.0612
HH_GENDER	1.8533**	0.8242	0.0011	5.9173	19.989
M_STATUS	0.0459	0.1475	0.0026	21.011	23.216
HH_SIZE	0.4455*	0.2397	0.0250	2.7323	3.2301
F_EXPER	-0.0279	0.0359	-0.0016	1.5847	1.0201
EDUC_LEVEL	0.0844	0.0725	0.0047	-4.7907	2.9582
ACC_CREDIT	-2.9270**	1.3282	-0.1643	-9.8867	23.169
ACC_EXT	4.1621**	1.9861	0.2337	-	-
KNW_UOF	3.0773*	1.8229	0.1728	175.24***	53.333
FAR_SIZE	2.5024	1.6823	0.1405	214.60***	52.504
OWN_LAND	4.2909*	2.0269	0.2409	-13.260	21.529
LSTOCK_SIZE	0.9562***	0.3409	0.0537	2.1751***	0.6012
SOC_GRANT	7.0403**	2.8770	0.3953	-11.202	27.959
DIST_FARM	0.0197	0.0961	0.0011	0.7525	3.2515
OFF_INCOME	0.0002	0.0003	0.0001	-0.0012	0.0081
CONSTANT	-17.0773***	6.0236		-0.0126*	64.578
/sigma	-	-	-	68.930***	7.6266
n = 189				*n* = 123	
LR $chi^2(15)$ = 206.52				Wald $chi^2(15)$ = 62.78	
Prob > chi^2 = 0.0000				Prob > chi^2 = 0.0000	
Log likelihood = 19.0				Log pseudo likelihood = -19.8	
Mean VIF = 1.62					
BP Chi^2 = 39.42					
Classification accuracy = 96.3%					
Prob > chi^2 = 0.0000					

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels of significance, respectively.

Source: author's construction.

In the analysis of the decision to adopt organic fertilizer (first stage), eight explanatory variables were statistically significant; these are household head gender (HH_GENDER), household size (HH_SIZE), access to credit (ACC_CREDIT), access to extension services (ACC_EXT), knowledge of organic fertilizer (KNW_UOF), land ownership (OWN_LAND), large livestock holding (LSTOCK_SIZE), and access to social grants (SOC_GRANT). The coefficient estimates have expected signs except for access to credit. Household head gender, household size, access to extension services, knowledge, land ownership, large livestock holding, and access to social grants have a statistically significant positive effect on the probability of adopting organic fertilizer. In contrast, access to credit has a statistically significant negative influence on the likelihood of adopting organic fertilizer.

In the analysis of the use intensity of organic fertilizer (second stage), four explanatory variables were statistically significant, and these were: age of farmer (AGE), knowledge of organic fertilizer (KNW_UOF), farm size (FAR_SIZE), and large livestock holding (LSTOCK_SIZE). The coefficient estimates have expected signs. Age, knowledge, farm size, and livestock size have a statistically significant positive effect on the use intensity of organic fertilizer by smallholder potato farmers.

5 Discussion

This study found that male-headed households were more likely to adopt organic fertilizer. The coefficient estimate of household head gender was found to be positive and statistically significant in explaining the decision to adopt organic fertilizer by smallholder potato farmers. The marginal

effects show that male-headed households were 0.11 per cent more likely to adopt organic fertilizer than their female-headed counterparts. These results are consistent with findings obtained by Diiro et al. (2015). A possible explanation is that male-headed households in the study area have more livestock holdings and better access to kraal manure, and hence are more likely to use organic fertilizer. According to Solomon et al. (2014), female-headed households are mostly poorly endowed in terms of labour, assets (including livestock), and income.

The results show that a one-year increase in the age of a farmer decreases the use intensity of organic fertilizer by 1.77kg/ha. This implies that as smallholder farmers become older, they reduce their use intensity of organic fertilizer. A possible explanation for this outcome is the high labour demand of organic fertilizer during preparation; therefore, as older farmers have less energy than young farmers, it is likely that older farmers will use lower quantities of organic fertilizer. Moreover, risk aversion is lower among younger farmers than among older farmers, so that the former are more likely to adopt and intensify the use of agricultural technologies and make long-term farm investments (Mwangi and Kariuki 2015).

As expected, the results indicate that an increase in household size (HH_SIZE) increases the likelihood of organic fertilizer adoption. The marginal effect results show that an increase in household size by one person will increase the probability of organic fertilizer adoption by 2.5 per cent. This implies that farmers with large households are also more likely to adopt organic fertilizer. An increase in household size means that there is more labour available for the preparation and application of organic fertilizer (Ketema and Bauer 2011; Mwangi and Kariuki 2015). Therefore, considering the high labour demand for organic fertilizer preparation and use, household size influences the likelihood of organic fertilizer adoption.

Although access to credit (ACC_CREDIT) was expected to positively influence the adoption of agricultural technologies, smallholder farmers with access to credit were found to be less likely to adopt organic fertilizer. The marginal effect results show that farmers with access to credit were 16.43 per cent times less likely to adopt organic fertilizer. A possible explanation for this is that farmers with access to credit prefer to direct their financial resources to other productive activities rather than investing in organic fertilization (Martey et al. 2014). For example, they might decide to purchase synthetic fertilizers rather than organic fertilizer because they can afford them.

As expected, smallholder farmers with access to extension services are more likely to adopt agricultural technologies. This study found that access to extension services increases the likelihood of organic fertilizer adoption by about 23.37 per cent. This finding is similar to the result obtained by several other studies, including those of Ali et al. (2018), Eba and Bashargo (2014), Gelgo et al. (2016), Nazziwa-Nviiri et al. (2017), and Obuobisa-Darko (2015). Extension service agents are an important source of information to farmers, as well as advice and training, which empowers and encourages farmers to seek or adopt relevant agricultural technologies that will enhance their agricultural productivity (Gelgo et al. 2016). This underlines the importance of extension services—and access to them—in the demonstration and dissemination of agricultural technologies.

This study also found that farmers with sufficient knowledge of using organic fertilizer (KNW_UOF) are more likely to adopt and intensify their use of organic fertilizer. The marginal effect results show that farmers with knowledge of organic fertilizer usage are 17.28 per cent times more likely to adopt organic fertilizer. This implies that the likelihood of adopting organic fertilizer increases when smallholder potato farmers are very knowledgeable about the composting (preparation), use, and application of organic fertilizer. According to Jabbar et al. (2003), the adoption of agricultural technologies is mainly influenced by the knowledge and perception of the type of technology concerned. At the same time, smallholder farmers who are very knowledgeable

about organic fertilizer usage increased their use intensity of organic fertilizer by 175.24 kg per hectare. Therefore, having knowledge about the proper preparation and use of organic fertilizer increases the likelihood of organic fertilizer adoption and use intensity.

As expected, an increase in farm size (FAR_SIZE) increases the use intensity of organic fertilizer. The results show that an increase in farm size by one hectare increases the level of organic fertilizer applied by 214.60 kg per hectare. This implies that as smallholder farmers' farm size increase, they tend to apply more organic fertilizer pro rata in their potato production. These results are consistent with those obtained by Gelgo et al. (2016) and Obuobisa-Darko (2015). Since organic fertilizer can be obtained at a low cost compared with synthetic fertilizer, farmers can benefit from economies of scale by increasing the level of organic fertilizer applied as farm size increases (Gelgo et al. 2016).

As expected, smallholder farmers with land ownership rights are more likely to adopt agricultural technologies. Results show that land ownership (OWN_LAND) increases the likelihood of organic fertilizer adoption by 24.09 per cent. According to Hailu et al. (2014), farmers are rational decision-makers, and as such they are more inclined to incur the costs of technologies if they own the land on which these are to be used, and more likely to invest in long-term soil fertility by adopting organic fertilizer in their potato production, because the benefits of their investment will accrue to them and not be shared with anyone else in the form of rent for land used.

As expected, smallholder farmers with larger livestock holdings (LSTOCK_SIZE) are more likely to adopt organic fertilizer. This study shows that an increase in livestock holding by 1 TLU increases the probability of organic fertilizer adoption by 5.37 per cent. These results are consistent with the findings of Gelgo et al. (2016). Livestock manure is the main ingredient of compost and hence a major source of organic fertilizer. Consequently, a larger livestock holding increases the probability of organic fertilizer adoption. Similarly, increasing livestock holding increases organic fertilizer use intensity. The truncated regression model results show that an increase in livestock holding by 1 TLU increases the use intensity of organic fertilizer by 2.175 kg per hectare. Therefore, smallholder farmers with more livestock are more likely to adopt and intensify their use of organic fertilizer on their potato production because they have better access to livestock manure.

Finally, this study found that smallholder farmers who have access to social grants are more likely to adopt organic fertilizer. The marginal effect results show that access to social grants increases the likelihood of organic fertilizer adoption by 39.53 per cent. According to Sinyolo et al. (2016), access to social grants reduces liquidity limitations faced by smallholder farmers. Smallholder farmers who are receiving social grants use some portion of these to purchase agricultural inputs. Indeed, social grants are crucial for reducing financial constraints on their agricultural production.

6 Conclusions and policy recommendations

This study aimed to evaluate the factors influencing the adoption and use intensity of organic fertilizer by smallholder potato farmers in South Africa. Useful findings have emerged that offer insight into pathways for improvement in organic fertilizer adoption. The study found that, although the majority (about 65 per cent) of smallholder farmers are using organic fertilizer to enhance their potato production, a significant proportion (about 35 per cent) are not using organic fertilizer.

The findings indicated that the factors influencing organic fertilizer adoption and the use intensity of organic fertilizer are separate. Results of the Cragg's DH model revealed that household head

gender, household size, access to credit, access to extension services, knowledge of using organic fertilizer, land ownership, livestock size, and social grants are statistically significant factors explaining smallholder farmers' adoption of organic fertilizer, while age, knowledge of organic fertilizer usage, farm size, and livestock size are statistically significant factors in determining smallholder farmers' organic fertilizer use intensity.

The finding that farmers from male-headed households have a higher likelihood of organic fertilizer adoption than those from female-headed households supports the need to develop differentiated services and options for women. Female-headed households are constrained by several factors in adopting agricultural technologies. One of these is that they are mostly poorly endowed in terms of labour, assets (including livestock), land ownership, and income. Therefore, it is essential to develop policies aimed at reducing the gender gap in organic fertilizer adoption.

It is also imperative to improve smallholder farmers' contact with and access to extension services such as advisory services, education, and training to enhance technical information dissemination among farmers. This will improve smallholder farmers' knowledge about adopting and using organic fertilizer, which will in turn prompt them to do so and consequently improve their agricultural productivity.

The importance of land ownership rights in increasing the likelihood of organic fertilizer adoption and the use intensity of organic fertilizer suggests a need to develop policies that strive to institute security of land tenure among smallholder farmers. Security of tenure is essential to smallholder farmers because it assures full access to future returns in production. As a result, policies that institute security of land tenure will encourage smallholder farmers to adopt and intensify the use of organic fertilizer to improve their crop productivity. Increased productivity will ensure that the farmers have sufficient output for home consumption and can also sell surplus production to their communities, thus generating cash income. In addition, this initiative would encourage smallholder farmers to increase their farm size, which in turn would increase the intensity of organic fertilizer use in their agricultural production.

Livestock ownership is crucial for both the adoption and use intensity of organic fertilizer. This study therefore supports the development of appropriate options for farmers with small livestock holdings. For example, there is a need to develop policies that encourage the commercialization of organic fertilizer. This can be achieved through the provision of incentives to producers so that they can invest in organic fertilizer production factories. Increasing the prospects for organic fertilizer commercialization will serve as an incentive for smallholder farmers to increase their livestock holdings and generate more organic fertilizer for crop production; any excess can be sold to other farmers or organic fertilizer processing centres.

Finally, the study revealed that access to social grants increases the likelihood of organic fertilizer adoption. There are smallholder farmers in remote rural areas who still have no access to social grants because they lack identity documents, childbirth certificates, and so on. Therefore, government and other development partners can further encourage organic fertilizer adoption by improving access to social grants among smallholder farmers who match the criteria of being social grant beneficiaries.

7 Limitations of the study and suggestions for further research

Potatoes are produced in all nine of South Africa's provinces, where there is a variety of cultures, religions, and socio-economic characteristics. The study was limited to KwaZulu-Natal Province,

mainly due to time and financial constraints for data collection. It is therefore recommended that further research of this kind should be conducted on other smallholder potato-producing areas across the country. To generate more information that can be generalized about South Africa, a larger sample size of respondents is also recommended.

References

Adediran, J., L. Taiwo, M. Akande, R. Sobulo, and O. Idowu (2005). 'Application of Organic and Inorganic Fertilizer for Sustainable Maize and Cowpea Yields in Nigeria'. *Journal of Plant Nutrition*, 27(7): 1163–81. https://doi.org/10.1081/PLN-120038542

Ajewole, O. (2010). 'Farmers' Response to Adoption of Commercially Available Organic Fertilizers in Oyo State, Nigeria'. *African Journal of Agricultural Research*, 5(18): 2497–503.

Ali, E.B., J.A. Awuni, and G. Danso-Abbeam (2018). 'Determinants of Fertilizer Adoption among Smallholder Cocoa Farmers in the Western Region of Ghana'. *Cogent Food and Agriculture*, 4(1): 1–10. https://doi.org/10.1080/23311932.2018.1538589

Baiphethi, M.N., and P.T. Jacobs (2009). 'The Contribution of Subsistence Farming to Food Security in South Africa'. *Agrekon*, 48(4): 459–82. https://doi.org/10.1080/03031853.2009.9523836

Baiyegunhi, L.J.S., and B.B. Oppong (2016). 'Commercialisation of Mopane Worm (Imbrasia belina) in Rural Households in Limpopo Province, South Africa'. *Forest Policy and Economics*, 62: 141–48. https://doi.org/10.1016/j.forpol.2015.08.012

Cedric, K., and L.E. Nelson (2014). 'An Evaluation of Mineral and Organic Fertilizers Utilization by Small-scale Farmers in Vhembe District, Limpopo Province, South Africa'. *International Journal of Manures and Fertilizers*, 3(9): 576–80.

Chipfupa, U., and E. Wale (2018). 'Explaining Smallholder Aspirations to Expand Irrigation Crop Production in Makhathini and Ndumo-B, KwaZulu-Natal, South Africa'. *Agrekon*, 57(3–4): 284–99. https://doi.org/10.1080/03031853.2018.1531773

Cousins, B. (2016). 'Land Reform–the Solution to Rural Poverty? The Case of South Africa'. *The International Journal for Rural Development* 21(03): 14–16.

Cragg, J.G. (1971). 'Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods'. *Econometrica (pre-1986)*, 39(5): 829–44. https://doi.org/10.2307/1909582

Danso-Abbeam, G., and L.J.S. Baiyegunhi (2017). 'Adoption of Agrochemical Management Practices among Smallholder Cocoa Farmers in Ghana'. *African Journal of Science, Technology, Innovation and Development*, 9(6): 717–28. https://doi.org/10.1080/20421338.2017.1380358

DeFauw, S.L., Z. He, R.P. Larkin, and S.A. Mansour (2012). 'Sustainable Potato Production and Global Food Security'. *Sustainable Potato Production: Global Case Studies*. New York: Springer. https://doi.org/10.1007/978-94-007-4104-1_1

Diiro, G.M., A.P. Ker, and A.G. San (2015). 'The Role of Gender in Fertiliser Adoption in Uganda'. *African Journal of Agricultural and Resource Economics*, 10(2): 117–30.

Eba, N., and G. Bashargo (2014). 'Factors Affecting Adoption of Chemical Fertilizer by Smallholder Farmers in Guto Gida District, Oromia Regional State, Ethiopia'. *Science, Technology and Arts Research Journal*, 3(2): 237–44. https://doi.org/10.4314/star.v3i2.31

FAO (2004). *The Ethics of Sustainable Agricultural Intensification*. United Nations: Food and Agriculture Organization.

FAO (2005). *Fertilizer Use by Crop*. United Nations: Food and Agriculture Organisation.

FAO (2008). *United Nations International Year of the Potato. Potatoes, Nutrition and Diet*. United Nations: Food and Agriculture Organization.

Farid, K., N. Tanny, and P. Sarma (2015). 'Factors Affecting Adoption of Improved Farm Practices by the Farmers of Northern Bangladesh'. *Journal of the Bangladesh Agricultural University*, 13(2): 291–98. https://doi.org/10.3329/jbau.v13i2.28801

Gelgo, B., P. Mshenga, and L. Zemedu (2016). 'Analysing the Determinants of Adoption of Organic Fertilizer by Smallholder Farmers in Shashemene District, Ethiopia'. *Journal of Natural Science Research*, 6(19): 35–44.

Ghirotti, M. (1993). 'Rapid Appraisal: Benefiting from the Experiences and Perspectives of Livestock Breeders'. *World Animal Review*, 77(4): 26–37.

Gujarati, D.N., and D. Porter (2009). *Basic Econometrics: International Edition*. New York: McGraw-Hill.

Hailu, B.K., B.K. Abrha, and K.A. Weldegiorgis (2014). 'Adoption and Impact of Agricultural Technologies on Farm Income: Evidence from Southern Tigray, Northern Ethiopia'. *International Journal of Food and Agricultural Economics*, 2(4): 91–106.

Jabbar, M.A., H. Beyene, M. Saleem, and S. Gebreselassie (2003). 'Role of Knowledge in the Adoption of New Agricultural Technologies: an Approach and an Application'. *International Journal of Agricultural Resources, Governance and Ecology*, 2(3–4): 312–27. https://doi.org/10.1504/IJARGE.2003.003974

Kassie, M., P. Zikhali, K. Manjur, and S. Edwards (2009). 'Adoption of Organic Farming Techniques: Evidence from a Semi-arid Region of Ethiopia'. *Environment for Development Discussion Paper-Resources for the Future*, 335(09-01): 1–18.

Ketema, M., and S. Bauer (2011). 'Determinants of Manure and Fertilizer Applications in Eastern Highlands of Ethiopia'. *Quarterly Journal of International Agriculture*, 50(3): 237–52.

Koch, B.H., and S.E. Terblanche (2013). 'An Overview of Agricultural Extension in South Africa'. *South African Journal of Agricultural Extension*, 41: 107–17.

Mahama, F., S. Lissah, J. Titriku, and E. Kunu (2018). 'Reasons Prompting the Adoption of Organic Fertilizers in Vegetable Production in Agotime-Ziope District, Ghana'. *Asian Research Journal of Agriculture*, 8(2): 1–8. https://doi.org/10.9734/ARJA/2018/34874

Martey, E., et al. (2014). 'Fertilizer Adoption and Use Intensity among Smallholder Farmers in Northern Ghana: a Case Study of the AGRA Soil Health Project'. *Sustainable Agriculture Research*, 3(1): 24–36. https://doi.org/10.5539/sar.v3n1p24

Media, S. (2018). *Kwazulu-Natal Top Business: KZN Municipalities*. Kzntopbusiness.co.za. Available at: http://kzntopbusiness.co.za/site/municipal-structure (accessed 5 February 2019).

Melesse, B. (2018). 'A Review of Factors Affecting Adoption of Agricultural New Technologies in Ethiopia'. *Journal of Agricultural Science and Food Research*, 9(3): 1–4.

Mwangi, M., and S. Kariuki (2015). 'Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries'. *Journal of Economics and Sustainable Development*, 6(5): 208–16.

NAMC (2012). *Potato Case Study of a Successful Black Farmer Fuelled by Potato Passion*. Pretoria: National Agricultural Marketing Council.

Nazziwa-Nviiri, L., B. Van Campenhout, and D. Amwonya (2017). 'Stimulating Agricultural Technology Adoption: Lessons from Fertilizer Use among Ugandan Potato Farmers'. IFPRI Discussion Paper. Washington, DC: International Food Policy Research Institute.

NDA (2005). *Norms and Standards for Extension and Advisory in Agriculture*. Pretoria: National Department of Agriculture.

Obuobisa-Darko, E. (2015). 'Socio-economic Determinants of Intensity of Adoption of Cocoa Research Innovations in Ghana'. *International Journal of African and Asian Studies*, 12(1): 29–40.

Okunlola, A., M. Ngubane, B. Cousins, and A. Du Toit (2016). 'Challenging the Stereotypes: Small-scale Black Farmers and Private Sector Support Programmes in South Africa'. Research Report (53). University of Western Cape: Institute for Poverty, Land and Agrarian Studies (PLAAS).

PSA (2014). 'Potato Industry Research Strategy: 2014–2017'. Pretoria: Potatoes South Africa. Available at: https://www.potatoes.co.za/research/potato-industry-research-strategy/ (accessed 2 September 2020).

Roberts, T.L. (2009). 'The Role of Fertilizer in Growing the World's Food'. *Better Crops*, 93(2): 12–15.

Sinyolo, S., and M. Mudhara (2018). 'Farmer Groups and Inorganic Fertiliser Use among Smallholders in Rural South Africa'. *South African Journal of Science*, 114(5–6): 1–9. https://doi.org/10.17159/sajs.2018/20170083

Sinyolo, S., M. Mudhara, and E. Wale (2016). 'The Impact of Social Grants on the Propensity and Level of Use of Inorganic Fertiliser among Smallholders in KwaZulu-Natal, South Africa'. *Agrekon*, 55(4): 436–57. https://doi.org/10.1080/03031853.2016.1243063

Solomon, T., A. Tessema, and A. Bekele (2014). 'Adoption of Improved Wheat Varieties in Robe and DigeluTijo Districts of Arsi Zone in Oromia Region, Ethiopia: a Double-Hurdle Approach'. *African Journal of Agricultural Research*, 9(51): 3692–703.

Stats SA (2019). *Mid-year Population Estimates 2019*. Pretoria: Statistics South Africa.

Terefe, T.A., and M. Ahmed (2016). 'Driving Force of Organic Fertilizer Use in Central Rift Valley of Ethiopia: Independent Double Hurdle Approach'. *Economics of Agriculture*, 63(4): 1265–79. https://doi.org/10.5937/ekoPolj1604265T

WWF (2019). *Climate Smart Smallholder Farming*. Cape Town: World Wide Fund for Nature. Available at: https://www.wwf.org.za/our_work/initiatives/climate_smart_smallholder_farming.cfm (accessed 25 August 2020).