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The determinants of willingness to pay for organic fertilizers: the case of smallholder vegetable farmers in Mpumalanga, South Africa

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The extensive use and production of chemical fertilizers poses a threat to the environment. Smallholder farmers in South Africa are characterized by low productivity. The adoption of sustainable agricultural practices such as the use of organic fertilizer is crucial. Although there have been studies on the adoption of organic fertilizer, the socio-economic factors determining the farmer's willingness to pay remain unclear. Therefore, this study was aimed at investigating the factors that affect willingness to pay for organic fertilizers by smallholder vegetable farmers. The study was arranged as a cross-sectional design where the data was collected using structured questionnaires from 131 randomly selected registered smallholder vegetable farmers. The collected data was analyzed using both descriptive statistics and a binary logistic regression model. The findings revealed that 61.83% of farmers were female and 38.17% male. In addition, the findings also indicate that 61.83% of the farmers were adults above the age of 35. Furthermore, the findings revealed that 70.23% of the farmers were willing to pay for organic fertilizers, suggesting a demand for organic fertilizers. The binary logistic results show that level of education (0.071), amount spent on fertilizer (0.043), and if challenges were encountered when using organic fertilizers (0.044), were positively influencing WTP, increasing WTP for organic fertilizers. These findings conclude that education is a major barrier in WTP for organic fertilizers. Therefore, it is recommended that farmers are educated on the benefits of organic fertilizers and procedures of application, including curing or organic manure for safe application in the field. Due to the high percentage of farmers willing to pay for organic fertilizers, it is recommended that organic fertilizers be commercialized for a stable supply to meet demand.

KEYWORDS
logistic regression, organic fertilizers, smallholder vegetable farmers, South Africa, sustainable agriculture, willingness to pay (WTP)

1 Introduction

South Africa's local and rural economy is highly driven by agriculture through smallholder farmers who provide food to the community through the cultivation of vegetables (Kapari et al., 2023). They are also drivers of food systems and assist in income generation and improve diets. However, these farmer are commonly faced with challenges that limit the capacity of their production and therefore limiting the capacity of food production (Touch et al., 2024). These challenges include, water access, labor, farm inputs, capital, market access and especially fertilizers (Fan and Rue, 2020). In rural areas like Nkomazi, smallholder vegetable farmers contribute significantly to household nutrition and food security by providing affordable, nutrient-rich produce to local consumers. Vegetables are known for being rich in vitamins, minerals, and dietary fiber, as essential for a balanced diet and are often cultivated with minimal skills and resource (Jose and Kuriakose, 2021). Their increasing demand is attributed to their nutritional and economic value as vegetable farming offers income opportunities and a pathway out of poverty for rural households (Jose and Kuriakose, 2020; Kharisma and Perdana, 2019; Samobo et al., 2022).

To meet the growing demands for vegetables, smallholder farmers must efficiently use input like fertilizers and water to enhance productivity. However, many rely heavily on chemical fertilizers because they are accessible and easy to apply, despite their long term effect on soil health, crop yield and climate change (Jote, 2023). The high cost of chemical fertilizers and other agricultural input, coupled with low farm incomes, limiting farmers ability to sustainable alternative. Derived from natural processes such as decomposed animal waste and plant materials, they are inexpensive, improve soil fertility and enhance long term productivity (Assefa and Tadesse, 2019; Bhatt et al., 2019). However, the adoption of organic fertilizer is influenced by several factors including lack of technical knowledge on nutrient content and application, and socioeconomic characteristics of farmers (Case et al., 2017). Additionally, farmers who grow vegetables may lack access to animal manure, further limiting adoption (Luczka and Kalinowski, 2020). Given that chemical fertilizers are costly and contribute to soil degradation, there is a growing need to promote the sustainable use of organic fertilizers among smallholder farmers.

The rapid increase in human population places growing pressures on agricultural systems to sustainably meet future food demands (Khatsi et al., 2024). However, the continuous overuse of chemical fertilizer has led to the depletion of soil fertility, reducing its nutrient holding capacity and threatening long term productivity (Xin, 2022). This decline not only affects soil health, it also jeopardizes the livelihoods of smallholder farmers whose income depends on consistent crop yields (Mukaila et al., 2021). In addition, the high cost of chemical fertilizer remains a major constraint for resource limited farmers, further intensifying food insecurity in rural communities. Improper disposal of animal waste also contributes to methane emissions, worsening climate change and exposing crops, especially vegetables to unpredictable weather conditions that can lead to lower yields and crop failure (Rashid et al., 2020).

Although the use of organic waste as fertilizers offers a sustainable alternative that can restore soil fertility and mitigate environmental degradation, adoption remains low among smallholder farmers in South Africa (Zondo and Baiyegunhi, 2021). The growing reliance on inorganic fertilizer, which reached 7.62 million metric tons in 2021 (FAOSTATS, 2023), reflects a lack of awareness, knowledge and trust in the effectiveness of organic fertilizer. Furthermore, some farmers who use organic waste do so without testing its safety, which can introduce pests and diseases if the waste originates from infected animals. These challenges highlight the need to promote safe and effective organic fertilizer use, informed by farmers' willingness to adopt such practices. Therefore, this study aims at commercializing organic fertilizers by investigating smallholder vegetable farmers' willingness to pay for organic fertilizers in Nkomazi, Mpumalanga. The specific objective (i) is to analyze the socio-economic and demographic characteristics of vegetable smallholder farmers; (ii) to assess the usage of organic fertilizer by vegetable smallholder farmers and (iii) to investigate the factors influencing smallholder vegetable farmer's willingness to pay for organic fertilizers in Nkomazi, Mpumalanga.

2 Conceptual framework

The conceptual framework that underpins the determinants of willingness to pay for organic fertilizers focuses more on socio-economic, demographic, and institutional factors. This is because these factors drive the decision, which can facilitate adoption and willingness to pay and use organic fertilizers. These factors are also linked with the challenges that smallholder farmers commonly face.

Fertilizers are inputs added to the soil to improve fertility and amend nutrient deficiencies for proper plant growth and higher yields. Organic fertilizers are substances that are made up of animal or plant, or natural byproducts that are used to enhance soil fertility and plant growth. To remedy nutrient deficiency, soil analysis has to be done to identify the nutrient status of the soil, so that a targeted fertilizer nutrient that is low in the soil can be amended. However, smallholder farmers lack the technical knowledge and capital to do soil sampling and submit the samples for analysis (Mokgolo and Mzezawa, 2023; Sileshi et al., 2025).

Due to this, the majority of smallholder farmers do not know the nutrient status of their soil. Though smallholder farmers do not know the nutrient status of their soil, they still apply fertilizers (Sileshi et al., 2025). Fertilizers in smallholder farming are just applied without knowledge of the nutrients that are deficient, but for increasing crop growth. Therefore, due to these different factors may affect their decision, these factors include socio-economic, demographic, and institutional factors, however they are not limited to these (Figure 1).

In terms of social-demographic factors, age is significant as young farmers are more likely to subscribe to innovative agricultural practices. Furthermore, in terms of marital status, Married farmers are reflected as household stability and decision making, they have greater financial responsibility and collaborative decision making that influences their willingness to pay for organic fertilizers. Whereas in terms of gender, male farmers usually receive more revenue compared to female farmers, were as female farmers were characterized by market access challenges (Zaata et al., 2025). Educated farmers are more likely to be willing to pay for organic fertilizers because they are more educated, and highly likely to be aware of the benefits and short fall of fertilizer usage (Ogunyiola et al., 2022).

A farmer's willingness to pay is also affected by cost, demand and supply of organic fertilizers. Institutional factors include government institutions, were by the DARDLEA places extension officers to assist farmers to be aware of sustainable agricultural practices as they catalyze the adoption of these practices (Kumar et al., 2025). Willingness

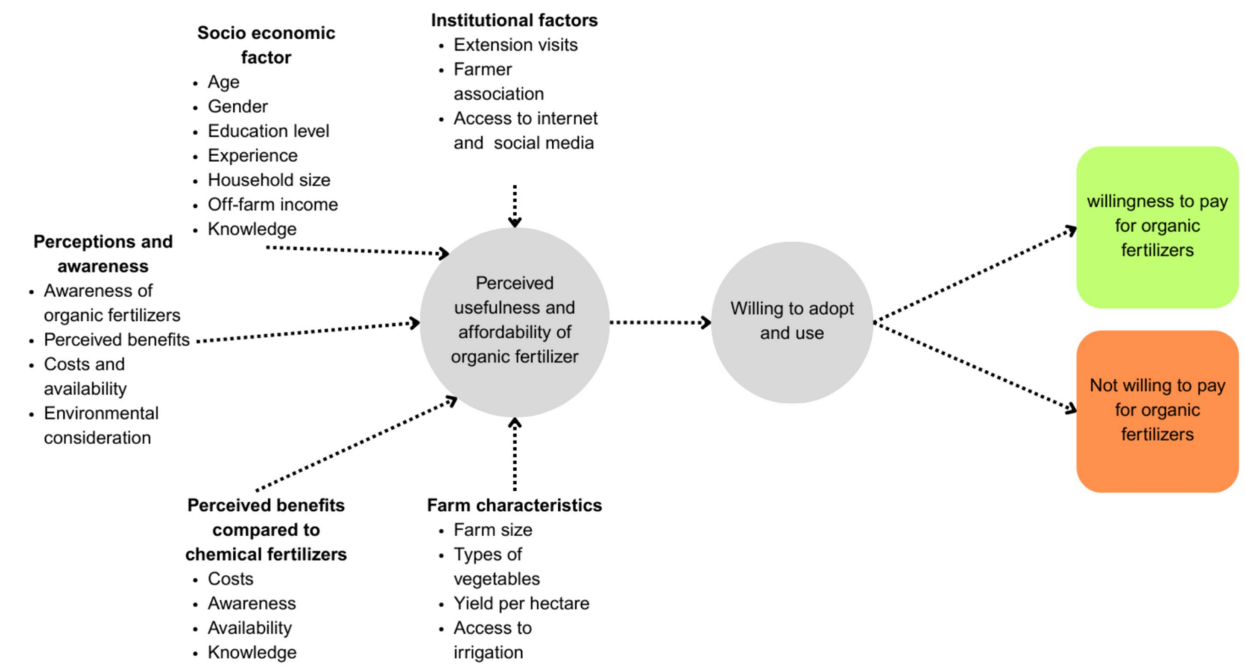

FIGURE 1
Conceptual framework showing factors influence willingness to pay organic fertilizers.

to pay for organic fertilizers is also linked with perceptions, especially in rural areas like Nkomazi. If the use of chemical fertilizer is common in rural areas, it stimulates farmers to use chemical fertilizers. Farmers may compare fertilizers and opt for the best-performing fertilizer.

Information about perceptions and awareness on smallholder farmers' adoption toward of organic fertilizer is outdated and rare especially in South Africa. Regular interaction and meeting with extension officers brings awareness and increases willingness to pay for organic farming techniques (Lothe et al., 2018).

3 Materials and methods

3.1 Description of study area

The study was carried out in Nkomazi local municipality, located in the Ehlanzeni District of Mpumalanga Province, South Africa. Geographically, Nkomazi lies between Northern Eswatini and Eastern Mozambique, positioned at coordinates 25.7097°S and 31.7195°E. It spans approximately 478,754 hectares and receives an average annual rainfall of 500–600 mm. It was selected as a study area due to its favorable climatic conditions, particularly the rainy seasons between October and March, which support vegetable production. It presents loamy soils and access to water from the Komati and Crocodile Rivers, further enhancing its suitability for the cultivation of various crops such as vegetables, maize, sugarcane and citrus fruits (Municipalities of South Africa, 2024). The local economy of Nkomazi depends on agriculture, tourism and mining (Nkomazi Municipality IDP, 2017-2021). Despite this, vegetable farming in Nkomazi remains largely small-scale and underdeveloped, highlighting the need for initiatives that encourage the use of organic fertilizers to enhance productivity and promote commercialization in the agricultural sector (Figure 2).

3.2 Research design

This study was arranged as a cross-sectional survey design where the data was collected at once in a specific point in time. This study addressed all objectives by collecting data using descriptive and inferential statistics via the application of mathematics and statistics to analyse the data and draw conclusions. This study was driven by objectives. Using structured questionnaires, variables were arranged to achieve these objectives. Data was collected through the use of quantitative research methods.

The study used quantitative methods to provide an understanding on factors affecting WTP for organic fertilizers among smallholder vegetable farmers. Quantitative research focuses on gathering statistical data about the socio-economic characteristics of the farmers, their use of organic fertilizers, and their willingness to pay for such fertilizers. Descriptive statistics were used to summarize the data, and inferential statistics, including binary regression, were applied to analyze the factors that influence fertilizer usage and willingness to pay.

3.3 Sampling procedure and sample size

According to Mabuza and Ndoro (2023) Nkomazi has 1,243 smallholder farmers, from the 1,243 farmers, there are 1,107 smallholder vegetable farmers. For this study, a list of registered vegetable smallholder farmers from the Department of Agriculture Rural Development, Land and Environmental Affairs (DARDLEA) was used to identify all participants. From the list, a total participating vegetable farmers were selected using a sample random sampling mixed with the Slovin's formula.

From the total number of smallholder vegetable farmers (1107), 133 farmers (Equation 2) took part in the study (Nkomazi Municipality IDP, 2017-2021). Slovin's formula was used to sample participants for this study.

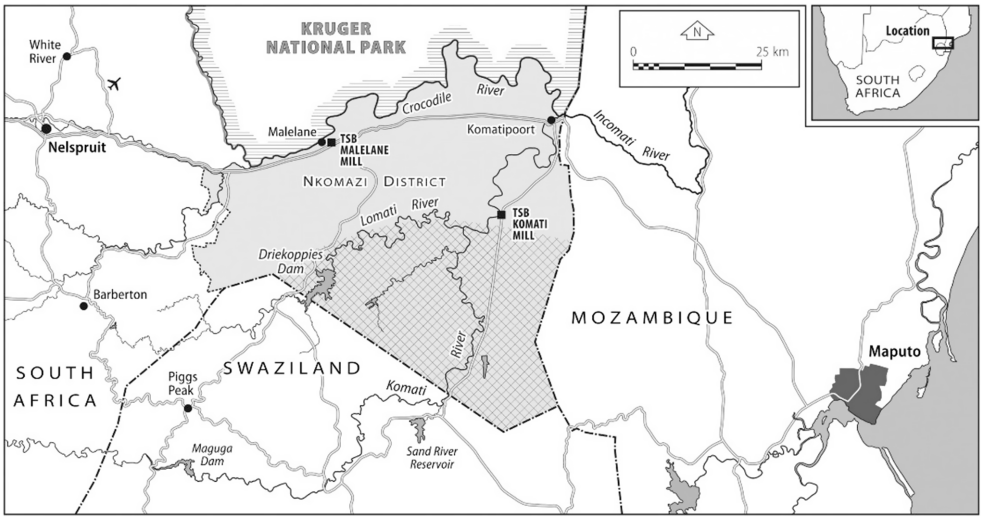

FIGURE 2
Map of Nkomazi local municipality, Mpumalanga. Source: Municipalities of South Africa (2024).

$$n = \frac{N}{\left(1 + N(e)^2\right)} \quad (1)$$

n = total sample size.
N = Total population of Nkomazi smallholder vegetable farmers.
e = Margin error
$n=1107/(1+0.08)^2$
n=133 participants/farmers
CI = 92%.

The simple random sampling procedure makes sure that all participants get equal chance to participate in the study. The probability for a smallholder farmer selected is represented in the formula:

$$P = \frac{n}{N} \quad (2)$$

$$P = \frac{137}{1107} * 100 = 12.38$$

Which means a respondent had 12.38% chance to be chosen to participate in this study (Equation 2).

To further understand the depth of this study. Out of 133 respondents, 2 respondents did not fill out the questionnaire completely, therefore were phased out during data analysis.

3.4 Data collection

The procedure of collecting data was driven by objectives, all farmers answered the same questionnaire, in questions in the questionnaire were aimed at achieving all research objective presented by the study. The questionnaires were developed by the authors, informed by established instruments and variables commonly used in related studies. The list of farmers was obtained from DARDLEA and all farmers were physically visited and allowed to fill the questionnaire.

The first section of the questionnaire collected the socio-economic and demographic characteristics of farmers (for objective i). The second section collected the farmer's fertilizer usage (for objective ii) and the final section was on a binary outcome to identify if farmers are willing to pay for organic fertilizers or not (for objective iii).

3.5 Data analysis

After questionnaires were filled, the data was stored on Microsoft Excel before the actual analysis on STATA software and were analysed based on objectives.

Objective i and ii were analysed using descriptive statistics. The use of means, median, frequencies, percentages and standard deviations were used to further discuss the data (Andrade, 2019).

Objective iii was analysed using binary logistic regression model, because the dependent variables, Respondents were asked if they are willing to use or pay for organic fertilizer and the possible outcome were yes (1) and no (0). Socioeconomic and demographic are going to be independent variables. This made it easier to understand and predict the factors that influence willingness. The model is specified using Table 1 and the formula below Equation 3:

$$logit\left(P\right) = 0 + B1\,X1 + B2\,X2 + B3\,X3\left(Age\right) + B4\,X4 + \ldots\ldots Bn\,Xn \quad (3)$$

Logit (P) = Probability of willing to pay or not willing to pay.
B_0 = Intercept.
$B_1, B_2, B_3 \ldots B_n$ = Coefficients.
$X_1, X_2, X_3 \ldots X_n$ = Independent variables (education, experience, gender, income, marital status, etc.)

3.6 Ethical considerations

This study was granted ethical clearance by the University of Mpumalanga, clearance number: UMP/NKUNA202131521/MSC/SAS/2025/01, authorizing the commencement of data collection. Additionally, formal permission was obtained from the Head of Department of DARDLEA to conduct the research within the Nkomazi Local Municipality. The study adhered to key ethical principles, including respect for participants, protection of privacy,

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TABLE 1 Explanatory variables used in the binary logit model and their expected.

Variable name	Type of measurement	Prior expectations
Willing to pay for organic fertilizers	Dependent variable (Logistic regression model) (No = 0; Yes = 1) (Dummy)	+
Independent/ predictor variables		
Age of a farmer	Actual number in years (Continuous)	+
Gender of HH	Farmer's sex (Male = 0; female = 1, prefer not to say = 3) (Dummy)	+/−
Marital status	Marital status (categorical)	+/−
Level of education	Level of education (Categorical)	+
Farm status	If the farm operates full time (0) or part time (1)	+
Household size	Total number of individuals living in a unit (Continuous)	+
Major source of income	Categorical (farming = 0, employment = 1 and pension = 2)	+
Average monthly income	Average monthly income of the household	+/−
Access to credit/loan	If a farmer has access or not (Yes = 1; No = 0) (Dummy)	−
Land size	Number of hectares that each household owns (Continuous)	+/−
Type of fertilizer used	Categorical variables	+/−
Source of fertilizer	Where farmers source/get their fertilizers (categorical)	+/−
Years using fertilizers	Number of years farmer has been using fertilizers (continuous)	+
Amount spent on fertilizer	Amount of money spent acquiring fertilizers	+
Encountered challenges	If farmers have encountered any challenges with organic fertilizers (Dummy) (Yes = 1; No = 0)	+
Environmental sustainability	Which fertilizers are environmentally sustainable (chemical = 1; Organic = 0) (Dummy)	−
Understanding of organic fertilizer	Farmer's understanding with how organic fertilizer (No understanding = 1 to Excellent = 5)	+

informed consent, voluntary participation and honesty throughout the research process.

4 Results and discussion

4.1 Discussion of socio-economic and demographic characteristics of farmers

Smallholder farmers are largely defined by their socio-economic conditions, which are often marked by high production costs that reduce income and profitability (Sahu et al., 2024). They typically operate on small pieces of land and depend on traditional and less innovative farming methods, limiting their productivity and ability to compete in commercial agricultural markets (Gwambene, 2021). Therefore, it is significant to identify the socio-economic condition of Nkomazi smallholder farmers because they determine if the area adopts and willing to pay for organic farming practices.

Figure 3 reveals that 61.83% of farmers in Nkomazi are female, while 38.17% are male, indicating that farming in Nkomazi is dominated by women. Similar findings were reported by Ubisi et al. (2023), who found that 63% of farmers were female and 37% were male, showing a continued trend toward female participation in farming. Historically, men dominated agriculture, nonetheless this shifted overtime, particularly in the 20th century. According to Zaata et al. (2025), male farmers tend to earn higher total revenues than females, with women more likely to face challenges such as storage, postharvest losses and limited market access, while men often cite issues related to mechanization. These gender dynamics influence access to resources and the adoption of agricultural innovation, including willingness to pay for organic fertilizers.

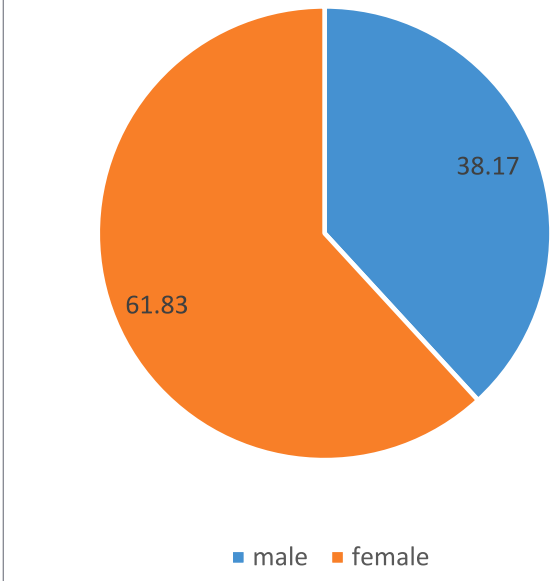

FIGURE 3
Gender of smallholder vegetable farmers.

Table 2 shows that farming in Nkomazi is largely dominated by older individuals (above 35) with only 12.21% of farmers being youth, 25.96% aged between 36 and 50 years, and 61.83% aged above 51 years old. This age distribution suggests that older farmers are more prevalent, which may affect their willingness to pay for and adopt new agricultural practices.

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TABLE 2 Age of smallholder vegetable farmers in Nkomazi.

Age	Frequency (%)
Less than 35 years	16 (12.21%)
36 to 50 years	34 (25.96%)
51 to 65 years	39 (29.77%)
66 years and above	42 (32.06%)

Education plays a crucial role in the adoption of agricultural practices by bridging the gap between farmers and agricultural innovations. According to the knowledge gap theory, more educated farmers are likely to be willing to pay for organic fertilizers due to greater awareness of their benefits and limitations (Ogunyiola et al., 2022). In South Africa, farmers are predominantly holders of secondary education (Mthombeni et al., 2021), which aligns with this study's findings showing that 74.81% of the farmers had secondary education, while tertiary and primary education almost equal at 24.43 and 25.19%, respectively, (Figure 4). Moreover education positively influences vegetable productivity, with studies indicating that each additional year of schooling increases profitability (Ali, 2024).

Extension visits play a crucial role in bridging the knowledge gap and influencing the adoption of organic farming practices (Ali, 2024). Agricultural extension officers provide technical and practical advice that shapes farmer's perceptions, willingness, and adoption of farming practices. Kumar et al. (2025) highlighted that extension services are pivotal in promoting organic agricultural practices, while Roman and Connor (2022) reported high yields and profits, demonstrating that extension support can enhance productivity and encourage sustainable practices. This study found that within a typical 3 month vegetable growth cycle, 42.75% of farmers received one extension visit, 16.03% received two visits and only 1.53% received three visits, while 39.69% of farmers reported receiving no visit at all (Figure 5). Such limited access to extension services restricts professional guidance throughout the growth season, negatively affecting farmer's success and adoption of organic fertilizers. Similarly, Hlatshwayo et al. (2021) observed that 26% of farmers in Limpopo and Mpumalanga had access to extension officers, leaving 74% without support. The high willingness of farmers to pay for extension services, as reported by Loki et al. (2019), where 98% of farmers in the Eastern Cape and KwaZulu-Natal expressed interest, underscores the urgent need to strengthen extension services in South Africa to address challenges and enhance the adoption of sustainable agricultural practices, including organic fertilizer use.

The study's finding indicates that majority of smallholder vegetable farmers in Nkomazi are married (51.91%), followed by single farmers (30.53%), widowed (16.03%) and least were divorced farmers at 1.53% (Figure 6). These findings were similar to those of Dynty et al. (2025) married (49.7%) were dominating followed by single, widowed and divorced farmers at 31.8,12.6 and 5.8%, respectively. The dominance of married farmers in quite popular in South Africa, married farmers are reflected as more financially responsible and committed toward long term agricultural investments due to collaborative decision making and stronger responsibilities compared to single farmers.

The study's findings indicate that 56.49% of vegetable farmers, seconded by employment at 37.40% (Figure 7). The sale of farm produce generates profit, creating an important income stream for farmers. Income and profitability from farming motivate farmers to continue

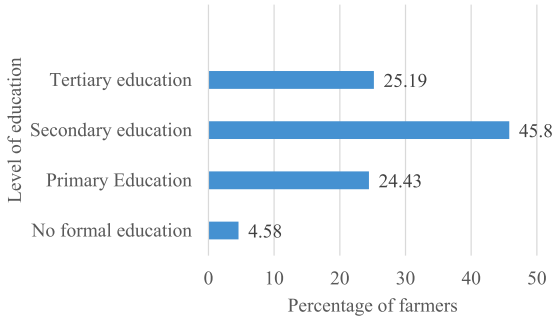

FIGURE 4
Level of education of smallholder vegetable farmers.

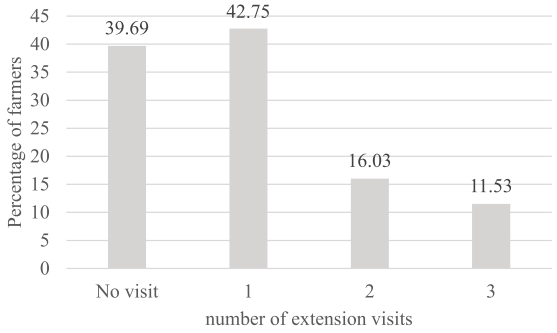

FIGURE 5
Number of extension visits in 3 months.

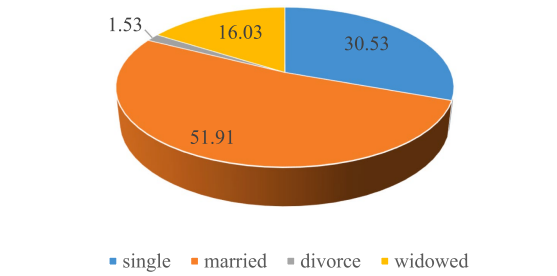

FIGURE 6
Marital status of smallholder vegetable farmers.

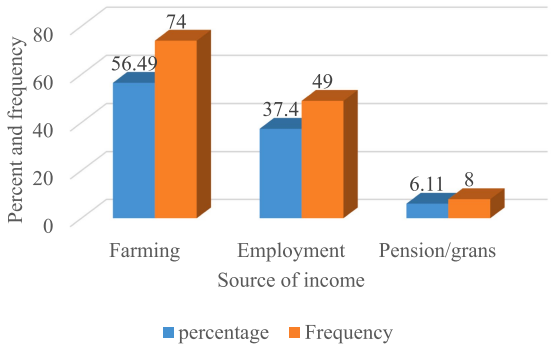

FIGURE 7
Major source of income of smallholder vegetable farmers in households in Nkomazi.

their agricultural activities, as sustained losses may force them to seek alternative income sources or even abandon farming altogether. Figure 7 illustrates that Nkomazi farmers rely primarily on farming as their primary source of income rather than employment and grant.

Figure 8 indicates that 59.54% of the respondents indicated that more than 51% of their household income was contributed by farming. These findings indicate that more than half of the participants rely on farming for their livelihoods, which was identified by Hlatshwayo et al. (2021), where the majority of communal farmers in Mpumalanga and Limpopo rely on farming.

The findings show that 35.11% of farmers in Nkomazi own livestock, while 64.89% do not. Among livestock owners, Table 3 indicates that cattle are the most commonly owned (58.69%) followed by goats, chickens, sheep and pigs at 32.61, 34.74, 10.87 and 2.17%, respectively. This pattern highlights the importance of cattle within local farming systems (Monkwe et al., 2023; Mthi et al., 2020), largely because they can graze on communal range lands, an open grazing system where animals freely access pasture and water (Gusha et al., 2023). Farmers practicing this traditional method rarely purchase feed for their cattle, as well as for their goats and sheep (Tavirimirwa et al., 2019; Gusha et al., 2023; Sinethemba and Beyene, 2022). Ownership of livestock directly supports organic farming practices as farmers utilize animal waste as fertilizer to enhance soil fertility.

4.2 Fertilizer usage by smallholder farmers

Nkomazi smallholder vegetable farmers reported using different types of fertilizers, including chemical, organic, and bio-fertilizers, with the aim of identifying which type they predominantly rely on. Figure 9 shows that 60.31% of farmers use only chemical fertilizers, 3.05% use only organic fertilizers, and 35.88% use a combination of both chemical and organic fertilizers. These results indicate a strong dependence on chemical fertilizers, a trend also observed broadly across South Africa (Uhunamure et al., 2021). This heavy reliance is influenced by factors such as availability, accessibility, knowledge, perceptions, and awareness regarding different fertilizer types.

Table 4 indicates that the majority of farmers spend between R501 and R1501 per 50 kg of fertilizer, while 27.85% spend more than R1501. The use of both chemical and organic fertilizers was the second most common practice, reported by 35.88% spent between R1 to R500 and 10.64% spent more than R1501. Only one farmer reported using a combination of chemical and bio fertilizers, spending R501 to R1501, and two farmers did not spend anything. Chemical fertilizers accounted for the highest costs typically exceeding R501, whereas organic fertilizer users spent little to nothing. The moderate expenditure patterns observed.

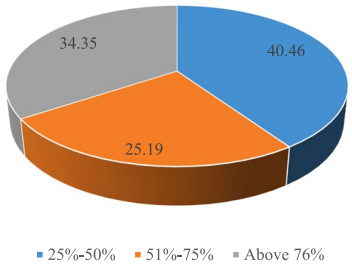

FIGURE 8
Percentage of income derived from farming.

The study's findings indicate that 70.23% of farmers are willing to pay for organic fertilizers, which indicates that the large portion of Nkomazi smallholder farmers are willing to pay for organic fertilizers (Table 5). Similar results were found by Zondo and Baiyegunhi (2021) were 83.6% of farmers were willing to pay for organic fertilizers. This suggests that in South Africa most farmers are willing to pay for organic fertilizers though they are using chemical fertilizers.

4.3 Determinants of the willingness to pay for organic fertilizers

The regression model was employed to analyze the relationship between various socio-economic and demographic characteristics and

TABLE 3 Number of vegetable smallholder farmers owning livestock.

Name of livestock	Number of farmers owning the animal (%)
Cattle	27 (58.69%)
Goat	15 (32.61%)
Chicken	16 (34.74%)
Sheep	5 (10.87%)
Pig	1 (2.17%)

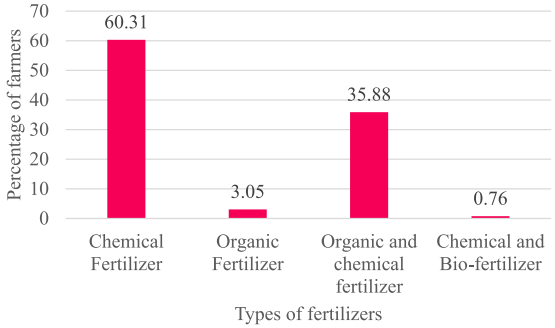

FIGURE 9
Type of fertilizers used by smallholder vegetable farmers.

TABLE 4 Amount spent per 50 kg per of fertilizers.

Amount spent for 50 kg of the current used fertilizer					
Type of fertilizer used	None	R1 to 500	R501 to R1501	More than R1501	Total
Chemical (%)	0	8 (10.13%)	49 (62.03%)	22 (27.85%)	79
Organic (%)	2 (50%)	1 (25%)	1 (25%)	0	4
Chemical and organic (%)	0	19 (40.43)	23 (48.94%)	5 (10.64%)	47
Chemical and bio-fertilizer (%)	0	0	1 (100%)	0	1
Total	2	28	74	27	131

TABLE 5 Farmers willing to pay for organic fertilizers.

Are you willing to pay for organic fertilizers	Percentage
Yes	70.23%
No	29.77%
Total	100%

TABLE 6 VIF test results of explanatory variables.

Variable	VIF	1/VIF
Age	2.67	0.374531
Gender	1.96	0.508959
Marital status	1.85	0.540421
Level of education	1.77	0.564131
Farm status	1.59	0.628062
Household size	1.59	0.630719
Major source of income	1.57	0.636891
Average monthly income	1.47	0.678410
Access to credit	1.44	0.692462
Size of farm	1.41	0.708171
Livestock ownership	1.40	0.714293
Type of fertilizer used	1.38	0.722492
Source of fertilizer	1.31	0.765008
Years using fertilizer	1.29	0.772683
Amount spent on fertilizers	1.26	0.790862
Challenges on fertilizer	1.23	0.813914
Environmental sustainability	1.16	0.865147
Understanding on fertilizers	1.09	0.920251
Mean VIF	1.53	

the dependent variable, which is willingness to pay for organic fertilizers. The Regression model is presented in Table 6, which shows that level of education, access to credit, type of fertilizer used, amount spent of fertilizers, challenges with organic fertilizers, and understanding of organic fertilizers were significant.

Prior to running of the model, a VIF test was conducted to assess multicollinearity among explanatory variables using Variance inflation factor (VIF). All VIF values were within the commonly accepted threshold (VIF < 10), indicating that multicollinearity was not a concern in this study.

After conduction of the VIF test, the model was then ran into Stata and the model output is displayed by Table 7.

The results indicate a positive and significant relationship between farmer's formal education and willingness to pay for organic fertilizers. Table 7 also indicates that which means that for a level increase in education, willingness to pay's probability increases by 10.3%. Education enhances farmers' analytical and decision-making abilities, allowing them to evaluate long-term benefits and perceive organic fertilizers as strategic investments rather than unnecessary costs and risk (Nastis et al., 2019). Educated farmers are also more exposed to new technologies, ideas, and market information, making them more receptive to sustainable practices and better able to identify market opportunities for organic produce. Zondo and Baiyegunhi (2021) and Udoh and James (2024) further confirm that education positively influences willingness to pay, with more educated farmers being quicker to adopt and invest in organic fertilizers. Similarly, Bambani and Vodouhe (2025) found that education improves recognition of soil fertility challenges and the uptake of soil fertility management practices, supporting the relevance of knowledge gap theory in explaining adoption behavior.

The findings underscore the importance of strengthening education and agricultural training to enhance organic fertilizer adoption. Policies could incorporate sustainable farming content into adult literacy programs and tailor extension services to match farmers' education levels. Educated farmers can serve as community role models and early adopters to promote faster and broader adoption of organic fertilizers within their local farming networks.

The negative coefficient for access to credit indicated having access to credit decreases WTP for organic fertilizers by 14.9. While those with access to credit are more willing and able to invest in them. This aligns with the findings by Zondo and Baiyegunhi (2021), who reported that smallholder potato farmers with credit were more willing to adopt cost-effective practices to ensure repayment. The significant negative relationship highlights that a lack of credit remains a major barrier, as smallholder famers often face financial constraints and prioritize immediate farm needs.

Aladejebi et al. (2018) and Belachew et al. (2020) emphasize that credit availability is crucial for adoption of sustainable agricultural practices, including soil fertility and water conservation measures. These findings underscore the importance of inclusive financial systems that target smallholders. Policymakers should consider promoting microfinance programs, seasonal credit facilities and low-interest loans tailored for sustainable inputs.

The negative relationship suggests that farmers already using organic fertilizers are less willing to purchase organic fertilizers compared to those relying on chemical fertilizers. The WTP for organic probability decreases by 1.8% if farmers are already using organic fertilizers. This reflects a principle of self-sufficiency, such that farmers who produce their own compost and livestock manure perceive little or no value in buying organic fertilizers. Ndambi et al. (2019) reported similar behavior in manure management, noting that farmers with effective organic practices are unlikely to invest in external amendments, while livestock ownership further reduces dependence on purchased inputs (Bergstrand, 2022).

These findings indicate that organic fertilizer users are generally unwilling to pay for products they can produce themselves. Chemical fertilizer users should be prioritized for awareness and practical demonstrations.

The positive coefficient indicated that farmers who spend more money on fertilizer are 11.1% likely to pay for organic fertilizer, as they seek to reduce overall input costs. Organic fertilizers are generally perceived as cost-effective as chemical fertilizers, making them attractive for improving farm profitability. Zondo and Baiyegunhi (2021) results revealed that farmers are willing to invest in organic fertilizers despite premium prices, reflecting a willingness to adopt environmentally sustainable practices (Foguesatto et al., 2020). These findings suggest that promoting awareness and ensuring access to organic fertilizers could increase adoption rates and support sustainable farming systems.

This highly significant negative result reveals a knowledge irony. This indicates that having higher understanding for organic fertilizers

TABLE 7 Factors affecting Nkomazi smallholder farmer's willingness to pay for organic fertilizers.

Variable	Dy/Dx	Std error	Z	P > z	[95% Confi. interval]	
Age	−0.0003697	0.0029704	−0.12	0.901	−0.0061916	0.0054521
Gender	0.0190507	0.0576528	0.33	0.741	−0.0939467	0.1320481
Marital status	0.0159988	0.0363068	0.44	0.659	−0.0551612	0.0871589
Level of education	**0.1031381**	**0.0543895**	**1.90**	**0.058***	**−0.0034633**	**0.2097396**
Farm status	0.1055379	0.0669171	1.58	0.115	−0.0256172	0.236693
Household size	0.0203046	0.0185721	1.09	0.274	−0.016096	0.0567052
Major source of income	−0.0030019	0.0608188	−0.05	0.961	−0.1222045	0.1162008
Average monthly income	−0.0445646	0.0587996	−0.76	0.449	−0.1598097	0.0706806
Access to credit	**−0.1493291**	**0.0643371**	**−2.32**	**0.020****	**−0.2754275**	**−0.0232308**
Size of farm	−0.019986	0.0145905	−1.37	0.171	−0.0485828	0.0086108
Livestock ownership	0.0094783	0.077281	0.12	0.902	−0.1419897	0.1609464
Type of fertilizer used	**−0.0183313**	**0.007748**	**−2.37**	**0.018****	**−0.0335171**	**−0.0031454**
Source of fertilizer	−0.0005124	0.0032475	−0.16	0.875	−0.0068773	0.0058525
Years using fertilizer	0.0033273	0.003629	0.92	0.359	−0.0037855	0.01044
Amount spent on fertilizers	**0.1116337**	**0.0519193**	**2.15**	**0.032****	**0.0098738**	**0.2133936**
Challenges on fertilizer	**0.2445916**	**0.1136649**	**2.15**	**0.031****	**0.0218124**	**0.4673708**
Environmental sustainability	0.0582293	0.0669588	0.87	0.385	−0.0730076	0.1894662
Understanding on fertilizers	**−0.1521945**	**0.0247319**	**−6.15**	**0.000*****	**−0.2006681**	**−0.103721**

Number of obs	131
LR Chi2 (18)	78.37
Prob>chi2	0.0
Pseudo R2	0.4912
Log Likelihood	−40.582412

Significance indicate by *, ** and *** defines significance at 90, 95 and 99%, respectively, bolded texts highlights significant variables".

reduces the probability to pay for organic fertilizers by 15.2%. This may be because a deeper understanding makes farmers either self-sufficient in producing their own inputs or more critical of the limitations of commercial organic products, such as labor intensity, bulkiness, slower nutrient release, and inconsistent quality. These findings are in contrast with what the key informants indicated. The relationship between knowledge and adoption is not always straightforward. Rogers' Diffusion of Innovations theory acknowledges that experienced adopters tend to examine uncertainties more carefully (Lavoie et al., 2021).

This requires a segmented extension approach. For farmers with limited knowledge, messaging should emphasize simplicity and benefits to spark interest. For knowledgeable farmers, extension should address their specific concerns, such as quality assurance, nutrient consistency, and long-term returns. Moreover, policies could reposition these informed farmers as entrepreneurs or suppliers of organic inputs, turning their expertise into a resource for others rather than just focusing on their adoption. The results provided by this study can be applied in other smallholder agricultural systems, meaning it is transferable. The observed relationship between education, credit access, input costs, and WTP can be relevant in other areas with similar extension access, input market constraints and small scale farming practices. However, they may be influenced by agro ecological conditions, institutional factors and policy initiatives.

4.4 Model specification sensitivity

The primary analysis uses a binary logistic regression model to estimate factors influencing farmers' willingness to pay for organic fertilizers. To test model stability, alternative specifications were examined by assessing the inclusion and exclusion of selected variables such as household size, farm size and major source of income. The results remained largely consistent with level of education access to credit, type of fertilizer used, amount spent on fertilizers, challenges with organic fertilizers and understanding of organic fertilizers remaining statistically significant predictors of WTP. This suggests that the model findings are robust and not highly dependent on the inclusion of specific control variables.

4.5 Sensitivity to outliers and extremes responses

The study involved survey data collected from 131 smallholder farmers which contain extreme responses, particularly regarding income levels and fertilizer expenditure. Key variables include household size, average monthly income and sensitivity to outliers. Despite difference in farmer's expenditure levels, regression finding suggested that there was a consistent positive correlation between fertilizer

spending and WTP. This suggests that extreme values did not significantly affect the study findings.

4.6 Sensitivity to sampling variation

The study used simple random sampling registered smallholder farmers in Nkomazi. While sampling variation can influence statistical estimates, the relatively representative sample of 131 respondents provided sufficient variability across demographic and socio-economic characteristics. The consistent relationship between major determinants an WTP indicate that the findings are likely generalized to similar smallholder farming contexts within the study area.

5 Conclusion and recommendations

The study successfully achieved its objectives, identifying factors influencing the adoption of organic fertilizers and their impact on smallholder farmers' WTP in Nkomazi. The socio-economic profile showed that the typical vegetable farmer is an experienced female over 51 years old, with secondary education, relying on farming as a primary source of income. A critical finding was the limited access to agricultural extension services, with nearly 40% of farmers receiving no visits during the crucial three-month vegetable growth cycle. Regarding current practices, chemical fertilizers were predominantly used, with 60.31% relying solely on them, 3.05% using only organic inputs, and 35.88% using a combination, showing some familiarity but limited reliance on organic options. Though there was low adoption of use of organic fertilizer, 70.23% of farmers were willing to pay for organic fertilizers.

Binary logistic regression revealed significant insights into WTP. Education positively influenced WTP, highlighting the role of knowledge in understanding long-term benefits. Conversely, access to credit unexpectedly had a negative effect, suggesting that financial means alone do not guarantee investment in organic inputs. Farmers already using organic fertilizers were less willing to pay for commercial products, while higher current fertilizer expenditures positively predicted WTP. Interestingly, greater knowledge of organic fertilizers negatively influenced WTP, likely due to awareness of practical limitations, while perceived challenges strongly deterred adoption. Overall, economic constraints, practical barriers, and perceived risks limited farmers' willingness to invest in organic alternatives.

The study underscores the urgent need for sustainable alternatives to chemical fertilizers to improve soil health, crop productivity, and food security among smallholder farmers. Although the adoption of organic fertilizers in Nkomazi is currently low, targeted interventions can address economic, knowledge, and logistical barriers, promoting environmentally friendly farming practices and enhancing sustainable agricultural outcomes.

Introduction of green subsidy to reduce upfront costs of certified organic fertilizer, making them competitive with chemical alternatives, Clear certification criteria and distribution via extension services or cooperatives can ensure accessibility and transparency. Furthermore there is a need to enhance the commercialization of organic fertilizers, to supply the farmers who are willing to pay for organic fertilizers.

Launching of ongoing government-funded campaigns to educate farmers on the economic and ecological benefits of organic fertilizers, promoting proper collection and processing of livestock waste. Messaging should emphasize profitability, soil health and risk reduction rather than purely environmental concerns.

Future research should explore processing livestock manure into usable organic fertilizer and expand to other provinces to identify regional factors influencing WTP. Studies should also investigate pests associated with manure, methods to mitigate them, and strategies to reduce chemical fertilizer use to prevent soil degradation, mitigate climate change, and strengthen food security. Expansion of research could stimulate organic fertilizer production, commercial organic farming, and broader adoption of sustainable agricultural practices.

According to Sarkar and Sarkar (2024), it is significant to identify the government initiatives have once been deployed in India to improve sustainable agriculture practices through soil health and management programs, these aimed at promoting soil health and sustainability. However despite government efforts, the use of chemical fertilizers have increased over the past years. Further studies and government efforts also need to identify strategies to mitigate the use of chemical inputs and develop more skills development program that will equip farmers with techniques on how to develop organic and sustainable farm input. This is significant as aquaculture, fertilizer use and livestock production are highly associated with improving United Nations SDGs (Rana et al., 2025).

6 Limitations

Nkomazi is an area that is exposed to temporal electrical blackout known as load shedding which affects a lot of communities in South Africa. The blackouts also affect the network, which made it challenging to draft the article. The cost of transportation from farm to farm made it challenging as most farmers did not respond to questionnaires which increased the research budget.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Mpumalanga Ethics Committee, clearance number (UMP/NKUNA202131521/MSC/SAS/2025/01). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SN: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Visualization, Writing – original draft, Writing – review & editing. MC: Conceptualization, Formal analysis, Project administration, Supervision, Validation, Visualization, Writing – review & editing, Data curation, Investigation, Methodology. BM: Conceptualization,

Investigation, Supervision, Validation, Visualization, Writing – review & editing. SM: Conceptualization, Validation, Visualization, Writing – review & editing. KO: Conceptualization, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declared that Generative AI was not used in the creation of this manuscript.

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