Environment, Development and Sustainability
https://doi.org/10.1007/s10668-024-05299-6

Farmer-oriented predictors of smallholder urban pig farming challenges and adoption of sustainable management practices in the Cape Metropole, South Africa

Rebecca Mmamakgone Mathobela[1,2] · Obert Chenjerayi Chikwanha[1] · Chenaimoyo Lufutuko Faith Katiyatiya[1] · Annelin Henriehetta Molotsi[1] · Munyaradzi Chris Marufu[3] · Phillip Evert Strydom[1] · Cletos Mapiye[1]

Received: 7 August 2023 / Accepted: 3 August 2024

Abstract
Understanding the drivers of farmers' challenges and adoption of sustainable agricultural practices (SAPs) is crucial for the sustainable development of the small-scale urban pig enterprise in sub-Saharan Africa. A total of 160 structured questionnaires were individually administered to determine factors driving small-scale farmers' challenges and adoption of SAPs in the Cape Metropole District, South Africa. Key challenges reported by the farmers were piglet mortality (88% of respondents), limited access to communal water taps (42%), feed scarcity (36%), and shortage of pig housing material (30%). Marginal effects from logistic regression revealed that farmers' chances to experience key challenges were high ($P \leq 0.05$) among African traditional religion believers, exotic pig breed owners, single source income earners and young farmers. Key SAPs adopted by farmers included restricted feeding (78% of respondents), controlled mating (70%), biosecurity (50%) and record keeping (50%). The probability of farmers' failure to adopt key SAPs was high among the less educated, young farmers and African traditional religion believers ($P \leq 0.05$). In conclusion, consideration of farmer-oriented factors that have been associated with increasing the likelihood of experiencing challenges and non-adoption of SAPs in development initiatives could enhance small-scale urban pig production in the studied areas.

Keywords Biosecurity · Intensive pig production · Mortality · Restricted feeding

1 Introduction

Globally, sub-Saharan Africa (SSA) is considered as one of the most rapidly urbanizing regions, with nearly two-fifths of its total population residing in urban areas (United Nations, 2018; Asadu et al., 2021). The rapid increase in urbanization is raising concern regarding food, nutrition and income security of the rising population of poor urbanites,

Extended author information available on the last page of the article

Published online: 19 August 2024

many of which neither have employment nor access to economic resources (Asadu et al., 2021). To cope, resource-poor urbanites engage in urban agriculture including small-scale pig production as a source of food, nutrition, and income (Poulsen et al., 2015). Owing to its low input requirements, high biological and economic productivity (Maes et al., 2020), small-scale pig production enterprise suits well to an urban environment characterized by land scarcity and high meat demand (Lindahl et al., 2019).

The global pig population currently stands at 784.2 million pigs of which China, the top producer accounts for nearly 60% of the population (Statista, 2023a). In 2020, South Africa had an estimated population of 1.36 million heads (Statista, 2023b) concentrated in the Northwest and Limpopo provinces [Department of Agriculture, Land Reform and Rural Development (DALRRD), 2021]. Contrary to the global trends where pork is the most consumed meat with a share of 36% [Food and Agriculture Organization Statistics (FAOSTAT), 2021], in South Africa it accounts for only 7% of the total meat consumption [Bureau for Food and Agricultural Policy (BFAP), 2014] because of the influence of cultural diversity, religious beliefs and dietary diversity (DALRRD, 2021; Molotsi et al., 2021). Interestingly, pork consumption in South Africa has been increasing over the past decade and is projected to continue rising due to increasing urbanisation, income per capita and prices of its competitors, beef and lamb (DALRRD, 2021). To keep pace with the projected pork demand, it is important to fully explore all the existing pig value chains while acknowledging the potential of small-scale pig farmers to produce sufficient volumes of pork to satisfy the domestic market with minimal environmental and health risks.

Pork in SSA is produced under different pig production systems ranging from extensive to intensive systems, often differing in terms of inputs, scale of production, degree of commercialisation, intensity of production, and marketing efficiency (Jacobson et al., 2014; Mathobela et al., 2024). An intensive small-scale, commercially oriented pig production system with limited technology, information and agricultural support services is the dominant farming system in SSA's urban areas (Kagira & Kanyari, 2010; Jacobson et al., 2014). Notably, the viability of this pig production system is particularly challenged by use of non-sustainable agricultural management practices and the poor conditions of farmers (Mathobela et al., 2024). Small-scale pig farming is highly entwined with the farming family's lifestyle, thus decisions to enhance its viability hinges on several farmer-oriented factors (Ström et al., 2017; Mathobela et al., 2024).

In SSA, several efforts have been made to enhance small-scale urban pig farming through adoption of sustainable agricultural practices (SAPs; Mathobela et al., 2024). Regratably, the adoption rates, spectrum and longevity of SAPs in the SSA's urban areas in general have not been sufficient to buffer households against food, economic, social and ecological insercurity (Garzón Delvaux et al., 2020; El Fartassi et al., 2023). This has been ascribed to knowledge gaps on factors driving farmer's decisions to cope with challenges and adopt SAPs. It is argued that the individual farmer is the primary actor in the process of making logical decisions to overcome challenges and adopt SAPs and is subsequently influenced by internal and external factors (Ajzen, 1991; Oino & Mugure, 2013). In this context, there has been rising awareness that decisions to overcome challenges and adopt SAPs are influenced by a plethora of farmer-oriented factors mostly socioeconomic, bio-physical, and institutional factors that shape their behavior (Dhraief et al., 2019; Priya & Singh, 2024). The same authors noted that these factors affect farmers' decisions differently, with their impact varying in magnitude and direction overtime, among individuals, across locations, SAPs, and agricultural enterprises amongst other factors. In SSA, however, little is known about the context-specific farmer-oriented factors that may be driving differences in small-scale urban pig farmers' decision to cope with challenges and adopt SAPs, and this merit investigation.

Insights into context-specific factors driving farmers' decision to overcome challenges and adopt SAPs are critical in enhancing farmers' problem-solving skills and adaptive capacity (Begho et al., 2022; Priya & Singh, 2024). This could form the foundation for creating effective coping strategies and evidence-based policies that promote rapid, widespread, and long-term adoption of SAPs on small-scale urban pig farms in SSA, including South Africa. To this end, the objective of the present study was to determine socioeconomic, bio-physical, and institutional factors that influence the challenges experienced by farmers and adoption of sustainable small-scale pig farming management practices in the Cape Metropole District, South Africa.

2 Literature review and theoretical framework

Small-scale urban pig farmers in SSA are generally confronted with a wide range of production challenges including diseases and parasites, feed and water scarcity, low-quality breeding stock and sub-standard housing structures (Mathobela et al., 2024). Other significant challenges include existence of informal and uncoordinated low-value markets, inappropriate waste disposal, limited space, insecure land tenure, and lack of acceptance due to its potential environmental and public health risks (Antwi & Seahlodi, 2011; Wanyama & Leitner, 2019). Farmers try to overcome these challenges by adopting sustainable pig health, feeding, housing, breeding, marketing, and waste management practices. Key sustainable management practices being adopted by small-scale urban pig farmers in SSA include biosecurity, restricted feeding of balanced diets formulated on-farm using local non-conventional feedstuffs, controlled mating and selection, use of simple least-cost houses constructed with locally available materials, and value addition of pig products and wastes (Mathobela et al., 2024). Sadly, farmers' failure to timeously cope with challenges, and either slow, small-scale and/ or short-term adoption of SAPs are evident in SSA (Mwangi & Kariuki, 2015; Garzón Delvaux et al., 2020; El Fartassi et al., 2023). This has been largely attributed to lack of understanding of factors that influence farmers' decision to cope with challenges and adopt SAPs (Liu et al., 2018; Foguesatto et al., 2020).

Preliminary ideas and concepts for the current study were conceived from empirical studies and reviews detailing factors influencing farmers' challenges and adoption of SAPs worldwide, with emphasis on livestock, particularly pigs in SSA. Recent literature shows that the likelihood of a farmer to encounter a challenge and decide to adopt SAPs are largely influenced by socioeconomic, biophysical, and institutional factors (Foguesatto et al., 2020; Priya & Singh, 2024). These factors shape individual's intrinsic motivations, attitudes and perceptions that may be better explained by psychological theories (Ajzen, 1991; Sok et al., 2021; Atta-Aidoo et al., 2022), which are beyond the focuses of this study.

Socioeconomic factors are subdivided into two main groups: farmer (i.e., personal/demographic) and farm (i.e., economic/financial) attributes. Farmer attributes relate to personal variables including gender, age, education level, family size (i.e., proxy for workforce) and religion. Farm attributes refer to farm economic variables such as income level, source of income, off-farm income, production system, farming experience, herd size and number of livestock species kept. These factors are the "resources" that farmers inherently possess and mostly used as proxy measures of farmers' financial, risk and networking capacity to cope with challenges and adopt SAPs (Rajendran et al., 2016; Doran et al., 2020). For example, it has been demonstrated that high-earning, more experienced and educated males with larger families are less likely to face challenges and have better chances of adopting SAPs than their counterparts (Dhraief et al., 2019; Malila et al., 2023; Priya & Singh, 2024).

Large herds generate more income than their counterparts, which may reduce chances of encountering challenges and positively influence SAPs uptake by farmers (Koketsu & Iida, 2020; Mathobela et al., 2024). With regards to number of livestock species kept, multi-species as opposed to mono-species farming promotes multiple income streams and livelihood diversifications, increasing farmers likelihood to cope with challenges and adopt SAPs (Martin et al., 2020; Mosnier et al., 2022). The influence of age on farmers decision to overcome challenges and adopt SAPs is ambiguous. Age drives farmers' physical function, labour supply, planning horizon, resource accumulation and risk preference. Though young versus old farmers have a long-range planning horizon, are less risk averse, more energetic, and open to solve challenges and embrace SAPs, they often lack authority, knowledge, experience, and resources to invest in overcoming challenges and implementing SAPs (Dhraief et al., 2019; Malila et al., 2023; Priya & Singh, 2024). Since Christianity promote humane pork production, it is likely to encounter fewer challenges and embrace SAPs relative to the most African traditional religion whose animal welfare practices are questionable, and Islam and Judaism religions that forbid pork production and consumption (Weka et al., 2021; Wilson, 2018).

Biophysical (i.e., ecological or environmental) factors largely refers to the geographical attributes of the farm. Among the farm biophysical attributes, size, geographic location, distance to market and physicochemical properties of the soil have been shown to impact farmer's decision to overcome challenges and adopt SAPs (Kassie et al., 2015; Ren et al., 2019; Foguesatto et al., 2020). To exemplify, an increase in farm size generally has positive impact on economic, social, and environmental sustainability of livestock farming (Ren et al., 2019; Başer & Bozoğlu, 2023). In this regard, it has been postulated that large farms are less likely to experience challenges and possess more resources to invest in SAPs (Rajendran et al., 2016). Some studies, however, show neutral or negative effects of large farms regarding overcoming of challenges and adoption of SAPs (Başer & Bozoğlu, 2023; Priya & Singh, 2024). The decrease in likelihood to overcome challenges and adopt SAPs with increase in farm size may be attributed to decrease in energy use efficiency and increase labour and adoption costs (Başer & Bozoğlu, 2023; Li et al., 2024). Short distances reduce travel time and transport costs to the market enabling farmers to have better access to the market and marketing information, which could assist farmers to cope with challenges and adopt SAPs (Foguesatto et al., 2020; Priya & Singh, 2024). Soil physicochemical properties, particularly soil type and fertility are positively correlated with agricultural production, thus could increase the possibility of overcoming challenges, and embracing SAPs (Kassie et al., 2015; Begho et al., 2022).

Institutional factors are empirically measured using different property rights and financial policy indices including availability of and access to land, inputs, credit, subsides, incentives, insurance, extension, veterinary care, training, information, and community development programs. Farmers who have access to any of these factors have lower chances of experiencing challenges and higher likelihood of adopting SAPs than their counterparts

(Dhraief et al., 2019; Li et al., 204; Priya & Singh, 2024). These proxies for economic status offer financial, technical, and institutional support that facilitate the early adoption process and formation of information exchange networks (Malila et al., 2023; Wang & Hu, 2023). Moreover, they shape farmer attitudes towards making appropriate farm-level decisions to overcome challenges and adopt SAPs (Malila et al., 2023; Wang & Hu, 2023). In most cases, institutional factors positively affect perceptions and attitudes of farmers, thereby influencing their integrity, reasoning, and ability to gather, process and apply knowledge, information, and expertise important in solving challenges and implementing SAPs (Foguesatto et al., 2020; Liu et al., 2018).

Based on the reviewed literature, it is apparent that a wide spectrum of factors influences farmers' probability to encounter challenges and decision to adopt SAPs. Notably, different factors distinctively influence farmers' decision to overcome challenges and adopt SAPs, and their impact could be negative, neutral, or positive depending on location, time, type of SAP and agricultural enterprise. Nevertheless, context-specific empirical studies showing how different factors influence small-scale urban pig farmers' chances to encounter challenges and decision to adopt of SAPs in SSA countries including South Africa are lacking and deserve further research. It is against this background that the current study examined the socioeconomic, bio-physical, and institutional factors that impact the challenges experienced by small-scale pig farmers and adoption of SAPs in the Cape Metropole District of South Africa.

3 Materials and methods

3.1 Ethical clearance and precautionary measures

The ethical approval of the current study was obtained from the Social, Behavioural and Education Research Ethics Committee (REC: SBE-17285) of the Stellenbosch University in compliance with the South African National Health Act No.61 2003 [Republic of South Africa (RSA), 2004]. The study was conducted in May 2021, during the Coronavirus disease (COVID-19) pandemic and all the precautionary measures, research guidance, rules and regulations as emphasised by the Research Ethics Committee were adhered to. There was an African Swine Fever (ASF) outbreak in the study area and all the necessary mitigating strategies, biosecurity and precautionary measures as advised by the provincial veterinary services personnel and imposed by the South African Animal Diseases Act 35 of 1984 (RSA, 1984), were adhered to during farm visits to combat the spread of the disease.

3.2 Study site and selection of farmers

The study was conducted in Mfuleni [Global Positioning System (GPS) coordinates: -34.008137, 18.675448], IthembaLab (-34.020630, 18.711254), Penhill (-33.973532, 18.717577), Khayelitsha (-34.040539, 18.714261) and Strand (-34.129302, 18.881187) low-income, high-density suburbs in the Cape Metropole District of the Western Cape Province, South Africa. These five suburbs were purposively selected based on their high numbers of small-scale pig producing households. Participants were selected from a list of all small-scale pig producing households in the respective suburbs obtained from the

Western Cape Department of Agriculture. Respectively, the list had 124, 75, 70, 61 and 53 farmers from Mfuleni, Khayelitsha, Penhill, Strand and IthembaLab bringing the sampling frame (i.e., target population) to a total of 383. The selection of farmers for the interview was done with the assistance of the extension officers and animal health technicians from the Western Cape Department of Agriculture based on pig ownership, their availability, and willingness to participate in the study. The sampling unit was the head of household owning at least two mature pigs. An opportunity (i.e., convenience) sampling technique was conducted to obtain a study sample of 160 pig farmers from Mfuleni (n=31), IthembaLab (n=33), Penhill (n=30), Khayelitsha (n=36) and Strand (n=30). The optimum sample size was calculated according to the Slovin's formula (Yamane, 1967) as follows:

$$\mathrm{n} = \frac{N}{1+N(e)^2} = \frac{383}{1+383(0.06)^2} = 161 \approx 160$$

Where, n=sample size required; N=the total number of small-scale pig farmers in the five surveyed suburbs which is 383, n=sample size which is 160; e=the acceptable sampling error which was 0.06. To this end, the authors acknowledge that the opportunistic (i.e., convenience) sampling method used may be biased and less representative due to the non-random selection of participants (Bornstein et al., 2013; Jager et al., 2017). For example, some household heads who work off-farm might have been missed as they were at work during the day and could only be available at night. However, conducting the interviews during day versus night at farmers homesteads allowed the authors to observe the pigs and the farm environment. This helped with verification of farmer, animal, and farm information, which perhaps led to more accurate findings.

3.3 Data collection

Data on household demographics, farm characteristics and pig production and practices (i.e., housing, feeding, watering, breeding management, health care and biosecurity) and farmer challenges were obtained through face-to-face personal interviews with pig farmers using pre-tested structured questionnaires administered in local languages (i.e., IsiXhosa, Afrikaans and English) by trained enumerators. A prototype of the questionnaire was drafted and pre-tested with 10 farmers in Kayamandi (GPS coordinates: -33.926706, 18.843263). Kayamandi is a low-income, high-density suburb in Stellenbosch with similar socioeconomic attributes to the surveyed suburbs. Pretesting assessed whether the questionnaire was correctly completed, respondents genuinely comprehended the questions, and were able and willing to provide the requested information. After the pre-test, changes were made to the questionnaire including re-phrasing and re-organisation of some questions to eliminate ambiguous, sensitive, and difficult questions and ensure clarity, logical flow of questions and instruction appropriateness. The questionnaire was refined prior to its administration in April 2021.

The questionnaire had a total of 122 questions, mostly closed-ended (dichotomous or multiple-choice) often followed by open-ended questions to explain the response/s provided. The duration of the interview ranged between 40 and 60 min per respondent. Prior to the interviews, the study's aims and possible benefits were clearly stated to the interviewees. After that, each interviewee gave their verbal and written informed consent. Participation was entirely voluntary, and participants were free to withdraw from the interview at any time. Participants were guaranteed privacy and anonymity. Data collected using questionnaires were complemented with personal observations, physical inspection, existing records, and photography where necessary. The questionnaire with the details of the questions asked is provided as a supplementary document.

3.4 Statistical analysis

Descriptive statistics for demographics, herd composition, pig husbandry, housing, feeding, water, breeding, reproduction, health, and biosecurity practices data were analysed using PROC FREQ of SAS 9.4. Pig herd size and structure data were subjected to PROC GLM of SAS at 5% ($P \leq 0.05$) level of probability and mean separation was performed using Tukey's test. The normality and homoscedasticity of this dataset was tested using the Shapiro–Wilk and Levene tests, respectively (Kelter, 2021).

The PROC LOGISTIC model was used to determine the socioeconomic, biophysical, and institutional factors influencing key challenges (i.e., limited access to communal water taps, scarcity of feed, shortage of pig housing material and piglet mortality) experienced by the farmers and key SAPs (i.e., record keeping, restricted feeding, controlled mating, and biosecurity) they adopted. A binomial logistic regression model was chosen due its ability to handle multiple explanatory variables and control for confounding variable effects, effectiveness in explaining dichotomous decision variables and easiness of output interpretation (Stoltzfus, 2011). However, the predicted values obtained using logistic regression can be outside the possible range if the discrepancies in the independent variables are not verified and there can be a non-linear relationship between input and response (Stoltzfus, 2011).

The logistic regression model predicted log odds of farmers experiencing a certain challenge or adopting a particular SAP. The independent variables incorporated in the model are presented in Table 1. In the model, the independent variables had maximum likelihood estimates that only converged and non-significant score tests for proportional odds assumptions. The independent variables incorporated in the model were selected using the forward selection option and embedded in the logical procedure of SAS v. 9.4 (SAS Institute Inc., Cary, NC). The model was specified according to Greene (2020) as follows:

$$\text{Pob }\left(Y_j = i\right) = P_{ji} = \frac{\text{expo}\left(X_j \beta_{\ i}\right)}{\sum \text{ expo}\left(X_j \beta_{\ k}\right)} \text{ where } 0 < P_{ji} < 1 \tag{1}$$

Equation 1 was linearized into (2):

$$\text{Prob }\left(Y_j = i\right) = P_{ji}\left(\beta_{\ 0} + \beta_{\ 1} X_1 + \beta_{\ 2} X_2 + \ldots ? \beta_{\ k} X_k\right) \tag{2}$$

Where: Prob ($Yj=i$) is the the probability of a farmer to experience a key challenge or adopt a key SAP with two response categories of either yes or no coded as 1 or 0; β_{0} = Intercept; β_1, β_2, …, β_n = coefficients of independent variables; χ_1, χ_2, …, χ_n = independent variables. The residual model after fitting the variables was:

Y_i (key challenge or key SAP) = $\beta 0$ + $\beta 1$(gender) + $\beta 2$(age) + $\beta 3$(religion) + $\beta 4$(education) + $\beta 5$(farming experience) + $\beta 6$(workforce) + $\beta 7$(income source) + $\beta 8$(farm size) + $\beta 9$(type of livestock kept) + $\beta 10$(herd size) + $\beta 11$(type of pig breeds kept) + $\beta 12$(production system)

Table 1 Description of socioeconomic, biophysical, and institutional factors influencing challenges experienced small-scale pig production practices and adoption sustainable agricultural practices in the Cape Metropole District, South Africa

Independent variable	Description of independent variables
Gender	Gender of the farmer (1 = Male, 2 = Female).
Age of the farmer	Age of the farmer [1 = Youth (Between 18 and 40 years) 2 = Adult older than 40 years)
Religion	Religion of the farmer (1 = African traditional, 2 = Christianity).
Education level	Educational level of the farmer (1 = No formal education to primary education, 2 = Secondary to tertiary education).
Farming experience	Farming experience of the farmer (1 = 10 years and less, 2 = More than 10 years).
Workforce	Type of workforce used by the farmer (1 = None/ family labour, 2 = Paid labour).
Sources of income	Source of income (1 = Pig sales only (one source), 2 = Other sources of income.
Farm size	Farm size [1 = Small (less than $500m^2$), 2 = Large ($500m^2$ and more)].
Types of livestock kept	Type of livestock kept by the farmer [1 = monoculture (Pigs only) livestock farming, 2 = multi-species livestock faming].
Herd size	Herd size [1 = Small (30 pigs and less), 2 = Large (More than 30 pigs)].
Type of breeds kept	Type of pig breeds kept by the farmer (1 = Exotic only, 2 = Indigenous/ Crossbreds).
Production system	Production system practiced by the farmer (1 = Intensive 2 = Semi-intensive).
Location	Location of the farm (1 = On-plot, 2 = Off-plot).
Extension services	Farmer receiving agricultural extension services (1 = Yes, 2 = No).
Pig production training	Farmer receiving pig production training (1 = Yes, 2 = No).

+ β13(location) + β14(extension services) + β15(pig training) + ε, where; β0 = Intercept, β1, …, β15 = Coefficients and ε = Error.

Estimated and exponentiated coefficients do not either convey the probabilities or the magnitude of change, hence marginal effects that estimate the change in the expected value of a dependent variable with a unit change in an independent variable (Greene, 2020) were specified as follows:

$$x_1, \frac{1}{N}\sum_{i=1}^{N}\frac{\beta\,.p_{i.}(1-p_i)}{100}$$

The marginal effects of logistic regression were predicted as the change in the probability of pig farmers to experience a key challenge or adopt a key SAP for a unit change in each factor. Probability values were considered significant at 5% ($P \leq 0.05$) level.

4 Results

4.1 Farmer and pig herd attributes

Majority of interviewed pig farmers were males (73%), aged 36–60 years (59%), Christians (74%), had post-secondary level of education (71%) and over 6 years of pig farming experience (51%) across the surveyed suburbs. Most respondents farmed on private land (71%), while 18% and 11% farmed on government and communal lands, respectively. Two-fifths of the farmers had no paid labour, whilst 31% had paid labour and 29% had family labour.

Live pig and pork sales were the main source of income for the interviewed farmers (95%). Secondary sources of income included sales of other livestock (20%), salary (15%), pension (12%), social grant (8%), part-time jobs (5%). Farmers (62% of respondents) across the five surveyed suburbs had farm sizes less than 500 m^2. The farmers kept pigs for sales (82% of respondents), consumption (31%), status (21%), manure (5%) and ceremonies (3%). Other livestock kept included chickens (28% of respondents), goats (16%), cattle (11%), other poultry species (7%) and sheep (3%). The average herd size for the surveyed suburbs was 30.2±6.2.

4.2 General pig farm records and management practices

Of the interviewed farmers, three-quarters always provided iron to piglets and two-fifths of them supplemented iron within three days after birth. Most pig farmers (61%) across the surveyed suburbs always provided creep feed to piglets and the three-fifths did so within a month after birth. Commercial creep feed was the dominant feed (77% of respondents) followed by kitchen swill (10% of the respondents), agro-by-products (8%) and vegetables (5%). Only 10% of the respondents performed tail docking and teeth clipping with two-fifths and half respectively doing it within seven days regardless of suburbs. More than half of the farmers always castrated their pigs within a month after birth irrespective of the suburbs.

Across all five suburbs, two-fifths of the farmers did not make use of identification methods. The farmers that adopted identification methods mostly used ear notching (27% of respondents) and ear tags (16%) within two months of birth (60%). Half of the farmers kept farm records. Of those that kept records, majority (37% of respondents) kept multiple type of records including production (89% of respondents), health (51%), financial (44%) and labour (15%) records. Specific records kept by the farmers comprised of birth and mortality numbers (38% of respondents), general sales and expenses (17%), general farm observations (15%), pregnancy and farrowing dates (9%), medication used (8%), progeny and breeding information (6%), feed (6%) and pig sales (2%). More than half of the farmers memorized farm records in their head while more than two-fifths used paper records. Only a small fraction used technology such as cell phone (6%) and computer (2%) for record keeping. Farmers kept the records either daily (28%), weekly (18%), bi-weekly (6%), monthly (20%) or when necessary (28%). Most farmers (45%) reported memorizing the records as the reason for not keeping paper and or computerized records. The likelihood of pig farmers to keep farm records was not influenced ($P > 0.05$) by any of the investigated predictor variables.

4.3 Pig housing management practices

Across all the five surveyed suburbs, many farmers provided housing (99%) enclosed by fence (89%). Common building materials used for the pig housing walls included iron sheets (92% of respondents), wood (84%), asbestos (16%) and bricks (10%). Iron sheets (89% of respondents), wood (17%) and asbestos (16%) were the predominant roofing material. Most farmers either used earth floors (73%), concrete (20%) or wood (7%) as flooring material. Though one-third of the farmers did not use any bedding material, the rest either used sawdust (46%), straw (17%), old clothes (3%) or shredded paper (1%) regardless of suburb. Most pig houses had farrowing pens (69% of respondents), grow-out pens (51%) and holding pens (57%). About 90% of the farmers kept pigs in groups and 9% in individual pens. Most pig houses (~60% of respondents) had no source of energy for light and heat while about two-fifths were solar powered.

Major pig housing challenges experienced by the farmers across all the five suburbs include shortage of building material (30% of respondents), waterlogged and muddy earth floors (21%), poor quality of the housing material (16%), inappropriately built pens (14%), leaking roofs (10%) and unavailability of space (9%). All the analysed factors significantly predicted ($P \leq 0.05$) small-scale farmer's likelihood to experience shortage of building materials with education and training as the key predictors (Table 2). According to the marginal effect estimates, a unit increase in farmer's level of education or training in pig production led to a reduction of 10.5% in the likelihood to experience shortage of building material.

4.4 Pig feeding management practices

Across all the five suburbs, the majority (80%) of farmers practiced intensive production system, while 16 and 4% practiced semi-intensive and extensive pig farming, respectively. Most of the farmers (~60%) fed pigs twice a day. 90% of the farmers practiced restricted feeding and 10% *ad libitum* feeding. Of the tested variables, gender, religion, education, and training had strong positive impact ($P \leq 0.05$) on farmers' probability to practice restricted feeding. The marginal effect estimates shows that males, Christians, more educated farmers, and those who received pig training were 12.5 to 12.8% more likely ($P \leq 0.05$) to practice restricted feeding than their counterparts.

Multiple feed resources given to the pigs included vegetables/ fruits rejected by commercial retailers (65% of respondents) followed by purchased commercial feed (54%), swill/ kitchen wastes (53%), agricultural by-products (27%), homemade complete diets (21%) and bakery/ dairy products (13%) regardless of the suburb. Three-quarters of the farmers did not know the daily feed consumption of their pigs. Feed troughs used by farmers included drums (45% of the respondents), buckets (38%), commercial troughs (16%), tyres (15%) and/ or broken sinks/ bathtubs (5%). Farmers stored pig feed either in the feed troughs (90%), feed sacks (8%), and municipal refuse bins (2%). About 60% of the farmers cleaned the feed troughs daily while 23% cleaned every two to four days. Major feed challenges experienced by the farmers across all five suburbs included feed scarcity (36% of respondents), high costs of feed (34%) and transport (4%). Religion, source of income, age and type of breed kept were the key determinants farmers' probability to experience feed scarcity ($P \leq 0.05$; Table 2). Specifically, the likelihood of farmers to experience feed scarcity decreased ($P \leq 0.05$) by 5.7 to 5.9% with 1% increase in Christians, sources of income, age, and exotic breeds.

4.5 Pig watering management practices

Two-thirds of the farmers indicated that drinking water was either adequate or abundant while one-fifth reported that it was inadequate. Farmers stored drinking water for the pigs in tanks (77%), water troughs (25%) and municipal refuse bins (5%). About 55% of the farmers used buckets, 35% plastic or steel drums, 12% tyres, 8% commercial troughs and/ or 5% broken sinks/ bathtubs as water troughs. Most respondents (68%) cleaned water

Table 2 Marginal effects on key production challenges experienced by small-scale pig farmers in the Cape Metropole District, South Africa

Variable	Marginal effect estimates	Standard Error	t Value	*P*>|t|	[95% Conf. Interval]	
Shortage of pig housing materials						
Gender	-1.0238	0.1917	-5.34	<0.0001	-1.3995	-0.6482
Age	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Religion	-1.0316	0.1941	-5.31	<0.0001	-1.4121	-0.6512
Education level	-1.0512	0.1936	-5.43	<0.0001	-1.4307	-0.6717
Farming experience	-1.0217	0.1944	-5.26	<0.0001	-1.4026	-0.6407
Workforce	-1.0141	0.1919	-5.28	<0.0001	-1.3902	-0.6379
Sources of income	-1.0238	0.1917	-5.34	<0.0001	-1.3995	-0.6482
Farm size	-0.9849	0.2105	-4.68	<0.0001	-1.3974	-0.5723
Type of livestock	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Herd size	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Type of breeds kept	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Production system	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Location	-1.0335	0.1914	-5.40	<0.0001	-1.4087	-0.6583
Extension services	-1.0316	0.1941	-5.31	<0.0001	-1.4121	-0.6512
Pig production training	-1.0512	0.1936	-5.43	<0.0001	-1.4307	-0.6717
Scarcity of feed						
Gender	-0.5568	0.1756	-3.17	0.0015	-0.9010	-0.2126
Age	-0.5653	0.1771	-3.19	0.0014	-0.9124	-0.2182
Religion	-0.5947	0.1798	-3.31	0.0009	-0.9471	-0.2423
Education level	-0.5423	0.1778	-3.05	0.0023	-0.8909	-0.1938
Farming experience	-0.5508	0.1794	-3.07	0.0021	-0.9024	-0.1993
Workforce	-0.5539	0.1775	-3.12	0.0018	-0.9017	-0.2061
Sources of income	-0.5766	0.1767	-3.26	0.0011	-0.9230	-0.2302
Farm size	-0.4583	0.1948	-2.35	0.0187	-0.8402	-0.0764
Type of livestock	-0.5568	0.1756	-3.17	0.0015	-0.9010	-0.2126
Herd size	-0.5568	0.1756	-3.17	0.0015	-0.9010	-0.2126
Type of breeds kept	-0.5653	0.1771	-3.19	0.0014	-0.9124	-0.2182
Production system	-0.5568	0.1756	-3.17	0.0015	-0.9010	-0.2126
Location	-0.5568	0.1756	-3.17	0.0015	-0.9010	-0.2126
Extension services	-0.4990	0.1775	-2.81	0.0049	-0.8469	-0.1511
Pig production training	-0.5539	0.1775	-3.12	0.0018	-0.9017	-0.2061
Limited access to communal taps						
Gender	-0.3114	0.1825	-1.71	0.0880	-0.6692	0.0463
Age	-0.3167	0.1841	-1.72	0.0854	-0.6775	0.0442
Religion	-0.3221	0.1857	-1.73	0.0829	-0.6861	0.0419
Education level	-0.3167	0.1841	-1.72	0.0854	-0.6775	0.0442
Farming experience	-0.3773	0.1874	-2.01	0.0441	-0.7446	-0.0100
Workforce	-0.3167	0.1841	-1.72	0.0854	-0.6775	0.0442
Sources of income	-0.2973	0.1831	-1.62	0.1044	-0.6561	0.0616
Farm size	-0.5108	0.2108	-2.42	0.0154	-0.924	-0.0976
Type of livestock	-0.3114	0.1825	-1.71	0.0880	-0.6692	0.0463
Herd size	-0.3114	0.1825	-1.71	0.0880	-0.6692	0.0463
Type of breeds kept	-0.3507	0.1846	-1.90	0.0575	-0.7125	0.0112
Production system	-0.3114	0.1825	-1.71	0.0880	-0.6692	0.0463

Table 2 (continued)

Variable	Marginal effect estimates	Standard Error	t Value	P>|t|	[95% Conf. Interval]	
Shortage of pig housing materials						
Location	-0.3114	0.1825	-1.71	0.0880	-0.6692	0.0463
Extension services	-0.2534	0.1848	-1.37	0.1703	-0.6157	0.1088
Pig production training	-0.3167	0.1841	-1.72	0.0854	-0.6775	0.0442
Mortality of piglets						
Gender	2.0015	0.2751	7.28	<0.0001	1.4623	2.5407
Age	1.9833	0.2754	7.20	<0.0001	1.4435	2.5231
Religion	2.0338	0.2842	7.16	<0.0001	1.4767	2.5908
Education level	1.9833	0.2754	7.20	<0.0001	1.4435	2.5231
Farming experience	1.9459	0.2760	7.05	<0.0001	1.4049	2.4869
Workforce	1.9833	0.2754	7.20	<0.0001	1.4435	2.5231
Sources of income	2.0015	0.2751	7.28	<0.0001	1.4623	2.5407
Farm size	2.0680	0.3200	6.46	<0.0001	1.4408	2.6952
Type of livestock	2.0104	0.2749	7.31	<0.0001	1.4716	2.5493
Herd size	2.0104	0.2749	7.31	<0.0001	1.4716	2.5493
Type of breeds kept	1.9924	0.2752	7.24	<0.0001	1.4530	2.5319
Production system	2.0104	0.2749	7.31	<0.0001	1.4716	2.5493
Location	2.0104	0.2749	7.31	<0.0001	1.4716	2.5493
Extension services	1.9741	0.2755	7.16	<0.0001	1.4340	2.5141
Pig production training	1.9833	0.2754	7.20	<0.0001	1.4435	2.5231

troughs daily. Difficulties in accessing communal taps (42% of respondents), insufficient water (17%), low water pressure (4%), dirty water (3%), lack of water storage facility (2%) and muddy tap water points (1%) were the water challenges experienced by the pig farmers across all five surveyed suburbs. Farmers likelihood to access communal taps was mainly determined by farm size, farming experience and type of breed kept ($P \leq 0.05$). A unit increase in indigenous breeds, farming experience and farm size was respectively associated with 3.5, 3.6 and 5.1% reduction in farmers' probability to experience difficulties accessing communal taps.

4.6 Pig breeding management practices

Across the surveyed suburbs, Landrace (57% of respondents) and Large White (56%) were the dominant pig breeds. The other breeds kept were Duroc (23%), non-descript crossbreds (21%) and Kolbroek (18%). Main reasons for keeping the dominant pig breeds included frame size (41% of respondents), high productivity (40%), availability (31%), performance (31%) and adaptability (25%). Most farmers (70%) practiced controlled mating as opposed to random mating (30%). The probability of farmers to practice controlled mating was more positively influenced ($P \leq 0.05$) by farm size education level, religion and type of breed kept (Table 3). In this regard, large farms, education, Christianity, and indigenous breed ownership increased ($P \leq 0.05$) the probability of farmers to practice controlled mating by 8.5 to 9.0% points. Pigs used for breeding were mainly sourced within the farmer's own herd (46% of respondents) and neighbouring farmers (33%). 60% of the farmers did not experience any breeding challenges. However, few farmers reported inbreeding (8%), difficulties

Table 3 Marginal effects on adoption of key sustainable pig management practices by small-scale urban pig farmers in the Cape Metropole District, South Africa

Variable	Marginal effect estimates	Standard Error	t Value	*P*>|t|	[95% Conf. Interval]	
Restricted feeding						
Gender	1.2716	0.2066	6.16	<0.0001	0.8667	1.6765
Age	1.2528	0.2070	6.05	<0.0001	0.8470	1.6585
Religion	1.2771	0.2100	6.08	<0.0001	0.8655	1.6887
Education level	1.2528	0.2070	6.05	<0.0001	0.8470	1.6585
Farming experience	1.2379	0.2109	5.87	<0.0001	0.8245	1.6512
Workforce	1.2007	0.2049	5.86	<0.0001	0.7992	1.6023
Sources of income	1.2295	0.2042	6.02	<0.0001	0.8293	1.6296
Farm size	1.1727	0.2244	5.23	<0.0001	0.7329	1.6126
Type of livestock	1.2388	0.2040	6.07	<0.0001	0.8391	1.6386
Herd size	1.2388	0.2040	6.07	<0.0001	0.8391	1.6386
Type of breeds kept	1.2295	0.2042	6.02	<0.0001	0.8293	1.6296
Production system	1.2388	0.2040	6.07	<0.0001	0.8391	1.6386
Location	1.2388	0.2040	6.07	<0.0001	0.8391	1.6386
Extension services	1.2335	0.2075	5.95	<0.0001	0.8269	1.6402
Pig production training	1.2528	0.2070	6.05	<0.0001	0.8470	1.6585
Controlled mating						
Gender	0.8253	0.1768	4.67	<0.0001	0.4788	1.1719
Age	0.8377	0.1784	4.69	<0.0001	0.4880	1.1874
Religion	0.8505	0.1801	4.72	<0.0001	0.4975	1.2035
Education level	0.8602	0.1798	4.78	<0.0001	0.5077	1.2127
Farming experience	0.7461	0.1790	4.17	<0.0001	0.3952	1.0969
Workforce	0.8281	0.1787	4.63	<0.0001	0.4778	1.1783
Sources of income	0.8348	0.1766	4.73	<0.0001	0.4887	1.1808
Farm size	0.8990	0.2005	4.48	<0.0001	0.5060	1.2920
Type of livestock	0.8348	0.1766	4.73	<0.0001	0.4887	1.1808
Herd size	0.8348	0.1766	4.73	<0.0001	0.4887	1.1808
Type of breeds kept	0.8568	0.1779	4.82	<0.0001	0.5081	1.2055
Production system	0.8348	0.1766	4.73	<0.0001	0.4887	1.1808
Location	0.8348	0.1766	4.73	<0.0001	0.4887	1.1808
Extension services	0.8183	0.1790	4.57	<0.0001	0.4676	1.1691
Pig production training	0.8061	0.1773	4.55	<0.0001	0.4585	1.1537
Biosecurity						
Gender	1.0647	0.1834	5.81	<0.0001	0.7053	1.4241
Age	1.0814	0.1853	5.84	<0.0001	0.7182	1.4446
Religion	1.0549	0.1859	5.67	<0.0001	0.6905	1.4194
Education level	1.0385	0.1840	5.64	<0.0001	0.6779	1.3991
Farming experience	1.0278	0.1866	5.51	<0.0001	0.6621	1.3935
Workforce	1.0726	0.1855	5.78	<0.0001	0.7090	1.4362
Sources of income	1.0986	0.1849	5.94	<0.0001	0.7362	1.4610
Farm size	0.8664	0.1959	4.42	<0.0001	0.4824	1.2504
Type of livestock	1.0733	0.1832	5.86	<0.0001	0.7143	1.4323
Herd size	1.0733	0.1832	5.86	<0.0001	0.7143	1.4323
Type of breeds kept	1.0561	0.1836	5.75	<0.0001	0.6963	1.4158

Table 3 (continued)

Variable	Marginal effect estimates	Standard Error	t Value	$P>\|t\|$	[95% Conf. Interval]	
Restricted feeding						
Production system	1.0733	0.1832	5.86	<0.0001	0.7143	1.4323
Location	1.0733	0.1832	5.86	<0.0001	0.7143	1.4323
Extension services	1.0638	0.1857	5.73	<0.0001	0.6998	1.4278
Pig production training	1.0473	0.1838	5.70	<0.0001	0.6871	1.4075

in finding breeding boars (7%), boars not able to mate (6%), low sow pregnancy rates (6%) and inconsistency of litter size (5%) as the breeding challenges they experienced.

4.7 Pig reproductive performance and management practices

68% of the farmers reported that the sows farrowed twice a year. No significant differences ($P>0.05$) were observed on litter size (10.4±0.39; mean±standard deviation), stillborn (1.6±0.39), piglets weaned per sow (7.3±0.37), sow farrowing interval (5.1±0.16 months), age at first farrowing (10.0±1.52 months) and sow longevity (2.1±0.23 years) in the herds kept by the farmers across the five suburbs. Almost all the farmers (99%) did not use any reproductive technology to enhance reproduction rates while 1% reported the usage of artificial insemination. Regardless of suburb, pig reproduction challenges experienced by farmers included deaths of newborn piglets (20% of respondents), infertility (5%), low reproduction rates (8%) and dystocia (3%).

4.8 Pig health and biosecurity management practices

Pig mortalities per annum (6.0±1.00) were similar ($P>0.05$) regardless of suburb. All the pig health and biosecurity parameters were not associated ($P>0.05$) with suburb. Piglets (88% of respondents) were the most common pig class that died followed by growers (17%) and weaners (14%). The chances of farmers to experience piglet mortality were largely increased ($P\leq0.05$) by farm size, religion, source of income, type of livestock kept herd size, location, and gender (Table 3). A unit increase in small farms, African traditional religion believers, reliance on single source of income, mono-species faming, small herd size, off-plot farms and female farmers was likely to increase ($P\leq0.05$) the probability of farmers to experience mortality of piglets by 20.0% (Table 2).

Major sources of mortalities included extreme weather conditions (26% of the respondents), diseases (23%), poor nutrition (14%) and parasites (7%) and ill-defined and unknown causes (60%). Common diseases that occurred in the farms include internal (23%) and external parasites (19%) infections, African swine fever (15%), unknown diseases (14%) diarrhoea (12%), pneumonia (9%) and hypernatremia (3%). Most diseases were more prevalent all-year-round (45%), but some occurred during the dry (30%) and wet (24%) seasons. Majority of the farmers (63%) vaccinated against the diseases, and one-fifth did not. About 95% of the farmers used conventional medicine while only 2% resorted to traditional medicine to control diseases. Of those that used traditional medicine to control diseases, 50% used aloe species, 17% fermented lemons, 18% salt and 16% a mixture of sulphur and water. Farmers who used traditional medicine to control diseases did so because it was affordable (75% of respondents) and had health benefits (25%).

Half of the interviewed farmers always followed biosecurity measures while the other half did not. Multiple biosecurity measures followed by the farmers included cleaning (65% of respondents), disinfecting (35%), limiting access to the farm (29%), disposing wastes (22%), burying carcasses (22%), using footbaths (11%) and strict monitoring of the farm (11%). All the analysed factors significantly influenced ($P \leq 0.05$) the probability of farmers to practice biosecurity measures. A unit increase in females, youths, African traditional believers, less educated participants, less experienced farmers, paid labour, reliance on a single source of income, small herds, mono-species farming, small farms, use of exotic breeds, semi-intensive farming, off-plot farms, lack of extension services and farmer training in pig production increased ($P \leq 0.05$) the likelihood of the farmers to disregard biosecurity measures by 8.7 to 11.0% (Table 3).

Farmers mentioned tapeworms (25%) and roundworms (21%) as common internal parasites in the surveyed areas. One-third of the farmers did not report any internal parasites while 30% were not sure of the occurrence of the parasites. Internal parasites were more prevalent all-year-round (60%) while others were prevalent in dry (21%) and wet (19%) seasons. Most of the farmers (83%) dewormed to control the internal parasites while 12% did not. Over 90% of the farmers used conventional medicine and 7% used traditional medicine to control the internal parasites. Majority of the farmers (42%) dewormed when it was necessary while others did it monthly (20%) or biannually (25%). Common traditional medicines used to control internal parasites included aloe species (18% of respondents), laundry bar soap (18%), a mixture of sulphur and water (18%), sea water (9%), potassium permanganate (9%), *Izifo zonke* (multipurpose concoction, 9%), salt (9%) and oil (9%). The farmers that used traditional medicine to control internal parasites did it because they were affordable (71%) and referrals from other farmers (29%).

Common external parasites reported in the studied suburbs were flies (25% of respondents), fleas (24%), ticks (20%), lice (16%) and mange (14%). One-fifth of the farmers did not observe any external parasites while 30% were not sure of the occurrence of the parasites on their farms. Farmers said that external parasites were prevalent all-year-round (47%), in the dry (44%) and wet (10%) seasons. Majority of the farmers (76%) either sprayed, dipped, or injected pigs to control the external parasites. 84% of the farmers used conventional medicine while 10% used traditional medicine to control the external parasites. Farmers controlled external parasites, when necessary (32% of respondents), biannually (22%), monthly (20%) or weekly (20%). Common traditional medicines used to control external parasites included oil (36% of respondents), jeyes fluid (an outdoor cleaning agent, 32%), diesel (18%), a mixture of sulphur and water (5%) and *madubula* household disinfectant (5%). Farmers made used of traditional medicine to control external parasites because of efficiency (65%), affordability (25%) and referrals (10%). Most of the farmers (53%) did not see predators on their farms. A few farmers reported thieves (18%), dogs (15%), rodents (rats and mice, 10%) and snakes (3%) as predators.

5 Discussion

The current study is the first to document insights for decision makers, livestock extensionists and development agents concerning factors influencing small-scale urban pig farmers' challenges and adoption of SAPs in SSA, particulary South Africa. In this context, discussion of current results will be mostly related to factors influencing small-scale livestock farmers' challenges and adoption of SAPs in SSA at large. In agreement with current findings, Molotsi et al. (2021) reported accurate record keeping as one of the main challenges confronting small-scale urban pig farmers in South Africa. Accurate, complete, reliable, and accessible records enables farmers to evaluate the performance of the piggery and make informed decisions. Lack of influence of the investigated factors on record keeping in the current study contradicts earlier findings by Tham-Agyekum et al. (2010) who reported that record keeping in poultry was influenced by farmer's age, gender, education level, farming experience and farm size. The influence of small-scale urban pig farmers' socioeconomic, biophysical, and institutional factors on record keeping is not well researched and warrant further investigation.

Shortage of housing materials identified by small-scale urban pig farmers as the major production challenge was previously attributed to high cost of pig building materials as reported by Kagira and Kanyari (2010) and Molotsi et al. (2021). The likelihood of farmers to experience shortage of building material was influenced by all the investigated factors with education and pig training as predominant factors. This is because farmers' socioeconomic, biophysical, and institutional factors largely influence affordability, availability, and durability of building materials with education and training specifically shaping farmer's specifications, preferences, and perceptions of building materials (Jacobson et al., 2014; Mathobela et al., 2024; Priya & Singh, 2024).

In agreement with current findings, the combination of feed scarcity and high feed costs has been reported as major factors challenging small-scale urban pig farming (Kagira & Kanyari, 2010; Molotsi et al., 2021). Feed scarcity was influenced by all the investigated socioeconomic factors, but religion and source of income were predominant. Expectedly, the likelihood of experiencing feed scarcity decreased with increase in Christians and secondary income sources. This may be attributed to Christians modern practices that promote humane animal welfare including minimizing deprivation, suffering and stress in pigs (Adam et al., 2019). Secondary income sources such as salary, personal savings, loans from relatives, cooperative societies, contribution schemes and credit facilities (Nwachukwu & Udegbunam, 2020) often provide farmers with liquid capital to acquire inputs including feed that enhance productivity (Mwangi & Kariuki, 2015).

Most pig farmers in the surveyed suburbs adopted restricted feeding practice owing to its benefits including reducing feed wastage, intake and costs while increasing feed digestion, nutrient utilization efficiency and animal performance (Pomar & Remus, 2019). As predicted, all the investigated socioeconomic, biophysical, and institutional factors influenced the chances of farmers to practice restricted feeding with farmer's gender, religion, age, and education as the dominant predictors. The observed gender differences in the adoption of restricted feeding could be attributed to the differences in biological attributes, social capital and labour endowment between men and women (Li et al., 2024). Current findings suggest that men had better access and control over production resources, technologies, and information [United States Agency for International Development (USAID), 2021], which could have positively influenced their adoption of optimal pig feeding practices than women [Food and Agriculture Organization of the United Nations (FAO), 2011]. However, recent studies from the global south are increasingly showing women dominating the adoption of SAPs and technologies in small-scale pig production (Carter et al., 2017; Dione et al., 2020; Mathobela et al., 2024). With regards to religion, Christianity tends to support humane treatment of animals including provision of adequate and balanced nutrition, which is equated to righteousness (Adam et al., 2019) relative to African traditional religion whose reality of applying the current universal definition of animal welfare is being contested (Qekwana et al., 2019).

In current study, older farmers could be assumed to have acquired knowledge, skills, resources, and experience over time to be better able to evaluate sustainable pig feeding practices than younger farmers (Mwangi & Kariuki, 2015; Okello et al., 2021). On the contrary, old age was found to be negatively associated with adoption of SAPs owing to high-risk sensitivity, short panning horizon and deteriorating physical function (Dhraief et al., 2019; Priya & Singh, 2024). Regarding education, more educated farmers know the benefits of feed restriction and have better capacity to adopt SAPs and technologies (Carter et al., 2017; Okello et al., 2021; Pomar et al., 2021). Education forms the foundation of SAP adoption through shaping respondents' attitudes and views, making them more sincere, sensible, and capable to evaluate the advantages of the SAPs (Mwangi & Kariuki, 2015; Priya & Singh, 2024). Nevertheless, high education levels have been reported to adversely impact adoption of SAPs as it increases the chances of farmers to engage in off-farm activities (Li et al., 2024).

Though communal taps were the main source of drinking water for pigs in the present study, farmers experienced difficulties in accessing them. Lack of access to communal taps often results in inappropriate watering practices including inadequate water supply or provision of contaminated water (Mathobela et al., 2024), which adversely influence animal welfare, health, and growth (Beyihayo et al., 2015). As predicted, farmers with more farming experience and larger farm sizes were less likely to experience problems in accessing communal taps. A positive influence of farming experience on access to communal taps is not surprising since experience increases farmers' understanding of the prevailing farming challenges and prompts search for alternative solutions (Anang & Asante, 2020). In addition, farming experience determines production output, which relates to means of production, management, and profitability of an agricultural enterprise (Liu et al., 2018; Begho et al., 2022). The decline in the likelihood of large farms to experience problems in accessing public water sources may be related to their higher yield, resource efficiency, nurturing economies of scale and greater income than that of small farms (Liu et al., 2018), which may positively impact farmers investment in sustainable water resources management. On the contrary, some previous studies have associated small farms with less water challenges and related it to their efficient energy uses, smaller herd sizes and lower water needs (Ren et al., 2019; Başer & Bozoğlu, 2023).

Most pig farmers in the surveyed areas were predominantly engaged with the controlled mating system but the supply of breeding sows from their own farms and borrowing of boars from neighbours put the animals at a higher risk of inbreeding, and transmission of pathogens and parasites (Kambashi et al., 2014; Leslie et al., 2015). Despite that all factors analysed in the current study significantly influenced controlled mating of pigs, farm size and education level had the greatest influence. This is possible because farmers with small farms are less likely to adopt controlled mating as they cannot afford to commit part of pig housing space for this practice unlike those with larger farm size (Mwangi & Kariuki, 2015; Priya & Singh, 2024). In addition, farmers operating larger farms enjoy economies of scale and have more resources to invest in SAPs (Liu et al., 2018; Mathobela et al., 2024) including controlled mating. However, a few studies have reported that small farms may have better chances of adopting SAPs owing to their low energy, labour, and adoption costs (Başer & Bozoğlu, 2023; Priya & Singh, 2024). Pertaining to education, farmers that are more educated tend to have better technical, financial, and networking capacity necessary for the adoption of SAPs than their counterparts (Abegunde et al., 2020; Priya & Singh, 2024). However, as discussed earlier, high education levels may negatively influence adoption of SAPs by increasing farmers involvement in off-farm activities (Li et al., 2024). Regarding the other factors, farmers who adopt SAPs tend to be older men with more income, experience, and diverse operations, better access to labour, training and extension and have larger herds located close to the homestead and/ or market (Liu et al., 2018; Begho et al., 2022; Priya & Singh, 2024).

The challenge of mortality, especially of piglets largely caused by accidents, extreme weather conditions and diseases corresponds with previous reports (Jacobson et al., 2014; Weka et al., 2021). Disease-mediated piglet mortality could be related to half of the farmers non-compliance with biosecurity measures as reported earlier by Leslie et al. (2015). The influence of the tested socioeconomic, biophysical, and institutional factors on piglet mortality and compliance with biosecurity measures was comparable to past studies (Mwangi & Kariuki, 2015; Kouam & Moussala, 2018; Wang & Hu, 2023). With respect to gender of the farmer, women's high likelihood of experiencing piglet mortality and disregarding biosecurity measures could be mostly because of their limited access to veterinary medicine, animal production and health training and/ or information, veterinary and extension services (Wang & Hu, 2023). These limitations arise due to women's socio-cultural barriers, societal expectations, family responsibilities, and restricted control over financial resources (Dione et al., 2020; Mutua & Dione, 2021). Regarding age, young farmers were more likely to experience piglet deaths and disregard biosecurity measures as they usually have less knowledge, experience, resources, and authority restricting them from effectively providing animal healthcare and implementing biosecurity measures compared to adult farmers (Kouam & Moussala, 2018). This contradicts earlier findings by Awosanya (2015), who reported young farmers to be three times more likely to practice biosecurity measures than adults, which was ascribed to a decrease in risk aversion as well as increase in energy and interest in long-term investment and implementation of biosecurity protocols.

Religion's effect on piglet mortality and compliance with biosecurity measures re-emphasizes Christian farmers' commitment to humane animal welfare including good health (Adam et al., 2019) compared to African traditional believers. It was not surprising that farmers with less education, training, farming experience and access to extension services were more likely to experience pig mortally and disregard biosecurity measures as they often have little knowledge, information, and expertise on animal disease prevention and control than their counterparts (Mutua & Dione, 2021; Wang & Hu, 2023). Access to education, training and extension services are strong adoption predictors that advances knowledge and skills and increase financial capacity and access to information (Danso-Abbeam et al., 2018; Nwachukwu & Udegbunam, 2020; Begho et al., 2022). However, these services come at a cost that may reduce farmer's capacity to cope with challenges and adopt SAPs.

Farmers relying on a single source of income, paid labour, keeping one type of livestock, owning small farms and herd sizes were more likely to experience piglet mortality and disregard biosecurity measures largely due to reduced spending and investment on animal healthcare. These socioeconomic and biophysical factors limit farmers' income streams, livelihood diversifications and application of sustainability principles (Mwangi & Kariuki, 2015; Mosnier et al., 2022). As proxies for income, they limit purchase of medicine and medical equipment for sick animals, building biosecurity facilities and farmers' capacity to take risks, access credit and widen information sources (Begho et al., 2022). In addition to decreasing income, production of one livestock species increase parasite pressure and reduce utilisation efficiency of feeding resources (Martin et al., 2020; Mosnier et al., 2022). Nonetheless, if appropriate practices are followed, mono-species livestock farming may have positive impacts on animal mortality and biosecurity through reduction of pathogen and parasitic cross-infections (Martin et al., 2020). In terms of pig herd size, small herds have higher piglet pre-weaning mortality, which can be attributed to poor biosecurity facilities, less human resources, and a lower level of genetic improvement than large herds (Koketsu et al., 2021).

As projected, farmers keeping exotic pigs had high chances of experiencing piglet mortality and disregarding biosecurity measures that may be partly related to lack of their adaptability to the local environments and high demand for feed, healthcare, and shelter, which is often unaffordable to small-scale farmers (Jacobson et al., 2014; Weka et al., 2021). Although exotic breeds tend to outperform indigenous breeds under favourable intensive production system and yield higher profits, indigenous breeds are more tolerant to feed and water scarcity, heat stress, diseases, and parasites (Halimani et al., 2020). Farmers raising pigs semi-intensively had increased chances of experiencing piglet deaths and disregarding biosecurity measures because the system exposes pigs to extreme weather conditions and allows them to roam freely increasing the likelihood of disease transmission, fighting and road accidents (Kouam & Moussala, 2018; Leslie et al., 2015). On the contrary, intensive farming system provides better housing and security for pigs and allow proper feed and water management, easy monitoring, and less destruction of the environment, which may reduce mortality and enhance adoption of SAPs (Nwachukwu & Udegbunam, 2020). Off-plot farmers' probability of experiencing piglet mortality and non-compliance with biosecurity measures was largely related to difficulties in consistently monitoring animal health, housing conditions, feeding, and farrowing to avoid animal diseases, hypothermia, maternal overlay cannibalism and starvation, which are the main causes of piglet mortality in intensive pig production (Weka et al., 2021).

6 Conclusions

Key challenges experienced by small-scale pig farmers include shortage of pig housing materials, scarcity of feed, limited access to communal water taps and piglet mortality. The likelihood of farmers to encounter key challenges was high amongst African traditional religion believers, exotic pig breed owners, single source income earners and young farmers. Record keeping, restricted feeding, controlled mating and biosecurity were the dominant SAPs. The probability of non-adoption of the dominant SAPs was mostly greater among the less educated, young farmers and African traditional religion believers than their counter parts. The identified socioeconomic, biophysical, and institutional factors provide insights into coping strategies and qualities of potential adopters of SAPs, which are important for the formulation of development policies aimed at enhancing small-scale urban pig production in the surveyed areas.

7 Limitations and future research

Application of the findings outside of the research area could be restricted by the potential for bias and unrepresentativeness in the opportunistic sampling technique used in the current study. It is recommended that future research should either use homogenous opportunistic sampling or probability sampling techniques to reduce potential bias, enhance sample representativeness and ensure generalizability of the findings (Bornstein et al., 2013; Jager et al., 2017). Sometimes the interview took a long time, and interviewees got exhausted and lost interest, which might have negatively impacted responses. The study's exclusive focus on institutional, biophysical, and socioeconomic factors to explain the decision-making process left out original factors that are described by several psychological theories (Ajzen, 1991; Sok et al., 2021; Atta-Aidoo et al., 2022), and this merit investigation. Another limitation is that potential interactions among the challenges and SAPs were not considered. This is significant because, in practice, farmers are highly likely to adopt a set of SAPs to address a multitude of production challenges simultaneously and decision-makers are confronted with alternative SAPs that can be adopted concurrently or sequentially as supplements, complements, or substitutes (Toma et al., 2018).

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10668-024-05299-6.

Acknowledgements The authors would like to thank the pig farmers in the Cape Metropole District for their participation in the survey and Western Cape Department of Agriculture officials for assisting in identifying the farmers.

Author contributions Rebecca Mmamakgone Mathobela: Investigation, Data curation, Writing, Original draft. Obert Chenjerayi Chikwanha and Chenaimoyo Lufutuko Faith Katiyatiya: Writing- Reviewing and Editing. Annelin Henriehetta Molotsi, Munyaradzi Chris Marufu and Phillip Evert Strydom: Supervision, Funding acquisition, and Writing- Reviewing and Editing. Cletos Mapiye: Supervision, Conceptualization, Project administration, Funding Acquisition, and Writing- Reviewing and Editing.

Funding The study was financed by Technology Innovation Agency administered through Red Meat Research and Development of South Africa. South African Pig Producers Organisation and Stellenbosch University Division of Social Impact provided additional research funds.
Open access funding provided by Stellenbosch University.

Data availability For this research, data and materials are accessible through corresponding author.

Code Availability Not applicable.

Declarations

Ethical approval The ethical approval of the current study was obtained from the Social, Behavioural and Education Research Ethics Committee (REC: SBE-17285) of the Stellenbosch University in compliance with the South African National Health Act No.61 2003.

Consent to participate Informed consent was sought from each respondent prior to commencing the interview.

Consent for publication All the authors give permission to publish this article.

Competing interest The authors declare no conflict of interest.

References

Abegunde, V. O., Sibanda, M., & Obi, A. (2020). Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo district municipality, South Africa. *Sustainability* 12(1), 195.

Adam, M. B., Clough, D., & Grumett, D. (2019). A christian case for farmed animal welfare. *Animals*, *9*, 1116.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211.

Anang, B. T., & Asante, B. O. (2020). Farm household access to agricultural services in northern Ghana. *Heliyon*, *6*, e05517.

Antwi, M., & Seahlodi, P. (2011). Marketing constraints facing emerging small-scale pig farmers in Gauteng Province, South Africa. *Journal of Human Ecology*, *36*(1), 37–42.

Asadu, A. N., Chah, J. M., Attamah, C. O., & Igbokwe, E. M. (2021). Knowledge of hazards associated with urban livestock farming in southeast Nigeria. *Frontiers in Veterinary Science*, *8*, 600299.

Atta-Aidoo, J., Antwi-Agyei, P., Dougill, A. J., Ogbanje, C. E., Akoto-Danso, E. K., & Eze, S. (2022). Adoption of climate-smart agricultural practices by smallholder farmers in rural Ghana: An application of the theory of planned behavior. *PLOS Climate*, 1(10), e0000082.

Awosanya, E. (2015). Demographic and management factors associated with biosecurity measure compliance on pig farms in South West Nigeria. *Sokoto Journal of Veterinary Sciences*, *13*(2), 34–41.

Başer, U., & Bozoğlu, M. (2023). The impact of farm size on sustainability of beef cattle farms: A case study of the Samsun province, Turkey. *International Journal of Agricultural Sustainability*, *21*(1), 2253647.

Begho, T., Glenk, K., Anik, A. R., & Eory, V. (2022). A systematic review of factors that influence farmers' adoption of sustainable crop farming practices: Lessons for sustainable nitrogen management in South Asia. *Journal of Sustainable Agriculture and Environment*, *1*(2), 149–160.

Beyihayo, G., Mwesigwa, R., & Pezo, D. (2015). *Pig feeding strategies: Uganda smallholder pig value chain capacity development training manual*. ILRI Manual 16. Nairobi, Kenya: International Livestock Research Institute.

BFAP (Bureau for Food and Agricultural Policy) (2014). *Evaluating the competitiveness of South African pork production within the global context* A first annual progress report on the agri benchmark project, conducted by the Bureau for Food and Agricultural Policy (BFAP) in collaboration with the Thünen Instit.

Bornstein, M. H., Jager, J., & Putnick, D. L. (2013). Sampling in developmental science: Situations, shortcomings, solutions, and standards. *Developmental Review*, *33*(4), 357–370.

Carter, N. A., Humphries, S., Grace, D., Ouma, E. A., & Dewey, C. E. (2017). Men and women farmers' perceptions of adopting improved diets for pigs in Uganda: Decision-making, income allocation, and intrahousehold strategies that mitigate relative disadvantage. *Agriculture & Food Security*, *6*(18), 1–24.

DALRRD (Department of Agriculture, Land Reform and Rural Development) (2021). *A profile of the South African pork market value chain 2021*. www.dalrrd.gov.za

Danso-Abbeam, G., Ehiakpor, D. S., & Aidoo, R. (2018). Agricultural extension and its effects on farm productivity and income: Insight from Northern Ghana. *Agriculture and Food Security*, *7*(74).

Dhraief, M. Z., Bedhiaf, S., Dhehibi, B., Oueslati-Zlaoui, M., Jebali, O., & Ben-Youssef, S. (2019). Factors affecting innovative technologies adoption by livestock holders in arid area of Tunisia. *New Medit A Mediterranean Journal of Economics Agriculture and Environment*, *18*(4), 3–18.
Dione, M., Ouma, O. R., Lule, E., Kakinda, P., Nyapendi, M. J., Birungi, R., Pyburn, R., R., & Kampala, U. (2020). Gendered perceptions of biosecurity and the gender division of labor in pig farming in Uganda Independent consultant. *Journal of Gender Agriculture and Food Security*, *5*(2), 13–26.
Doran, E. M. B., Zia, A., Hurley, S. E., Tsai, Y., Koliba, C., Adair, C., Schattman, R. E., Rizzo, D. M., & Méndez, V. E. (2020). Social-psychological determinants of farmer intention to adopt nutrient best management practices: Implications for resilient adaptation to climate change. *Journal of Environmental Management*, *15*(276), 111304.
El Fartassi, I., Milne, A. E., Alami, E., Rafiqi, R., Hassall, M., Waine, K. L., Zawadzka, T. W., Diarra, J., A., & Corstanje, R. (2023). Evidence of collaborative opportunities to ensure long-term sustainability in African farming. *Journal of Cleaner Production*, *392*, 136170.
FAO (Food and Agriculture Organization of the United Nations) (2011). *The state of Food and Agriculture 2010-11. Women in agriculture: Closing the gender gap for development*. *ISSN* 0081–4539.
FAOSTAT (Food and Agriculture Organization Statistics) (2021). *World Food and Agriculture – Statistical Yearbook 2021*. FAO. ISBN 978-92-5-134332-6.
Foguesatto, C. R., Borges, J. A. R., & Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. *Science of the Total Environment*, *729*, 138831.
Garzón Delvaux, P., Riesgo Alvarez, L., Gomez, Y., & Paloma, S. (2020). Sustainable agricultural practices and their adoption in sub-Saharan Africa, EUR 30283 EN, Publications Office of the European Union, Luxembourg, JRC Technical Report. https://doi.org/10.2760/360761, JRC121035.
Greene, W. H. (2020). Econometric Analysis: Global Edition (8th ed) Pearson Education, In Stoltzfus JC. 2011. Logistic regression: a brief primer. *Academic Emergency Medicine*, 18(10), 1099–1104.
Halimani, T., Edward, Mapiye, O., Marandure, T., Januarie, D., Imbayarwo-Chikosi, V. E., & Dzama, K. (2020). Domestic free-range pig genetic resources in southern Africa: Progress and prospects. *Diversity*, *12*, 68.
Jacobson, M., Lindberg, J. E., & Lundeheim, N. (2014). *Urban and Peri-urban Agriculture for Food Security in Low-income Countries-Challenges and Knowledge Gaps*. SLU-Global Report 2014:4.
Jager, J., Putnick, D. L., & Bornstein, M. H. (2017). More than just convenient: The scientific merits of homogeneous convenience samples. *Monographs of the Society for Research in Child Development*, *82*(2), 13–30.
Kagira, J. M., & Kanyari, P. W. N. (2010). Questionnaire survey on urban and peri-urban livestock farming practices and disease control in Kisumu municipality, Kenya. *Journal of the South African Veterinary Association*, *81*(2), 82–86.
Kambashi, B., Picron, P., Boudry, C., Théwis, A., Kiatoko, H., & Bindelle, J. (2014). Smallholder pig production systems along a periurban-rural gradient in the western provinces of the Democratic Republic of the Congo. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, *115*(1), 9–22.
Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., & Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land use Policy*, *42*, 400–411.
Kelter, R. (2021). Bayesian and frequentist testing for differences between two groups with parametric and nonparametric two-sample tests. *Wiley Interdisciplinary Reviews: Computational Statistics*, *13*(6), 1523.
Koketsu, Y., & Iida, R. (2020). Farm data analysis for lifetime performance components of sows and their predictors in breeding herds. *Porcine Health Management*, *6*(24), 1–12.
Koketsu, Y., Iida, R., & Piñeiro, C. (2021). A 10-year trend in piglet pre-weaning mortality in breeding herds associated with sow herd size and number of piglets born alive. *Porcine Health Management* 7(4).
Kouam, M. K., & Moussala, J. O. (2018). Assessment of factors influencing the Implementation of Biosecurity Measures on Pig Farms in the Western Highlands of Cameroon (Central Africa). *Veterinary Medicine International*, *2018*, 9173646.
Leslie, E. E. C., Geong, M., Abdurrahman, M., Ward, M. P., & Toribio, J. A. L. M. L (2015). A description of smallholder pig production systems in eastern Indonesia. *Preventive Veterinary Medicine*, *118*(4), 319–327.
Li, J., Ma, W., & Zhu, H. A. (2024). Systematic literature review of factors influencing the adoption of climate-smart agricultural practices. *Mitigation and Adaptation Strategies for Global Change*, *29*(2), 1–38.
Lindahl, J. F., Magnusson, U., & Grace, D. (2019). Urban livestock-keeping: Contributions to food and nutrition security. In: Reference module in food science. *Elsevier*, *3*, 317–321.

Liu, T., Bruins, R. J. F., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. In *Sustainability* 10 (2), 432–463.

Maes, D. G. D., Piñeiro, D. J., Edwards, C., S., & Kyriazakis, I. (2020). A critical reflection on intensive pork production with an emphasis on animal health and welfare. *Journal of Animal Science*, *98*, 15–26.

Malila, B. P., Kaaya, O. E., Lusambo, L. P., Schaffner, U., & Kilawe, C. J. (2023). Factors influencing smallholder Farmer's willingness to adopt sustainable land management practices to control invasive plants in northern Tanzania. *Environmental and Sustainability Indicators*, *19*, 100284.

Martin, G., Barth, K., Benoit, M., Brock, C., Destruel, M., Dumont, B., Grillot, M., Hübner, S., Magne, M. A., Moerman, M., Mosnier, C., Parsons, D., Ronchi, B., Schanz, L., Steinmetz, L., Werne, S., Winckler, C., & Primi, R. (2020). Potential of multi-species livestock farming to improve the sustainability of livestock farms: A review. *Agricultural Systems*, *181*, 102821.

Mathobela, R. M., Molotsi, A. H., Marufu, M. C., Strydom, P. E., & Mapiye, C. (2024). Transitioning opportunities for sub-saharan Africa's small-scale urban pig farming towards a sustainable circular bioeconomy. *International Journal of Agricultural Sustainability*, *22*(1), 2315918.

Molotsi, A. H., Cupido, M., & Hoffman, L. C. H. (2021). Characterization of smallholder pig production systems in the Western Cape, South Africa. *Tropical Animal Health and Production*, *53*(2), 325.

Mosnier, C., Benoit, M., Minviel, J. J., & Veysset, P. (2022). Does mixing livestock farming enterprises improve farm and product sustainability? *International Journal of Agricultural Sustainability*, *20*(3), 312–326.

Mutua, F., & Dione, M. (2021). The Context of Application of Biosecurity for Control of African Swine Fever in Smallholder Pig systems: Current gaps and recommendations. *Frontiers in Veterinary Science*, *8*, 689811.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of New Agricultural Technology by Smallholder Farmers in developing countries. *Journal of Economics and Sustainable Development*, *6*(5), 208–216.

Nwachukwu, C. U., & Udegbunam, C. (2020). Rural pig production and pork consumption in Imo State, Nigeria. *Nigerian Journal of Animal Science*, *22*(1), 165–185.Okello, D. M., Odongo, W., Aliro, T., & Ndyomugyenyi, E. (2021). An assessment of pig feed diversity amongst smallholder pig farmers in Northern Uganda. *Cogent Food and Agriculture* 7(1), 1937867.

Oino, P., & Mugure, A. (2013). Farmer-oriented factors that influence adoption of agroforestry practices in Kenya. Experiences from Nambale District. Busia County. *International Journal of Scientific Research*, *2*(4), 442–449.

Okello, D. M., Odongo, W., Aliro, T., & Ndyomugyenyi, E. (2021). An assessment of pig feed diversity amongst smallholder pig farmers in Northern Uganda. *Cogent Food and Agriculture*, *7*(1), 1937867.

Pomar, C., & Remus, A. (2019). Precision pig feeding: A breakthrough toward sustainability. *Animal Frontiers*, *9*(2), 52–59.

Pomar, C., Andretta, I., & Remus, A. (2021). Feeding strategies to reduce nutrient losses and improve the sustainability of growing pigs. *Frontiers in Veterinary Science*, *8*, 742220.

Poulsen, M. N., McNab, P. R., Clayton, M. L., & Neff, R. A. (2015). A systematic review of urban agriculture and food security impacts in low-income countries. *Food Policy*, *55*, 131–146.

Priya, P., & Singh, S. P. (2024). Factors influencing the adoption of Sustainable Agricultural practices: A systematic literature review and lesson learned for India. *Forum for Social Economics*, *53*(1), 1–17.

Qekwana, D. N., Mccrindle, C. M. E., Cenci-Goga, B., & Grace, D. (2019). Animal welfare in Africa: strength of cultural traditions, challenges and perspectives. *Animal Welfare: From Science to Law*, 2019, 103–107.

Rajendran, N., Tey, Y. S., Brindal, M., Ahmad Sidique, S. F., Shamsudin, M. N., Radam, A., & Hadi, A., A. H. I (2016). Factors influencing the adoption of bundled sustainable agricultural practices: A systematic literature review. *International Food Research Journal*, *23*(5), 2271–2279.

Ren, C., Liu, S., van Grinsven, H., Resi, S., Jin, S., Liu, H., & Gu, B. (2019). The impact of farm size on agricultural sustainability. *Journal of Cleaner Production*, *220*, 357–367.

RSA (Republic of South Africa) (1984). *Government Gazette: Animal Diseases Act 35 of 1984*. Report No. 9152.

RSA (Republic of South Africa) (2004). *Government Gazette: National Health Act 61 of 2003*. Report No. 26595.

Sok, J., Borges, J. R., Schmidt, P., & Ajzen, I. (2021). Farmer Behaviour as reasoned action: A critical review of Research with the theory of Planned Behaviour. *Journal of Agricultural Economics*, *72*(2), 388–412.

Statista (2023b). Stock of pigs in South Africa from 2010 to 2020 (in million heads). https://www.statista.com/statistics/1306708/population-of-pigs-in-south-africa/

Statista (2023a). Number of pigs worldwide in 2022, by leading country (in million head). https://www.statista.com/statistics/263964/number-of-pigs-in-selected-countries/

Stoltzfus, J. C. (2011). Logistic regression: A brief primer. *Academic Emergency Medicine*, *18*(10), 1099–1104.
Ström, G., Djurfeldt, A. A., Boqvist, S., Albihn, A., Sokerya, S., San, S., Davun, H., & Magnusson, U. (2017). Urban and peri-urban family-based pigkeeping in Cambodia: Characteristics, management and perceived benefits and constraints. *Plos One* 12(8), e0182247.
Tham-Agyekum, K., Appiah, E., Nimoh, P., & Fred, P. (2010). Assessing farm record keeping Behaviour among small-scale poultry farmers in the Ga East Municipality. *Journal of Agricultural Science* 2(4). ISSN 1916–9752 E-ISSN 1916–9760.
Toma, L., Barnes, A. P., & Sutherland, L. A. (2018). Impact of information transfer on farmers' uptake of innovative crop technologies: A structural equation model applied to survey data. *The Journal of Technology Transfer*, *43*, 864–888.
United Nations (2018). Revision of World Urbanization Prospects. New York: United Nation Department of Economic and Social Affairs. 2018.
USAID (United States Agency for International Development) (2021). *Gender good practices in livestock programming*. https://pdf.usaid.gov/pdf_docs/PA00Z5PH.pdf
Wang, J., & Hu, X. (2023). Factors influencing disease prevention and control behaviours of hog farmers. *Animals*, *13*(5), 787.
Wanyama, I., & Leitner, S. (2019). *A review on health and environmental aspects of current manure management practices in pig production systems in Uganda*. International Livestock Research Institute. https://hdl.handle.net/10568/107206
Weka, R., Bwala, D., Adedeji, Y., Ifende, I., Davou, A., Ogo, N., & Luka, P. (2021). Tracing the Domestic Pigs in Africa. In *Tracing the Domestic Pig*. IntechOpen. https://doi.org/10.5772/intechopen.95077
Wilson, R. T. (2018). Domestic livestock in African cities: Production, problems and prospects. *Open Urban Studies and Demography Journal*, *4*(1), 1–14.
Yamane, T. (1967). *Statistics, an introductory analysis* (2nd ed.). Harper and Row.

Authors and Affiliations

Rebecca Mmamakgone Mathobela[1,2] · Obert Chenjerayi Chikwanha[1] · Chenaimoyo Lufutuko Faith Katiyatiya[1] · Annelin Henriehetta Molotsi[1] · Munyaradzi Chris Marufu[3] · Phillip Evert Strydom[1] · Cletos Mapiye[1]

✉ Cletos Mapiye
cmapiye@sun.ac.za

Rebecca Mmamakgone Mathobela
mmamakgone@gmail.com

Obert Chenjerayi Chikwanha
ochikwanha@sun.ac.za

Chenaimoyo Lufutuko Faith Katiyatiya
chenaik@sun.ac.za

Annelin Henriehetta Molotsi
annelind@sun.ac.za

Munyaradzi Chris Marufu
chris.marufu@up.ac.za

Phillip Evert Strydom
pestrydom@sun.ac.za

1 Department of Animal Sciences, Stellenbosch University, Cape Town, South Africa

2 Western Cape Department of Agriculture, Cape Town, South Africa

[3] Department of Veterinary Tropical Diseases, University of Pretoria, Pretoria, South Africa