

Article

Uptake and Level of Use of Climate-Smart Agricultural Practices by Small-Scale Urban Crop Farmers in eThekweni Municipality

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Abstract: Climate fluctuations significantly impact small-scale farmers' farm welfare (food, nutrition and income). This situation highlights an urgent need to invest in climate-smart agriculture (CSA) practices. Climate-smart agriculture has prospects for enhancing agricultural productivity and resilience. Therefore, this study addresses the knowledge gap concerning the uptake and level of use of CSA practices by small-scale urban crop (SSUC) farmers, which is critical to enhancing food and income security in urban settings. The relatively low adoption and uptake of CSA practices among small-scale farmers warrants an investigation of the factors influencing its adoption and level of use, especially in urban agriculture (UA) settings. Using a multi-stage sampling technique, this study collected data from 412 SSUC farmers through a semi-structured questionnaire. Descriptive analysis, the composite score index (CSI), and an ordered probit model (OPM) were utilised for the analysis. The results reveal that most (74%) are aware of CSA practices. Despite the high awareness of CSA practices by SSUC farmers, many (66%) are medium users of CSA practices, suggesting a moderate CSA practices level of use in eThekweni Municipality. The top five preferred CSA practices include crop diversification (with a CSI of 3.694), followed by crop rotation (3.619), mulching (3.608), drought tolerant crops (3.459) and organic manure (3.442). The popularity of these CSA practices in eThekweni Municipality suggests their immediate benefits when implemented or their lesser complexity in terms of implementation. Age, gender (being male), and household size exhibit a statistically significant negative influence on the CSA practices' level of use, increasing the likelihood of being in the lower user category. Yet, education, group membership and farming experience promote a higher level of use of CSA practices. The results show that while awareness is critical, socio-economic factors should not be ignored when upscaling the adoption of widespread CSA practices. Therefore, targeted and tailored socio-economic programmes that are age-directed, gender-sensitive, educational, emphasise collective action and leverage the experiences of urban farmers would be paramount in promoting effective CSA practices adoption and uptake by SSUC farmers in eThekweni Municipality, thus enhancing UA resilience against climate change reparations.

Keywords: adaptation; sustainable agriculture; urban farming; smallholder farming



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1. Introduction

The achievement of the Sustainable Development Goals (SDGs) is earmarked for 2030 and has turned a spotlight on urgent global priorities, for example, SDG 1—no poverty (seeks to combat poverty), SDG 2—zero hunger (ending hunger), and SDG 13—climate action (combating the effects of climate change) [1]. The SDGs emphasise the necessity of sustainable practices across all sectors, particularly agriculture, which is crucial in maintaining food security, alleviating poverty, and responding to climate variability [2]. Given the prediction that the global population will exceed 10 billion by 2058, the pressure on agricultural systems to perform sustainably and efficiently is more pronounced than

ever [3]. Therefore, the agricultural sector and food systems will primarily be vulnerable to the impacts of climate change, worsening the current challenges of food security and agricultural sustainability [4].

Agricultural systems worldwide face multiple threats that jeopardise their ability to sustain the global population. Dependence on climatic conditions makes crop and livestock production highly susceptible to climate variability, further complicating the quest for food security and sustainable agriculture [5]. Again, unsustainable agriculture contributes significantly to environmental degradation through mechanisms such as deforestation for agricultural expansion, methane emissions from livestock, and nutrient runoff from over-fertilisation. This situation is further intensified by the limited availability of arable land, which is increasingly encroached upon by urbanisation, necessitating more efficient land use and management of water resources [6].

In Africa, agriculture is the mainstay of the economy and a significant source of employment [7]. In 2022, the agricultural sector accounted for nearly 17% of sub-Saharan Africa's gross domestic product (GDP) and employed approximately 43% of the working population, underscoring its economic and social importance [8]. It is clear that agriculture underpins economic stability and is critical to ensuring food security, particularly given the majority's reliance on subsistence farming. Small-scale farmers responsible for growing essential crops, such as maize, rice, and cassava, are integral to agricultural productivity [9]. Recent studies have demonstrated that enhancements in agricultural productivity, including innovations in farming techniques and new technologies, have significantly increased crop yields [10]. These improvements in agriculture have made food more accessible and affordable, directly decreasing food insecurity [11]. Economically, the sector contributes substantially to household income, benefiting both rural and urban communities and elevating the overall standard of living. Investing in agriculture is critical; for example, irrigation systems and roads and improvements in market access have notably boosted farm profitability. These developments have enabled small-scale farmers to reinvest in their operations, enhancing productivity and economic returns [12]. Improving small-scale farmers' economic well-being directly contributes to their food and nutrition status. Additionally, diversifying agricultural products and integrating value-added processes have proven effective in increasing farm incomes and building resilience against market volatility and climatic changes [13].

However, despite the substantial agricultural benefits for Africa, the sector faces severe challenges, primarily due to climate change [14]. Erratic weather patterns and increased pest and disease outbreaks disrupt crop yields and farming cycles. This situation necessitates adopting adaptive and mitigative practices, like deploying drought-tolerant crop cultivars and implementing sustainable water management practices, which are critical for securing the sector's future [15]. South Africa's situation mirrors the continental context, with small-scale farmers facing significant climatic challenges like frequent droughts, unpredictable rainfall, and occasional floods [16]. These adversities pose severe risks to food and livelihood security, underscoring the importance of targeted interventions to support farmers.

As urbanisation accelerates globally, the landscapes of many regions are rapidly transforming, increasing pressure on agricultural systems within urban areas. For instance, small-scale urban crop (SSUC) farmers have become increasingly vital in meeting the dietary needs of burgeoning urban populations [17]. However, small-scale urban farmers contend with unique challenges, including constrained access to arable land, water, and essential inputs and exposure to environmental pollution and land degradation [18]. Urban-specific challenges further complicate the resilience of small-scale farmers to climate change and variability, stressing a need for integrated solutions that address both rural and urban agricultural dynamics [19].

In the wake of climate-related stresses, climate-smart agriculture (CSA) practices emerge as a strategic framework to address the changing climate's pressing challenges, particularly for small-scale urban crop farmers [20]. Climate-smart agriculture can be

defined as an adaptation (enhanced resilience) and mitigation (reducing greenhouse gases) approach to reorienting farming systems to bolster food and income security through increased productivity in the face of climate change [21]. The CSA approach promotes sustainable agricultural practices and offers a comprehensive framework that aims to mitigate the impacts of climate change while facilitating necessary adaptations [22]. Farming practices under the CSA umbrella, which include agroforestry, conservation agriculture, integrated pest management and precision farming, among many others, seek to boost agricultural productivity and enhance resilience and environmental sustainability [23]. Therefore, CSA practices have prospects for SSUC farmers to improve their livelihoods significantly. For instance, conservation agriculture can improve soil health and increase yield stability [24]. At the same time, precision farming presents precise and efficient utilisation of resources like fertiliser and water, reducing costs and environmental impacts [25]. Agroforestry enhances biodiversity and provides secondary income sources through the sale of timber or fruit, further securing the financial stability of farmers [26]. Despite CSA practices' adoption benefits, the level of CSA practices adoption by SSUC farmers is hindered by several barriers, including limited access to land, water, and necessary inputs, coupled with challenges such as environmental pollution and land degradation [27]. Furthermore, the initial costs of transitioning to innovative agricultural practices such as CSA can be prohibitive without substantial support from governmental and non-governmental organisations [28].

South Africa is battling the triple challenges of unemployment, poverty and food insecurity. While South Africa is regarded as food secure at the national level, food insecurity is a reality at the local level, with the situation worsening due to the impacts of climate change on the urban and rural poor small-scale farmers. Urban agriculture (UA) also faces unique challenges, such as limited access to land, water issues, resource access, inadequate infrastructure, access to credit and market constraints, and inadequate support frameworks such as agricultural extension services. Therefore, the uptake of CSA practices in South Africa, particularly by SSUC farmers, could significantly enhance productivity and resilience to climate change, which are critical for achieving food and income security.

With the growing interest in climate change reparations, sustainable food systems, and the influence of urbanisation, small-scale urban farmers are highly vulnerable, stressing the significance of integrating CSA practices. Climate-smart agriculture is, therefore, imperative to ensure food, nutrition and income security for the vulnerable farming populations, especially in urban contexts. However, despite the promises and constraints of integrating CSA practices, there is limited context-specific research concerning SSUC farmers that interrogates their uptake and level of use, which aligns with the intensifying effects of climate-related stresses on urban contexts. Sustainable farming practices will be critical for enhancing food security, reducing urban poverty, and mitigating environmental impacts as urbanisation continues. Given the significant gap in understanding the uptake and level of use of CSA practices among SSUC farmers, particularly in areas like eThekweni Municipality, where urban pressures are intense, this paper examines the dynamics of CSA practices uptake and level of use. Previous climate change reparations research on agriculture in South Africa has primarily focused on rural farmers, often overlooking UA [29]. Similarly, research in CSA practices is skewed towards rural areas over urban settings, particularly in developing countries [30]. This oversight hinders the development of targeted interventions and policies to build resilience and enhance UA's productivity [31].

While research on the uptake and level of use of CSA practices has been conducted in the South African rural setting, it is critical to acknowledge that an umbrella approach cannot achieve desirable outcomes between rural and urban settings or context-specific settings. Therefore, this research on the uptake and level of use of CSA practices in eThekweni Municipality is critical to determine the factors influencing the uptake and level of use of CSA practices to optimise its benefits for food and income security in the face of climate change. The information generated could be helpful in relation to enacting practical solutions to the challenges of UA, such as low crop yields (food production) and resource

inefficiencies, including addressing scientific challenges to sustainable UA that could benefit policy-making, enhance farmer support programmes and ultimately promote the widespread use of CSA practices, improving agricultural sustainability and productivity.

This paper sought to (1) determine CSA practices' level of use, (2) describe the CSA practices used and awareness of them, and (3) assess the determinants of CSA practices' level of use among SSUC farmers in eThekweni Municipality. A nuanced understanding of CSA practices and level of use is critical for all stakeholders, including policymakers, researchers and UA practitioners, to develop tailored CSA practices to support and promote sustainable UA, thus enhancing the resilience of urban food systems in the face of growing climate change challenges.

2. Materials and Methods

2.1. Selection and Description of the Study Area

The current research was administered in eThekweni Municipality (Figure 1), located within the KwaZulu-Natal (KZN) Province of South Africa. eThekweni Metropolitan Municipality is one of South Africa's largest metropolitan areas, with the largest being Johannesburg and the second Cape Town. eThekweni Metropolitan Municipality is geographically positioned between latitude 29.8120° S and longitude 30.8039° E, covering approximately 2556 km².

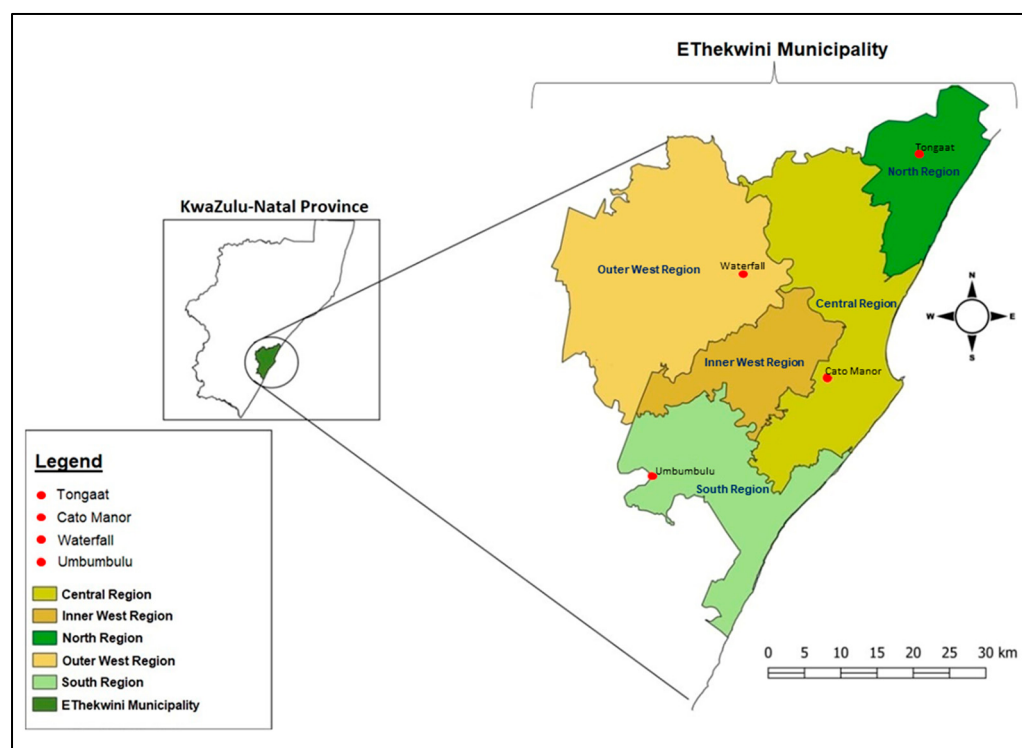


Figure 1. Map showing the study areas in eThekweni Municipality, KwaZulu-Natal. Source: University of Zululand Department of Geography [32].

eThekweni Municipality is surrounded by the iLembe District in its northern part, the uGu District in the southern part, the uMgungundlovu District on the western side, and the Indian Ocean to the east [33]. Durban is eThekweni Municipality's most prominent and significant urban centre [34]. KZN's agricultural sector is notable for contributing 81% of South Africa's sugarcane production. KZN Province is significant in producing fruits, vegetables, and livestock, reflecting its dynamic and diverse agricultural landscape [35]. The selection of KZN, specifically eThekweni Municipality, was purposively based on its rich farming activities and a substantial proportion of SSUC farmers [36]. eThekweni Municipality offers a rich setting due to its unique challenges and opportunities concerning climate change,

urbanisation and agriculture. Specifically, the location of eThekweni Municipality is ideal, given it is on the east coast of South Africa and experiences significant climate change impacts, including temperature rises and shifts in rainfall patterns. Again, eThekweni Municipality has demonstrated considerable potential for UA in South Africa. For these reasons, eThekweni Municipality was ideal for this study on the uptake and level of use of CSA practices and presented a unique opportunity to explore gaps and contribute to understanding CSA practices' dynamics, formulating strategies and policy to upscale CSA practices adoption by SSUC farmers intended to increase urban agricultural productivity, income, and combat poverty through adaptation and resilience to climate change for the urban poor farmers affected by climate change and the effects of urbanisation on food production. This research employed a multi-stage sampling process targeting distinct agroecological zones within eThekweni Municipality: Tongaat Ward 62, Cato Manor Ward 29, Waterfall Ward 9, and Umbumbulu Ward 109, each chosen for its unique urban agricultural potential. Concerning climate, eThekweni Municipality has a humid subtropical climate. The eThekweni climate has hot summers and mild winters, averaging 33 °C and 16 °C, respectively, and an annual rainfall of 893 mm, which is conducive for diverse agricultural activities [37]. However, the dependence on rain-fed systems and land degradation issues heightens the municipality's exposure to climate-related impacts, presenting risks to agricultural productivity and urban food security [38]. Additionally, the population of eThekweni Municipality has grown steadily over the past decade, highlighting the necessity for robust UA to support the expanding urban population [39].

2.2. Research Design

A quantitative cross-sectional design was employed, facilitating data collection concerning the phenomenon under study at a single point in time. This design is particularly appropriate for the present research, where cost-effectiveness and time efficiency are paramount [40]. Several studies investigated the extent of CSA practices' level of use and impacts on SSUC farmers' welfare through a cross-sectional design, for example, Chitakira and Ngcobo [30] and Bongole et al. [41]. Utilising a cross-sectional design enabled a comprehensive analysis of the adoption of CSA practices and the level of use by SSUC farmers in eThekweni Municipality. This design allowed for a focused examination of the variables of interest, providing a solid foundation for drawing informed conclusions about the extent of CSA practices' uptake within eThekweni Municipality [42].

2.3. Conceptual Framework

The ambitious aim of CSA practices is to enhance sustainable agriculture and climate change adaption productivity, and to reduce or remove greenhouse gas emissions crucial for sustainable development [43]. Achieving the goals of CSA practices in tandem with the SDGs (1, 2 and 13) requires significant modifications to farming systems, particularly improvements in soil fertility and moisture retention, which are essential for optimising crop growth conditions [44]. These changes often involve adopting advanced agricultural technologies and innovative practices identified as CSA innovations, practices or technologies [45]. However, the adoption of CSA practices by SSUC farmers is shaped by a complex interplay of determinants that include the farmers' socio-economic characteristics, such as education, financial resources, and access to extension services, which significantly shape their ability and willingness to adopt new practices [46]. For instance, age, gender, marital status, and income are crucial, primarily affecting risk tolerance and resource access [47]. Technological CSA practice options, such as agroforestry, conservation agriculture, and drought- and semi-arid-tolerant crops, are critical for enhancing resilience and ensuring food security under climatic pressures. Urban innovations like vertical and hydroponic farming exemplify how urban spaces can integrate these technologies effectively. A framework for assessing CSA practices' adoption and level of use as low, medium, or high, measuring how deeply these practices have penetrated farming systems and identifying barriers to adoption has been incorporated in various studies; for example, Ojoko

et al. [48] and Ahmed and Naphtali [49]. Still, these studies focused on rural settings, but the need to incorporate CSA practices is equally critical for SSUC farmers. The dynamics of adopting CSA practices are broad and complex, encompassing economic, environmental, institutional and social attributes (see Figure 2). Economically, CSA practices can enhance the cost-efficiency of farming operations and create new market opportunities. However, farmers need economic means such as financial resources and access to credit to adopt and see the benefits. Yet, CSA practices may not lead to immediate gains, which may discourage potential adopters and their level of use. Environmentally, CSA practices help sustain urban ecosystems, addressing the urgent needs associated with climate change [50]. Therefore, the perceptions of farmers concerning the environmental benefits (enhanced soil health and biodiversity) could encourage higher levels and sustained use of CSA practices, which aligns with ecological and long-term sustainable farming.

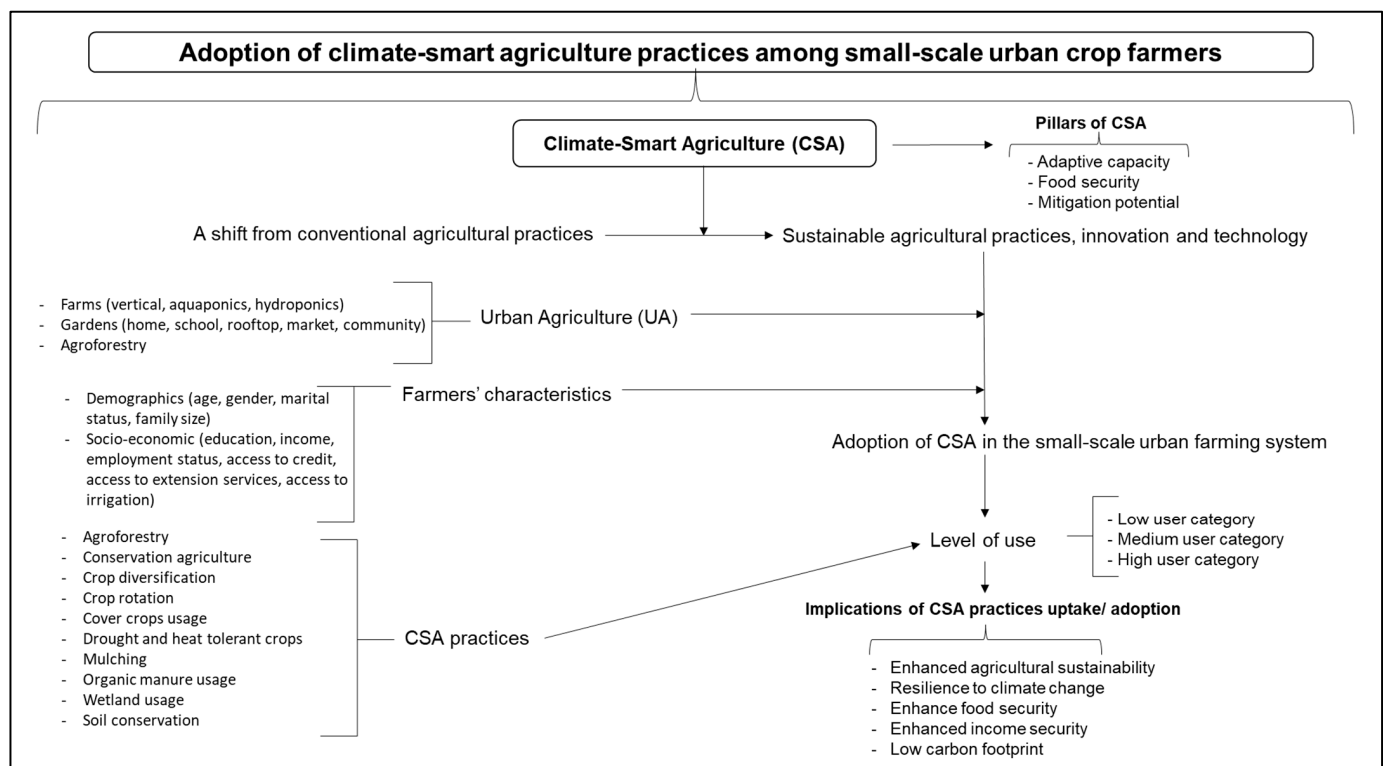


Figure 2. Conceptual framework for the adoption of CSA practices and level of use among small-scale urban crop farmers. Source: Author's conceptualisation (2024).

In contrast, if farmers oppose environmental views or perspectives that include unpredictable weather patterns, uncertainty, and adaptation costs, it could hinder CSA practices' adoption and level of use. Institutionally, the support systems for agriculture are vital in enabling the adoption of CSA practices by providing necessary resources, knowledge, and policy support, which are essential for successful integration [51]. Policymaking influences the adoption by facilitating or hindering access to technologies and markets [52]. Likewise, the absence of supporting mechanisms or a supportive policy framework could hinder CSA practices' adoption and level of use, which could be synonymous with the effectiveness. Without incentives, resources, subsidies, or regulatory frameworks to encourage CSA practices' adoption and use, farmers could be unmotivated to implement CSA practices, leading to lower levels of use. Socially, CSA practices' adoption can change labour dynamics and community engagement, while from a technological perspective, it involves the innovation and dissemination of relevant technologies [53]. These aspects underscore the complexities and critical factors influencing CSA practices' adoption and uptake (level of

use) among SSUC farmers, highlighting the challenges and opportunities within urban agricultural systems.

2.4. Description and Selection of Respondents

This research utilised a multi-stage sampling technique. Following the purposive area selection of KZN and eThekweni Municipality, the third stage involved a purposive selection of Waterfall Ward 9, Cato Manor Ward 29, Tongaat Ward 62, and Umbumbulu Ward 109, chosen for their high concentration of SSUC farmers and specific climatic conditions conducive to this study. The selected SSUC farmers from each ward were hypothesised not to be significantly different, given they were all under the same geographic and climatic conditions of eThekweni Municipality. The respondents also farmed within the selected ward and did not practise UA outside their wards. eThekweni Municipality is vast and has relatively many SSUC farmers in KZN Province. Therefore, multi-stage sampling was appropriate in this context. The sampling relied on a population of SSUC farmers within eThekweni Municipality. Subsequently, SSUC farmers within the chosen wards were selected using a mix of purposive and snowballing (referral) methods. These methods were favoured for efficiency and cost-effectiveness [54,55]. To determine an adequately representative sample size, Cochran's formula [56] was employed, as expressed in Equation (1):

$$n_{\infty} = \frac{z^2 p(1-p)}{e^2} \quad (1)$$

The following mathematical symbols in Equation (1) denote the following:

n_{∞} is the sample size,

z^2 is the standard error associated with the confidence level,

p is the variability or standard deviation,

e is the ideal precision level (margin of error),

p is the approximate proportion of the SSUC population.

Using Cochran's sampling technique (confidence level of 95%, confidence interval of 5), the required sample size was 384 SSUC farmers (Equation (2)).

$$n_{\infty} = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} = 384 \text{ farmers} \quad (2)$$

Combining multi-stage sampling, Cochran's formula and purposive sampling in the context of this study offered robust handling of the complex urban farming population structure while ensuring statistical rigour and in-depth inquiry. The respondents were purposefully selected based on practising small-scale UA, crop farming, and implementing CSA practices in their UA activities. In South Africa, small-scale farmers produce crops or livestock on small plots of land, typically less than 2 ha, with family labour for household consumption and a surplus for the market to generate income. In the context of this study, SSUC farmers practised UA activities on any open lands within eThekweni Municipality or their place of residence. Based on the required calculated sample size of 384 SSUC farmers, the multi-stage sampling technique implied purposively picking 96 SSUC farmers from each ward. However, the data collection surpassed the initial calculation (a response rate of over 100%), encompassing 110 SSUC farmers from Tongaat, 101 from Cator Manor, 103 from Waterfall, and 98 from Umbumbulu, totalling 412 participants. This oversampling, incorporating an additional 28 farmers willing to participate, was not only a practical decision to enhance the study's statistical robustness but also an ethical one, acknowledging the interest and willingness of SSUC farmers to contribute to the research. The referral (snowballing method) explained earlier aroused more interest among the SSUC farmers, thus causing them to be willing to participate. Therefore, the researchers could not discriminate or exclude the SSUC farmers that other SSUC farmers referred to. This scenario explains the oversampling in the study. Ultimately, including these additional willing respondents referred to by other SSUC farmers allowed for a more extensive dataset,

increasing the reliability of this study's findings and offering a richer insight into the practices and challenges SSUC farmers face. The researchers believe the oversampling did not have a material influence on the results but provided richer insights.

2.5. Data Collection

This study employed primary data collection through a structured survey method. A structured survey elucidates specific phenomena and tests relational hypotheses within the established framework [57,58]. Data were captured using closed- and open-ended questions to gather extensive information. The questionnaire respondents were the SSUC farmers (the persons involved in UA activities), who were residents of eThekweni Municipality and were involved in UA activities. This approach enabled comprehensive descriptive and inferential analyses, facilitating the extraction of empirical evidence pertinent to the research objectives. The questionnaire was translated into isiZulu to align with the language preferences of SSUC farmers in eThekweni Municipality, ensuring clarity and comprehension. isiZulu is a native and most commonly spoken language in KZN.

A pilot study involving 40 SSUC farmers from Tongaat, representing 10% of the target sample, was implemented to assess the questionnaire's effectiveness [59]. Data from the pilot can be part of the final study but should be treated cautiously. For this research, the pilot test was excluded from the analysis to minimise bias, thus enhancing the integrity of the study [60,61]. Collecting data on farming activities and associated metrics from the previous season ensured the dataset's uniformity, regularity, and completeness. The surveys were administered directly to those engaged in urban farming at the household level, securing reliable and high-quality data on their agricultural practices. The scope of the data collection included socio-economic characteristics such as age, gender, household status, educational attainment, and income, along with insights into CSA practices, awareness, and other pertinent factors.

The trained enumerators were well-versed in ethical research practices, effective questioning techniques, and accurate response summarisation, as recommended by Kassim et al. [62]. An interviewer administered the questionnaires to avoid potential biases or misunderstandings. Data collection was conducted from 29 May to 26 June 2023 and avoided schedules that conflicted with local events such as funerals, weddings, and other significant social gatherings, including social grant payout days. Before the data collection began, the necessary approvals were secured from eThekweni Municipality's Institute of Learning (MILE) and ethics clearance was granted by the University of KwaZulu-Natal (protocol number: HSSREC/00005367/2023). All the respondents had to sign an informed consent form before participating in the study, ensuring ethical compliance and awareness of the research aims and procedures.

2.6. Data Management and Analysis

Data were systematically organised and encoded using Microsoft Excel 365 (Microsoft Corporation, Washington, DC, USA), followed by a thorough examination to ensure consistency, completeness, and removal of anomalies. After that, the refined dataset was analysed using Stata 18 (StataCorp, College Station, TX, USA). Data were stored on a hard disk in the researchers' computing device, including backups on an external hard drive and cloud storage (OneDrive), with robust security measures to guarantee the data's safety and integrity. This paper aimed to assess the uptake and level of use of CSA practices by SSUC farmers in eThekweni Municipality. This objective was achieved through a composite score index (CSI) to cluster farmers into different user categories of CSA practices and an ordered probit model (OPM) to determine the factors influencing the CSA practices' levels of use. The composite score, derived from the farmers' responses regarding CSA practice levels, categorised the farmers into low, medium and high users. This user-level categorisation was proxied as the dependent variable in the OPM, while the hypothesised explanatory factors were the predictor variables, as informed by the literature.

2.6.1. Descriptive Statistics

Descriptive statistics were utilised to describe the SSUC farmers' demographic and socio-economic characteristics and the CSA practices adopted by SSUC farmers in eThekwin Municipality. The descriptive analysis encompassed the frequency distribution (percentages) and measures of the central tendency (means, range and standard deviations). The data were displayed through graphs and tables. For example, Ojoko et al. [48] used the descriptive statistical technique in their research. Ojoko et al. [48] indicated that most small-scale farmers inadvertently practice CSA as part of their traditional farming. Therefore, it was critical to identify and assess the frequency of SSUC farmers using CSA practices.

2.6.2. Composite Score Index

Ojoko et al. [48] adapted a composite score index to determine the level of use of CSA practices by SSUC farmers in eThekwin Municipality. A CSI technique combines items representing a variable to create a score, or data point, for the variable/attribute in question [55]. In this research, the level of use of CSA practices follows three user domains: low, medium, and high. The responses on the level of use of CSA practices by the SSUC farmers informed the computation of the composite score. Here, the rating was a binary scale with a numeric value of 1 to depict "yes" while 0 was a "no" regarding any specified CSA practices by SSUC farmers in eThekwin Municipality. Respondents can only achieve 10 (maximum) and 0 (minimum) points. Therefore, the researchers used statements (responses) corresponding to the maximum (10) number of potential CSA practices used by SSUC farmers in eThekwin Municipality. Equation (3) expresses the user CSI (low, medium and high) of CSA practices by SSUC farmers in eThekwin Municipality.

$$\begin{aligned} \text{Low users} &= \text{SSUC farmers with points between (Mean - SD) and 0} \\ \text{Medium users} &= \text{SSUC farmers between upper and lower categories} \\ \text{High users} &= \text{SSUC farmers with points between 10 and (Mean + SD) point} \end{aligned} \quad (3)$$

2.6.3. Ordered Probit Model

To estimate the level of use of CSA practices' uptake by SSUC farmers in eThekwin Municipality and the factors driving it, this study adopted an OPM. Similar studies have applied OPMs to estimate the level of use of CSA practices or sustainable agricultural practices (SAPs). For example, Amankwah [63], although in a rural setting, used the OPM to determine the intensity of adoption and the factors influencing the adoption of SAPs. Similarly, Antwi-Agyei and Amanor [64] used an OPM to estimate smallholder farmers' level of use of CSA practices in rural Ghana. Again, Ali et al. [65], in their study in the Central Rift Valley of Ethiopia, assessed the intensity/level of adoption of CSA practices in rural farm households using an OPM. Despite the OPMs used in rural settings by previous studies, this approach applies to urban settings, mainly focusing on the role of socio-economic factors in assessing the adoption and level of use of CSA practices. The lack of urban studies underscores the need for research focusing on urban settings concerning the level of use and uptake of CSA practices. Ordinarily, multinomial and ordinal logit models are most commonly used where the dependent variable has three or more categories. The dependent variable categories are assigned values in a meaningful sequential order. The ordered logit models are more appropriate for estimating the relationships between ordinal (categorical and ordered) outcomes and explanatory variables [66]. Contrarily, the multinomial logistic regression discards the ordinal information of the outcome.

Therefore, given that CSA practices are categorical and ordinal, the OPM is the most appropriate for this study. The OPM is appropriate given that the outcome variable (dependent variable) is categorical, with more than two ordinal categories; in other words, the values of each category have a meaningful sequential order [67]. The dependent variable, representing different levels of CSA practices usage, is derived from the CSI. Therefore, the OPM is formulated as follows (Equation (4)):

$$y_i^* = \beta x_i + e_i, i = 1, \dots, n \quad (4)$$

Here, y_i^* represents an unobserved variable, x_i is a vector of the independent variables, β is the parameter vector to be estimated, and e_i is the random error term with a mean of zero and a variance of one [68]. The decision rule is defined by:

$$y_i^* = \begin{cases} 0, & \text{if } \mu_0 \leq y_i^* < \mu_1 \\ 1, & \text{if } \mu_1 \leq y_i^* < \mu_2 \\ 2, & \text{if } \mu_2 \leq y_i^* < \mu_3 \\ \dots \\ J, & \text{if } \mu_{J-1} \leq y_i^* \leq \mu_J \end{cases} \quad (5)$$

where $\mu_0 < \mu_1 < \mu_2 < \dots < \mu_J - 1$ are the estimated thresholds, known as the “cut-off points” for each category. Assuming $\varepsilon \sim N(0, 1)$ (normalising the variance of the error term ε to one), the likelihood function for parameter estimation is constructed from the defined probabilities, expressed in Equation (6):

$$Prob = [y_i = j | X_i] = F(\mu_j - \beta x_i) - F(\mu_{j-1} - \beta x_i) \geq 0, j = 0, 1, \dots, J. \quad (6)$$

This leads to the sample likelihood function, facilitating the maximum likelihood estimation of the OPM. The marginal effects are calculated based on these probability estimates to understand the impact of variable changes on the dependent categories. In this study, these estimates were computed using the average values from the dataset [69]. The empirical model is outlined in Equation (7):

$$\begin{aligned} y_{ia}^* &= \beta_a \text{Gender} + \delta_a \text{Marital status} + \varepsilon_i, i = 1, 2, 3 \dots n \\ y_{ib}^* &= \beta_b \text{Gender} + \delta_b \text{Marital status} + \theta_b \text{Age} + \varepsilon_i, i \\ y_{ic}^* &= \beta_c \text{Gender} + \delta_c \text{Marital status} + \theta_b \text{Age} + \alpha_c \text{Education} + \varepsilon_i, i = 1, 2, 3 \dots n \end{aligned} \quad (7)$$

The dependent variable, y_i^* , is categorised based on farmers' levels of use of CSA practices: 1 for the low-user category, 2 for the medium-user category, and 3 for the high-user category. To examine the hypotheses and consider additional factors influencing farmers' level of use of CSA practices, the model incorporated several independent variables (as determined in the literature): X_1 = Gender, X_2 = Marital status, X_3 = Age, X_4 = Education (schooling years), X_5 = Household size, X_6 = Membership of agricultural-related group, X_7 = frequency of extension visits, X_8 = Access to agricultural credit, X_9 = Access to irrigation, X_{10} = Employment status, X_{11} = Farm experience, X_{12} = Average distance to farming site X_{13} = Farm income. These explanatory variables are detailed in Table 1.

Table 1. Explanatory variables used in the ordered probit model and their expected outcomes.

Variable	Description and Measurement (Type)	Expected Outcome (+/−)
Gender	SSUC farmer's gender (female = 0; male = 1) (dummy)	−
Marital status	Marital status of the SSUC farmer (single = 0; wedded (married, divorced, widowed) = 1) (dummy)	+ / −
Membership of agricultural-related group	Whether the SSUC farmer belonged to an agricultural-related group or association (no = 0; yes = 1) (dummy)	+
Frequency of extension visits	Whether the SSUC farmer had frequent contact with the extension agents or never (never = 0; frequent (often, very often and seasonally) = 1) (dummy)	+
Access to agricultural credit	Whether the SSUC farmer had ready access to credit (no = 0; yes = 1) (dummy)	+
Access to irrigation	Whether the SSUC farmer had ready access to irrigation technology (no = 0; yes = 1) (dummy)	+

Table 1. Cont.

Variable	Description and Measurement (Type)	Expected Outcome (+/−)
Employment status	SSUC farmer's employment status (unemployed = 0; formally employed = 1) (dummy)	−
Age	Age of the SSUC farmer in years (continuous)	+ / −
Education (schooling years)	Number of years of formal schooling by the SSUC farmer (continuous)	+
Household size	Number of members of the SSUC farmer's household (continuous)	+
Farm experience	Number of years of farming experience by the SSUC farmer (continuous)	+
Average distance to the farming site/farm	The distance from home to the farm site in kilometres (continuous)	+
Farm income	Total yearly income from farm enterprise/s (actual farm income records or monetary value of yield if absent) (continuous)	+

+ / − Depicts the direction of influence (positive/negative) Source: Author (2023).

Description of the explanatory variables used in the ordered probit model

Table 1 summarises the explanatory variables inputted into the OPM to analyse the determinants and level of use of CSA practices among SSUC farmers in eThekweni Municipality. These include gender, marital status, age, education, household size, membership of agricultural-related groups, frequency of extension visits, access to agricultural credit, access to irrigation, employment status, farm experience, average distance from farming site, and farm income.

The explanatory variables presented in Table 1 are hypothesised to influence CSA practices' adoption and level of use by SSUC farmers in eThekweni Municipality. The influence of gender is hypothesised to place males at a higher level of use or category of CSA practices than females. This situation is because females are likely to have limited access to resources, or their adoption rate of CSA practices could be hindered by the cultural roles they play. Marital status is predicted to place wedded SSUC farmers at a higher or lower level of use of CSA practices. In the first instance, wedded individuals possibly have more household stability, encouraging a higher rate of adopting new techniques. On the contrary, wedded SSUC farmers have to contend with family pressures and decision-making matrices, which could slow the decision-making and uptake of CSA practices. Age's influence on the adoption and level of use of CSA practices is inconclusive. Older farmers could be more receptive to the adoption and uptake of CSA practices as older farmers are highly experienced and could have the necessary resources to implement full-scale adoption of CSA practices.

Nonetheless, younger farmers could be more open to adopting new technologies such as CSA practices than older farmers, who may want to stick to tradition and old ways. Education is expected to positively impact CSA practices' adoption, as more educated farmers will likely be better informed about sustainable practices. Therefore, educated farmers are hypothesised to be in the higher user category of CSA practices than their uneducated counterparts. Household size is hypothesised to positively affect the uptake and level of use of CSA practices, assuming that larger households have labour at their disposal, especially for labour-intensive CSA practices. Membership of agricultural-related groups, contact with extension agents, access to agricultural credit, and access to irrigation technology are all anticipated to positively influence CSA practices and place the SSUC farmers in the higher level/user category due to the enhanced resource access and information dissemination that come with collective action, extension support and resource liquidity. In contrast, employment status and average distance to the farming site are expected to correlate negatively with CSA practices' level of use. Formally employed SSUC farmers would have divided attention between investing more time and resources in CSA practices' implementation and their daily routine formal work activities, likely lowering their interest in CSA practices. Also, formally employed individuals do not entirely depend on farming as a livelihood. Concerning the distance to the urban farm, it is likely to increase

production challenges such as theft, logistical costs and time management, which may result in low returns, thus demotivating investment in CSA practices' adoption and level of use. Finally, farm experience and income are hypothesised to positively affect CSA practices' level of use/uptake, with more experienced and financially stable farmers likely more capable of implementing complex and costly sustainable practices.

3. Results and Discussion

3.1. Socio-Economic Characteristics of Respondents

Table 2 indicates a higher prevalence (71%) of female SSUC farmers than males (Table 2). This finding suggests that males migrate or prefer other non-agricultural livelihood portfolios due to potentially higher incentives in the off-farm sectors. This gender distribution aligns with findings by Thobejane [70], who noted a predominance of females in UA as males gravitate towards secondary urban industries.

Table 2. Demographic and farm characteristics of the sampled small-scale urban crop farmers in eThekweni Municipality.

Variable	Frequency	Percentage (%)		
Gender				
Male	121	29.00		
Female	291	71.00		
Marital status				
Wedded (married, divorced, widowed)	159	38.59		
Single	253	61.41		
Membership of an agricultural-related group				
Yes	195	47.33		
No	217	52.67		
Frequency of extension visits				
Had extension visits	220	53.4		
Never	192	46.60		
Access to credit				
Yes	87	21.12		
No	325	78.88		
Access to irrigation				
Yes	367	89.08		
No	45	10.92		
Employment status				
Employed formally	29	7.04		
Unemployed	383	92.96		
	Mean	Max	Min	SD
Age	54.607	80	28	11.898
Education (years)	8.228	18	0	4.230
Household size	8.289	19	1	3.450
Farming experience	5	52	19.388	10.153
* Average distance to farming site/farm (km)	0.1	12	2.88	2.29
Farm income (annual) (ZAR)	12,600	361,800	155,563.80	60,903.44

Abbreviations: ZAR, Max, Min and SD stand for South African Rands, maximum, minimum and standard deviation; * is the land ownership pattern, with 52.18% reporting owning the land (fully or partially paid off) and 47.82% not owning the land (rented, had permission to occupy, or used without permission) Source: Survey data (2023).

The marital status reveals that most (61.41%) of the SSUC farmers were single (Table 2). Single individuals could facilitate their involvement in UA activities and possibly have

higher levels of use of CSA practices due to lesser family obligations, as noted and alluded to by Atta-Aidoo et al. [71]. Nearly half (47.33%) of the SSUC farmers belonged to an agricultural group, while a slightly larger (52.67%) remainder of the SSUC farmers in eThekweni Municipality did not (Table 2). The results show a mixed bag of collective action with SSUC farmers in eThekweni Municipality, with a fair proportion benefiting from shared knowledge and resources, which are crucial for CSA practices' full-scale adoption and a substantial proportion not. This finding is consistent with Maulu et al. [72], who documented the lack of affiliation with agricultural groups among many small-scale urban farmers. This situation would likely result in SSUC farmers who do not belong to farmer groups lagging (low-level users) regarding CSA practices' adoption and utilisation. A substantial proportion (46.6%) of SSUC farmers reported having no interaction with agricultural extension support services (Table 2). Limited access to extension support could hinder awareness and sustained use of CSA practices, resulting in low CSA practices uptake, as portrayed by Mapiye et al. [73]. Lack of access to credit resembles financial constraints, as evident by the majority (78.88%) of SSUC farmers in eThekweni Municipality (Table 2). Limited financial and resource liquidity may limit necessary investments in CSA practices' full-scale adoption and uptake. Sardar et al. [74] observed that small-scale urban farmers were constrained by credit access when adopting new farming innovations. Most (92.96%) of the SSUC farmers in eThekweni Municipality were not formally employed, indicating a high reliance on UA as a livelihood (Table 2). This finding is echoed by Serote et al. [75], who said that most small-scale urban farmers had agriculture as their primary livelihood, subjecting them to the impacts of agricultural disruptions under climate-related stresses.

The age of the SSUC farmers in eThekweni Municipality spans from 28 to 80 years, with an average of 55 years (Table 2). This age distribution shows an economically active urban farming population, but at the same time, the mean age of 55 suggests an ageing population. Belay et al. [76] observed that small-scale urban farmers comprised older people. An elderly urban farming population could have better CSA practices and levels of use linked to their resource endowment and experiences. At the same time, they may also be constrained in terms of CSA practices' use due to limited knowledge and awareness of modern innovations compared to younger urban farmers. Table 2 shows a mean of 8 schooling years among SSUC farmers in eThekweni, ranging from no formal education to 18 schooling years. Generally, the SSUC farmers had attained some basic education. Basic education is critical for comprehending and adopting new CSA practices. Therefore, SSUC farmers with more education could be in a higher user category of CSA practices than their counterparts. The results depict relatively high household sizes for SSUC farmers in eThekweni Municipality, as demonstrated by a mean household size of 8, ranging from 1 to 19 members (Table 2). Household members are critical in providing labour for labour-intensive CSA practices. Therefore, households with a larger household size stand to be in the higher user category/level of use of CSA practices over smaller households.

Approximately 90% of SSUC farmers in eThekweni Municipality had access to irrigation (Table 2). Irrigation technology supplements or enhances UA activities and can potentially increase CSA practices' level of use despite challenges like droughts, as postulated by Gurjar et al. [77]. Atsiaya et al. [78] and Mogaka et al. [79] emphasised the significance of farming experience in relation to CSA practices' uptake. The SSUC farmers in eThekweni Municipality demonstrate substantial farming experience, averaging 19 years (Table 2). Farming experience positively influences CSA practices' adoption and uptake, with more experienced farmers likely to be in the high user category. Akter et al. [80] discussed that farmers' proximity to urban farms significantly lowers production-associated costs, thus enhancing productivity. The distance to a farming site may demonstrate a link to the land tenure. Land tenure is a critical aspect of urban farming. Urban farmers typically use open land or vacant lots, community gardens, and rooftops for their UA activities. In this study, SSUC farmers travelled an average distance of 3 km to farming sites (open or vacant spaces) to practice their UA activities from their residences in their wards within eThekweni Municipality (Table 2). This situation demonstrates the willingness of SSUC

farmers to practice UA and the connection to two different spaces (their residence and a farming site). Above half (52.18%) owned the land, which was either fully or partially paid off, while the remainder (47.82%) did not own the land—rented it, had permission to occupy it, or used it without permission. This pattern could also reflect land tenure challenges. Secure land tenure and owning the land enable or guarantee urban farmers to invest in the land and CSA practices, leading to more sustainable and productive urban farming systems. Farm income plays a critical role in investment back into farm operations. The annual farm income of SSUC farmers in eThekwin Municipality ranged from ZAR 12,600 to ZAR 361,800, with an average of ZAR 155,563.80 (Table 2). Benchmarking and extrapolating with the South African national wage average of ZAR 26,032 per month [81], although lower, this farm income average reflects a reasonably fair income status among SSUC farmers, which could support the initial investments required for CSA practices' full-scale adoption and uptake. Autio et al. [82] echoed farm income's significance in terms of investment in CSA practices and effective implementation.

3.2. Awareness of Climate-Smart Agricultural Practices by Small-Scale Urban Crop Farmers in eThekwin Municipality

Figure 3 presents the awareness of CSA practices among SSUC farmers in eThekwin Municipality. The findings show that most (73.79%) SSUC farmers were aware of CSA practices. The remainder (15.53 and 10.68%) were unaware or unsure. The high awareness level regarding CSA practices among SSUC farmers in eThekwin Municipality indicates widespread exposure to CSA practices, likely enhancing their level of use. Awareness is recognised as a crucial initial step towards adopting CSA practices, as delineated by Sardar et al. [74]. Similarly, Kifle et al. [83] found that informed farmers show increased CSA practices' adoption, which translates to improved knowledge and skills. However, a small portion of SSUC farmers in eThekwin Municipality remains unaware of CSA practices, likely due to outreach and education shortfalls, posing barriers to CSA practices' adoption and effective use. Jellason et al. [84] pointed out that some farmers use CSA practices unknowingly, not realising that the practices are part of the framework of CSA practices. Therefore, removing awareness barriers to enhance communication and education strategies is paramount to emphasising the clear understanding and accessibility of CSA practices for all urban farmers in eThekwin Municipality to support widespread and effective adoption of CSA practices.

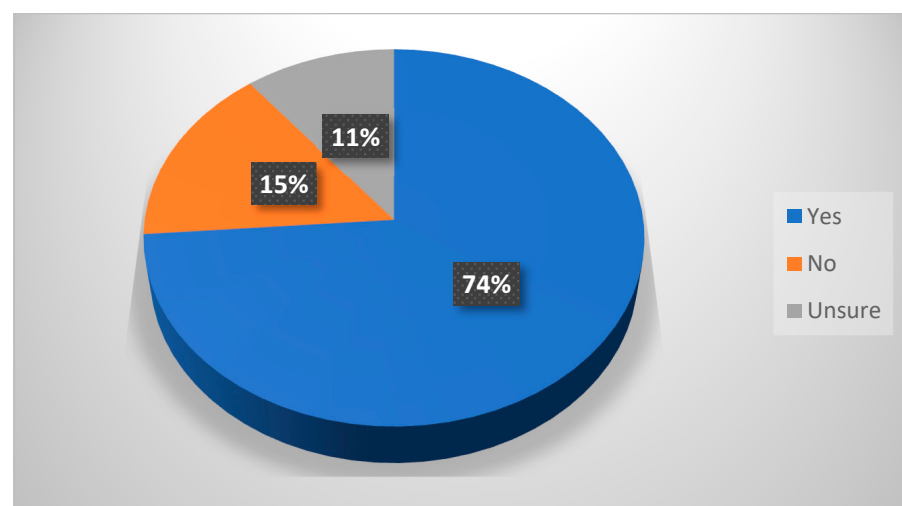


Figure 3. Awareness of climate-smart agricultural practices among small-scale urban crop farmers in eThekwin Municipality Source: Survey Data (2023).

3.3. Information Sources of Climate-Smart Agricultural Practices by Small-Scale Urban Crop Farmers in eThekweni Municipality

Figure 4 illustrates the various information sources accessed by SSUC farmers in eThekweni Municipality for awareness of CSA practices. Media sources, including radio, television, newspapers, and online platforms, were the primary sources reported by approximately 36% of the sampled SSUC farmers (Figure 4). While media sources are pivotal in disseminating knowledge of CSA practices, Ikendi [85] contended that they often provide insufficient detail for effectively implementing specific CSA practices' methodologies. Farmer associations were the second source of information (reported by about 25%), followed by farmer field days (about 23%) (Figure 4). Other information sources include farmer associations and field days that link farmers to research institutions and offer first-hand experience, respectively [86,87]. Other sources of information included friends and neighbours (reported by 12%) of the sampled SSUC farmers, on-farm trials (about 3%) and extension services (about 2%) (Figure 4). Friends and neighbours, on-farm trials and extension services are critical sources of information for CSA practices [73,88,89]. However, SSUC farmers in eThekweni Municipality did not fully leverage these sources, which may impede broader adoption of CSA practices.

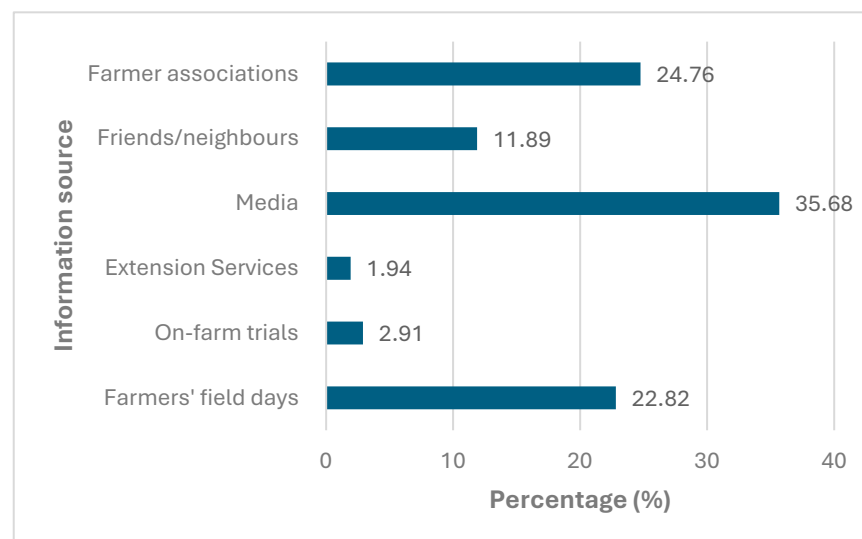


Figure 4. Information sources for climate-smart agricultural practices among small-scale urban crop farmers in eThekweni Municipality Source: Survey Data (2023).

3.4. Climate-Smart Agriculture Practices Adoption and Their Level of Use by Small-Scale Urban Crop Farmers in eThekweni Municipality

Table 3 summarises the level of use of CSA practices among SSUC farmers in eThekweni Municipality. The CSI demonstrates the relative adoption and effectiveness of varying CSA practices used by SSUC farmers in eThekweni Municipality. Crop diversification was the top-ranked CSA practice, with a CSI of 3.694, followed by crop rotation (3.619), mulching (3.608), drought tolerant crops (3.459) and organic manure (3.442) (Table 3). These CSA practices were in the top five, suggesting they are the most favoured practices in eThekweni Municipality. This preference could be due to the immediate perceived benefits of CSA practices. Several studies also corroborate small-scale farmers' preference for these CSA practices [30,90]. Other practices include cover crops, soil conservation, wetland usage, conservation agriculture and agroforestry, ranked lowest in that order (Table 3). The lower preference for these CSA practices might stem from implementation-related challenges such as complexity, initiation costs, and prolonged benefits [48]. Therefore, addressing CSA practices' implementation barriers is imperative to upscale the widespread adoption and uptake of CSA practices. For example, Manono [91] suggested a multifaceted approach to address gaps in implementing and managing farming practices to enhance farmers'

awareness and education, develop robust monitoring systems and tailor interventions to local contexts by involving farmers in decision-making. This participatory approach could ensure that CSA practices are practical for and beneficial to urban farmer-specific circumstances, including sustained use. Another study by Yang et al. [92] on the valorisation of biomass-derived polymers to functional biochar materials for supercapacitor applications via pyrolysis demonstrated the relevance and potential for biomass valorisation, which is a low-cost but significant climate-smart practice that transforms agricultural waste into biochar through pyrolysis to improve soil health, enhance water retention, and reduce greenhouse gasses through carbon sequestration in the short term. Incorporating biomass-derived products by SSUC farmers in eThekweni Municipality could be among the CSA practices that promote resilience and productivity.

Table 3. Ranking and level of use on the adoption of climate-smart agricultural practices by small-scale urban crop farmers in eThekweni Municipality.

CSA Practices	Composite Score Index	Ranking
Crop diversification	3.694	1
Crop rotation	3.619	2
Mulching	3.608	3
Drought tolerant crops	3.459	4
Organic manure use	3.442	5
Cover crops usage	2.381	6
Soil conservation	1.750	7
Wetland usage	1.627	8
Conservation agriculture	1.313	9
Agroforestry	1.209	10
Category of users of CSA practices	Frequency	Percentage (%)
Low	70	17
Medium	272	66
High	70	17
Total	412	100

Source: Survey data (2023).

Concerning the extent of CSA practices' adoption and level of use, most (66%) of the SSUC farmers in eThekweni Municipality were medium users of CSA practices, with the low and high users accounting for a smaller portion (17%) each (Table 3). The finding of substantial medium adopters suggests an existing potential to upscale CSA practices' level of use and uptake. This potential could be achieved through targeted interventions and extension services, which can transition the medium users into higher users. High adopters, although relatively low, could serve as champions to influence and educate their urban peers, promoting a collaborative environment conducive to adopting CSA practices. However, this would require a comprehensive framework to tackle the adoption barriers to promote CSA practices' widespread uptake, especially for the low users of CSA practices [93].

3.5. Factors Influencing the Level of Use of Climate-Smart Agricultural Practices by Small-Scale Urban Crop Farmers in eThekweni Municipality

Table 4 summarises the OPM estimation of the factors influencing the level of use of CSA practices by SSUC farmers in eThekweni Municipality. The likelihood ratio chi-square statistic (312.19) is very high, and the associated probability $\text{Prob} > \chi^2$ (0.000) indicates that the OPM is statistically significant, suggesting that the model possesses a reliable explanatory capacity concerning SSUC farmers' levels of adoption/uptake of CSA practices (Table 4). The pseudo- R^2 score is 0.5914 (Table 4). A pseudo- R^2 score of 0.5914 shows the robust explanatory power of the OPM, suggesting that it was a good fit, explaining about 60% of the variability in the outcome (CSA practices' adoption levels).

Table 4. Results of the factors influencing the level of use of CSA practices by small-scale urban crop farmers in eThekweni Municipality.

Variable	Low User Category			Medium User Category			High User Category		
	dy/dx	Std Error	p-Value	dy/dx	Std Error	p-Value	dy/dx	Std Error	p-Value
Gender (male/female)	0.0555967	0.0182633	0.002 **	−0.0067406	0.0089151	0.450	−0.0488561	0.0156769	0.002 **
Marital status (wedded/single)	0.0141137	0.0176194	0.423	−0.0017112	0.0030805	0.579	−0.0124025	0.0154305	0.422
Membership of farm-related group (yes/no)	−0.0520075	0.0214701	0.015 *	0.0063054	0.0082207	0.443	0.0457021	0.0194401	0.019 *
Frequency of extension visits (had extension visits/never)	0.0107625	0.0191888	0.575	−0.0013048	0.0027769	0.638	−0.0094576	0.0169555	0.577
Access to credit (yes/no)	0.0149816	0.0180709	0.407	−0.0018164	0.003098	0.558	−0.0131653	0.0159936	0.410
Access to irrigation (yes/no)	−0.0302821	0.0260504	0.245	0.0036714	0.0055894	0.511	0.0266107	0.0229515	0.246
Employment status (formally employed/unemployed)	−0.0443992	0.027723	0.109	0.005383	0.0081481	0.509	0.0390162	0.0230514	0.091
Age (years)	0.0014574	0.0007988	0.068 *	−0.0001767	0.0002207	0.423	−0.0012807	0.0007556	0.090 *
Education (schooling years)	−0.006225	0.0028901	0.031 *	0.0007547	0.0010036	0.452	0.0054703	0.0025823	0.034 *
Household size	0.0306111	0.0033313	0.000 ***	−0.0037113	0.0045363	0.413	−0.0268998	0.0045698	0.000 ***
Farming experience	−0.0033247	0.000993	0.001 ***	0.0004031	0.0005126	0.432	0.0029216	0.0009233	0.002 **
Distance to the farming site/farm (km)	0.0041956	0.0034211	0.220	−0.0005087	0.0006958	0.465	−0.0036869	0.0031284	0.239
Awareness of CSA practices (yes/no)	−0.0336987	0.0219767	0.125	0.0040857	0.005266	0.438	0.029613	0.020437	0.147
Observations									
LR chi ² (13)							412		
Prob > chi ²							312.19		
Pseudo R ²							0.0000		
							0.5914		

Notes: *, **, and *** show statistical significance at the 10, 5 and 1% levels, respectively. Source: Survey data generated through Stata version 18 (2023).

The OPM results in Table 4 show that gender, group membership, age, education, household size and farming experience significantly influenced the level of use of CSA practices by SSUC farmers in eThekweni Municipality. These variables statistically and significantly influenced the lower and higher CSA practices user categories, with the influence on medium users being insignificant. The impact of gender is statistically significant at the 1% level (p -value = 0.002) for the low and high user categories (Table 4). The marginal effect suggests that being a male would increase the likelihood of being in the low user category by about 6% and conversely decrease the chances of being in the high user category by approximately 5% (Table 4). This finding shows that urban male farmers are more likely to be in the low user category than the high user category, reflecting differential gender roles and complexities in UA and attitudes towards CSA practices. Male farmers may perceive the benefits of CSA practices' adoption as less directly impactful than traditional farming methods [94]. Similarly, Wahab et al. [95] asserted that male farmers might prioritise maximising yields and profits. In contrast, female farmers might emphasise sustainable practices, environmental stewardship, and community engagement, which are likely to promote the uptake of CSA practices.

Membership of a farming group was statistically significant at the 10 and 5% levels, with p -values of 0.015 and 0.019 for the low and high CSA practices user categories, respectively (Table 4). The OPM marginal effects predict the likelihood of a decrease by 5% of being categorised as a low user of CSA practices if a farmer belongs to a farmer group (Table 4). Similarly, being part of a farmer group increases the chances of being a high user of CSA practices by approximately 5% (Table 4). This finding was expected and agrees with the prior expectation that membership of farm-related groups positively correlates with higher adoption and use levels concerning CSA practices. Ma and Rahut [22] and Jena et al. [96] suggested that farmer groups are pivotal to CSA practices' adoption as they provide robust social networks providing education, support and resource access likely to encourage adoption and sustain high levels of use of CSA practices.

The OPM shows that age's influence is statistically significant at a 10% level, with p -values of 0.068 and 0.090 for the low and high CSA practices user categories, respectively (Table 4). The OPM marginal effects predict that for an additional year in the age of the SSUC farmer, the probability of being in a low CSA practices user category slightly increases by 0.15%, while the likelihood of being categorised as a high CSA practices user decreases slightly by 0.13%, suggesting a mild influence of age on CSA practices' adoption levels (Table 4). Overall, the results indicate that age is likely to decrease the level of SSUC farmers' use of CSA practices. Diro et al. [97] observed that older farmers were more likely to adopt sustainable practices due to their accumulated knowledge and resources. Still, they noted a plateau effect at higher levels of adoption. This assertion is also in consonance with Masi et al. [98], who found that although older farmers initially show higher levels of use of CSA practices, over time, this decreases due to physical limitations, openness and receptiveness to complex technologies or practices.

The OPM illustrates a statistically significant influence of education on the CSA practices' adoption levels at 5% level, with p -values of 0.031 and p -value = 0.034 for the low and high user categories, respectively (Table 4). The OPM demonstrates that more schooling years lessens the probability of being classified as a low CSA practices user slightly by 0.62%, while it boosts the chances of being in the high CSA practices user category slightly by 0.55% (Table 4). Although education slightly impacted the CSA practices' level of use, this finding is synonymous with the prior expectation that education correlates with a shift towards higher adoption levels of CSA practices. While the descriptive analysis suggests a somewhat older farming population, it could be expected that the majority of SSUC farmers could be less educated compared to the younger farmers, as many elderly in African or developing countries had received lesser education, which could lead to lower levels of use of CSA practices among older urban farmers. Nonetheless, the finding that the elderly were more receptive to CSA practices could be explainable due to their experience, traditional indigenous farming knowledge, and climate-smart methods they have used to adapt to

a changing climate over time. Again, the descriptive analysis showed that most SSUC farmers had received basic education. Basic education, although not adequate to fully comprehend the technical aspects of CSA practices, coupled with farming experience and extension services (training) and knowledge sharing among SSUC farmers, can arguably provide a foundation for understanding and boosting the uptake of CSA practices. This finding is corroborated by Kifle et al. [83] and Akter et al. [80], who underscored the role of education in the adoption of complex CSA practices, better access to information and the ability to comprehend the benefits of CSA practices adoption, making small-scale farmers prone to adopt and effectively implement CSA practices.

Household size was significantly associated with being in the low and high CSA practices user categories at 1%, with p -values of <0.001 in each category (Table 4). The marginal effects show that large households would be about 3% more likely to be in the low user category, while it would decrease the chances of being a high CSA practices user by about 2.7% (Table 4). This finding suggests that SSUC farmers with larger households could limit the adoption and use of high-level CSA practices. In theory, larger farming households face more pressure due to the food demand, which can be an incentive to adopt CSA practices to enhance food production. Climate-smart agriculture practices promise to improve agricultural productivity and income through enhanced resilience to climate change, which could lead to a food-secure farming household. Although this finding contrasts with the prior hypothesis, it is explainable. While larger households are said to manage basic CSA practices due to labour availability [99], the resource allocation per capita (like time, money, and attention to more detailed practices) might be constrained in more prominent families. Diro et al. [97] emphasised that although large households can benefit from adopting CSA practices, resources become stretched or misdirected to cater to other family demands, potentially limiting the capacity to invest and engage deeply with more complex or resource-intensive CSA practices.

Table 4 shows that farming experience is statistically significant at a 1% level for the low and high user categories, with p -values of 0.001 and 0.002, respectively. More years of farming experience would decrease the chances of being a low CSA practices user by about 0.3% and increase the likelihood of being a high CSA practices user by 0.29% (Table 4). The findings highlight the relevance of farming experience in enhancing the adoption of more complex CSA practices. The findings prove the initial expectation. With experience, SSUC farmers gain insights and skills that may motivate or enable them to adopt more advanced agricultural practices rather than sticking to minimal or basic levels of CSA practices, as observed by Kangogo et al. [100]. Again, experienced SSUC farmers are more likely to adopt high levels of CSA practices due to better knowledge and comprehension of the benefits, technical skills, or greater confidence in managing the risks associated with more intensive CSA practices. This finding is also supported by Atta-Aidoo et al. [71], who asserted that experienced farmers are more adept at handling the complexities associated with CSA practices and are more likely to implement them effectively.

4. Conclusions and Recommendations

This study assessed the uptake and level of use of CSA practices among SSUC farmers in eThekwin Municipality. The adoption of CSA practices by SSUC farmers in eThekwin Municipality demonstrates the need to embrace climate change resilience in UA. The findings show that SSUC farmers widely adopt CSA practices that offer immediate benefits, less complexity and low-cost practices that address pertinent urban farming challenges such as limited space, water scarcity, infertile soils, increasing temperatures and water shortages. The findings reveal that the media, field days, and farmer associations are pivotal in disseminating knowledge about CSA practices to SSUC farmers. While awareness is critical to the adoption of CSA practices, the findings underscore the significance of social and economic factors in effective adoption of CSA practices. Socio-economic factors such as age, gender, household size, education, group membership, and farming experience significantly influence the uptake and level of use of CSA practices in eThekwin Municipality. Other

variables, such as marital status, frequency of extension visits, access to credit, access to irrigation, employment status, distance to the farming site/farm and awareness of CSA practices, were insignificant in the uptake and level of use of CSA practices by SSUC farmers in eThekwin Municipality, as evidenced by the literature, and the study's prior hypotheses does not diminish their role. While these parameters did not significantly affect the outcome variable or show an immediate apparent impact, they may be essential for understanding the broader context and controlling potential confounding factors. Still, they could be relevant to understanding underlying patterns, resource access, or societal attitudes towards adopting CSA practices. Again, further research may reveal new insights into the role of these parameters. Given that the SSUC farmers in eThekwin Municipality were mainly elderly and faced relatively lower incomes and socio-economic challenges, these physical and economic constraints limit their investment in widescale CSA practices, resulting in a preference for low-cost and less labour-intensive practices. Targeted support and education are critical for promoting heightened and diverse CSA practices to improve food security and income stability. This study recommends the following to promote widespread and effective adoption of CSA practices:

- Gender-sensitive programmes that address unequal gender participation in UA activities; for example, ensuring equal access to resources, information, and gender-specific training.
- Strengthening support (training, access to credit, and extension services) for farmer groups and networks to leverage peer learning and resource sharing.
- Implementing age-specific interventions for older urban farmers, such as labour-saving technologies and simple practices requiring less physical activity.
- Developing and implementing targeted educational programmes prioritising broadcasting CSA practices benefits catering to prominent demographics; for example, using simple and accessible language and media.
- Leveraging seasoned urban farmers' vast knowledge and experience through a mentorship programme to capacitate younger or less experienced urban farmers through practical learning, thus fostering support networks to sustain agricultural innovation and resilience.

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