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Data Article

Climate-smart agricultural practices, productivity, and food-nutrition security in rural South Africa: A dataset of smallholder maize farmers

Abeeb Babatunde Omotoso[a,c], Simon Sebatana Letsoalo[a], Saidat Adebola Daud[c], Christopher Tshwene[a], Abiodun Olusola Omotayo[a,b,*]

[a] *Department of Agricultural Economics and Extension, Faculty of Natural and Agricultural Science, North-West University, South Africa*
[b] *Food Security and Safety Focus Area Research Group, North-West University, South Africa*
[c] *Oyo State College of Agriculture and Technology, P.M.B. 10, Igboora, Nigeria*

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ABSTRACT

The intensifying impacts of climate change have adversely affected smallholder maize farmers, leading to low productivity, decreased incomes, and food-nutrition insecurity. As a result, an understanding of farmers' adaptation techniques to offset the negative impacts of climate change is imperative. Here we present the data on the impact of climate-smart agricultural (CSA) practices on productivity and food-nutrition security (FNS) in the 2022-2023 agricultural production season among smallholder maize farmers in North-West Province, South Africa. The survey that gave this dataset was conducted via a multistage sampling technique through a well-structured questionnaire from 316 smallholder maize farmers selected from 20 randomly sampled villages in South Africa. The finding revealed that climate change is evident in the study location by the significant decline in productivity and FNS of the smallholder maize farmers. Notably, the productivity of CSA adopters and non-adopters is 13.85 and 7.26,

* Corresponding author at: Food Security and Safety Niche Area- Department of Agricultural Economics and Extension, Faculty of Natural and Agricultural Sciences, North West University, North West Province, South Africa. Tel: +27611649252.

E-mail address: Olusola.Omotayo@nwu.ac.za (A.O. Omotayo).

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respectively. We estimated the HFIAS of CSA adopters and non-adopters to be 2.23 and 5.85, respectively. Consequently, various CSAs adopted in the study area include drought-tolerant maize varieties (DTMV), mulching, cover cropping, and zero tillage. The study outcomes indicate that to achieve the FAO's sustainable agricultural goals and create a world free of hunger by 2030, South Africa's farmers must foster their CSA adoption intensity in order to enhance productivity and FNS through building resilience to climate change.

Specifications Table

Subject	Agricultural sciences
Specific subject area	Climate-smart agricultural practices, productivity and food-nutrition security
Type of data	Cross-sectional primary data presented in Table and Figures
How data were acquired	A multistage sampled of rural smallholder maize farmers via a well-structured questionnaire
Data format	Raw and analyzed statistical data
Data collection parameters	A well-structured questionnaire administered to the farmers
Description of data collection	Dataset was collected through a cross-sectional survey of 316 randomly selected smallholder maize farmers from 20 villages in North-West Province, South Africa. Data were collected on socioeconomic characteristics, farm productivity, household consumption parameters and food expenditure pattern
Data location	North-West Province, South Africa
Data accessibility	Submitted along with the article
Repository name	https://figshare.com
Data identification number	https://figshare.com/account/home#/data
Direct URL to data	https://figshare.com/articles/dataset/data_in_bried_on_CSA_HDDS_and_HFIAS_xlsx/24087975

1. Value of the Data

- Dataset revealed the various CSA employed by smallholder maize farmers to mitigate climate change impacts as well as the impacts of adoption on their food-nutrition security. The implications of this knowledge are significant for enhancing adaptation measures and for policy recommendations
- Other researchers may use this data to do further statistical studies that can advance empirical knowledge of the complementarity between climate change adaptation measures and the welfare outcome (food-nutrition security) of the smallholder maize farmers
- Instrumental variables like endogenous switching regression should be adopted because it will help in mitigating selectivity biases owing to self-selection to adopt or not to adopt any climate change adaptation strategies
- A test of the instrument should also be carried out to test the validity of instrument variables (access to extension training) employed in the model
- The information emanating from this study may be used by researchers, academics, extension and advisory organizations, and policymakers to gauge the severity of climate change impacts among smallholder farmers, which is important given the ongoing need to mitigate its consequences.

2. Objectives

Climate change's occurrence has posed a serious threat to human society, particularly in South Africa, where its impact is most pronounced on rural farm families, who are becoming increasingly vulnerable to the impacts [4,18]. Subsequently, drastic changes in rainfall patterns as well as rising temperatures led to adverse growth conditions in planting calendars, changing growing seasons, and impacting South Africa's crop production [17]. Consequently, these changes affect food prices and land use and cause uncertainty in smallholder maize farming households' food-nutrition security (FNS) [17].

Notably, grain yields in South Africa, especially maize, which is the major staple food of households, have declined by 25 % [4]. Thus, this situation had a severe impact on the livelihoods and FNS of rural farmers, who contribute around 65 % of the country's food system [3]. More so, the impact of climate change on FNS is increasingly severe [4,19], while the impact is compounded by the country's socioeconomic, environmental, and demographic trends coupled with limited land and water resources, economic transformation, and challenges in agriculture and the food systems value chain [10,18]. These trends have prompted food security experts to conclude that agriculture and FNS in South Africa will face significant challenges in a world where temperatures are continually rising [10,16].

This prognosis prompted the Food and Agriculture Organization (FAO) and other international multilateral organizations to contend that the implementation of CSA practices is crucial for the country to enhance FNS [15,17]. Therefore, to achieve sustainable productivity, smallholder maize farmers are expected to adopt different adaptation techniques to cope with the threats to their productivity posed by climate change [11,12]. There are several types of CSA techniques, but it is the individual farmer's unique perception of climate change that will inevitably determine the type and extent of the methods that they choose to implement [2,14]. Farm-level adaptations to climate change can take on many forms, including agroforestry, soil water conservation, crop management modifications, and effective land-use management practices such as crop diversification, mulching, and irrigation [1,7,8].

Thus, identifying the synergy among the adopted CSA strategies, as well as understanding the dynamics of the adaptation decisions of the smallholder maize farmers is essential to sustaining productivity and household FNS in South Africa, especially in the North-West province, which remains a key hub of maize production in the country. This study will add to the research on the synergy between households' FNS and CSA adoption by determining the impact of farmers' adoption of CSA in maize farming systems on their productivity and FNS.

3. Experimental Design, Materials and Methods

The dataset used in this research was derived from a survey that was administered from November 2022 to June 2023. The collection of study data was conducted via the use of a well-structured questionnaire, which was administered to the respondents by enumerators who had received appropriate training. The instrument underwent a pre-test using the re-test approach to assess its reliability. The purpose of this action was to guarantee the appropriate uniformity of the tool and prevent any potential confusion. A strong reliability value of $r = 0.81$ was achieved via the correlation of the two sets of recorded data, indicating a high level of instrument dependability. The selection of smallholder maize farmers in the North-West province of South Africa (Fig. 1) involved the use of a multi-stage sampling approach.

To verify the representativeness of the data, the first stage consists of selecting all four municipalities within the North-West province. In the second stage, a sample of fifteen villages renowned for maize production in the North West region was selected using a random sampling technique, with the guidance and support of district extension officials. In the third stage, a total of 30 villages were randomly selected from each local municipality. These villages were largely engaged in subsistence maize cultivation. The selection process was facilitated by local

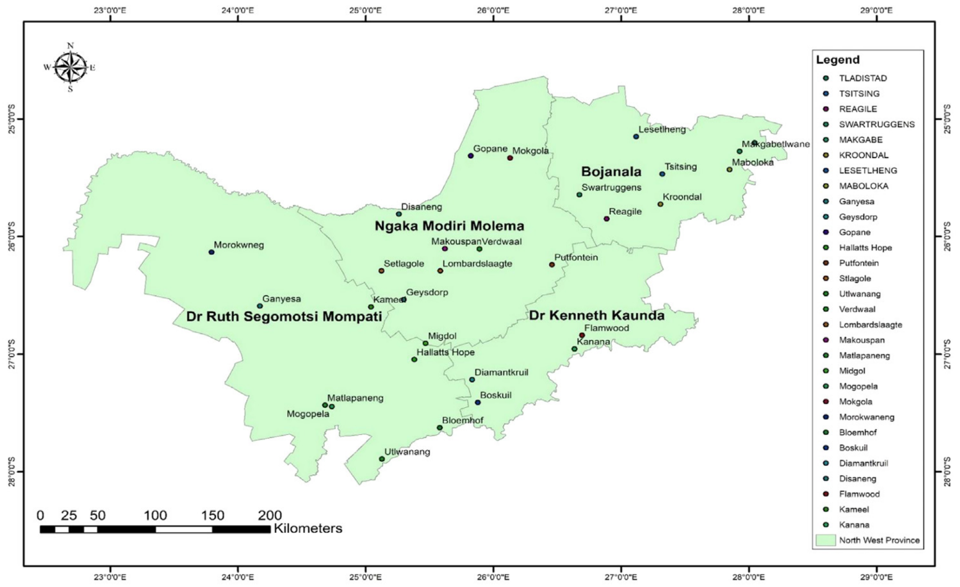

Fig. 1. Geographical representation of the selected smallholder maize production villages in North-West Province, South Africa.

extension officials. The last stage included the process of selecting a total of 316 active smallholder maize farmers from the pool of accessible smallholder maize farmers, as provided by the district extension officers in North-West Province, South Africa. The data that was gathered was subjected to analysis using descriptive statistics and *t*-test analysis.

4. Data Description

The data were collected via a micro-level survey using a face-to-face interview-administered questionnaire. The study was conducted with a sample size of 316 smallholder maize farmers selected through a multi-stage sampling procedure from the study area in the 2022/2023 planting season. Consequently, the information shown in Table 1 provides an overview of the socio-economic characteristics of the smallholder maize farmers who were selected from the North-West Province of South Africa. The mean age of the respondents was 45 years. This suggests that a considerable proportion of the participants were in their youth and possessed the capacity to make a positive impact on agricultural output in the research region. Additionally, it was found that 73.0 % of the subsistence maize producers were married, as indicated by the results, consisting of an average of 5 members would incur substantial costs for food, clothing, and the implementation of agricultural decisions. This finding is consistent with the opinion of Omotoso et al., [16], that married farmers are more committed to their agricultural pursuits because success ensures the survival of their families.

On the contrary, agrarian communities generally regard household size as a significant determinant of labour availability for agricultural tasks [5,13]. Furthermore, it was found that a significant proportion of the participants (79.00 %) possessed access to climate-related information, whereas approximately 2/3 (72.0 %) had interactions with extension agents. It is noteworthy that extension advisory services play a critical role in facilitating the exchange of knowledge and encouraging farmers to embrace novel technologies, thereby enhancing productivity and households' FNS [16,18]. The findings were consistent with those of [5,9], which stated that small-

Table 1
Summarized statistics of variables used in the study

Variables	Descriptions	Mean	Std. Dev.
Dependent variables			
CSA adoption	(1) if the household head (HH) adopted any CSA, (0) if otherwise	0.84	0.58
Adoption intensity of CCAS	Number of CSA adopted by the HH	4.02	3.17
Productivity			
a. Quantity of maize harvested (ton/ha)	Quantity of maize harvested (both adopters and non-adopters)	8.34	4.31
Adopter's quantity of maize	CSA adopters' quantity of maize harvested	13.85	7.09
Non-adopter's quantity of maize	CSA non-adopters quantity of maize harvested	7.26	3.77
b. Net farm income from maize (Rands/ha)	Revenue from maize sale (both adopters and non-adopters)	5593.72	1495.34
Adopter's Net farm income	CSA adopters' revenue from maize sale (Rands/ha)	7834.91	5118.16
Non-adopter's Net farm income	CSA non-adopters' revenue from maize sale (Rands/ha)	4904.35	2821.27
Consumption			
Adopters' maize consumed (ton)	Quantity of maize consumed within the households	0.32	0.38
Adopters' maize sold	Quantity of maize sold by HH	13.53	7.03
Non-adopters' maize consumed (ton)	Quantity of maize consumed within the households	0.28	0.31
Non-adopters' maize sold (ton)	Quantity of maize sold by HH	6.98	4.72
Independent variables			
Gender	If HH is male= (1), if female= (0)	0.62	0.51
Age	Actual household head's age in years	44.69	15.82
Educational level	(1) formal education, (0) = non-formal	0.76	0.42
Farming experience	Years of maize farming experience	6.71	3.17
Marital status	If HH is married= (1), otherwise= (0)	0.73	0.48
Main occupation	(1) if HH's main occupation is farming, (0) if otherwise	0.84	0.35
Off-farm income	Income from livestock sales and other activities	0.56	0.32
Household size	Number of people in the household	5.15	2.17
Farm size	Total land cultivated (in hectares)	4.31	1.18
Extension contacts	(1) if HH has access, (0) if otherwise	0.72	0.47
Membership of organization	(1) if HH is a member of any organization; (0) if otherwise	0.61	0.42
Credit source	(1) if HH has access, (0) if otherwise	0.68	0.56
Climate information	**Sources of information (info) on climate change by HH**		
Smartphone	(1) if HH receives climate info through smartphone, (0) if otherwise	0.72	0.39
Radio	(1) if HH receives climate info through radio, (0) if otherwise	0.81	0.31
Community meeting	(1) if HH receives climate info through community meetings, (0) if otherwise	0.69	0.28
Flyers/Posters	(1) if HH receives climate info through flyers/posters (0) if otherwise	0.71	0.33
Local newspaper	(1) if HH receives climate info through newspaper and community bulletins, (0) if otherwise	0.58	0.25
Extension training	If yes= (1), otherwise= (0) (Dummy)	0.71	0.34

holder farming is a multifaceted concept comprising several aspects, primarily low income, such as inadequate market engagement, labor patterns, and small-scale production.

Additionally, the productivity distribution of the participants indicates that the smallholder farmers earned an estimated R5593.72 on average from their farms. Table 1 subsequently displays the approximated quantities of maize sold (adopters and non-adopters) and ingested

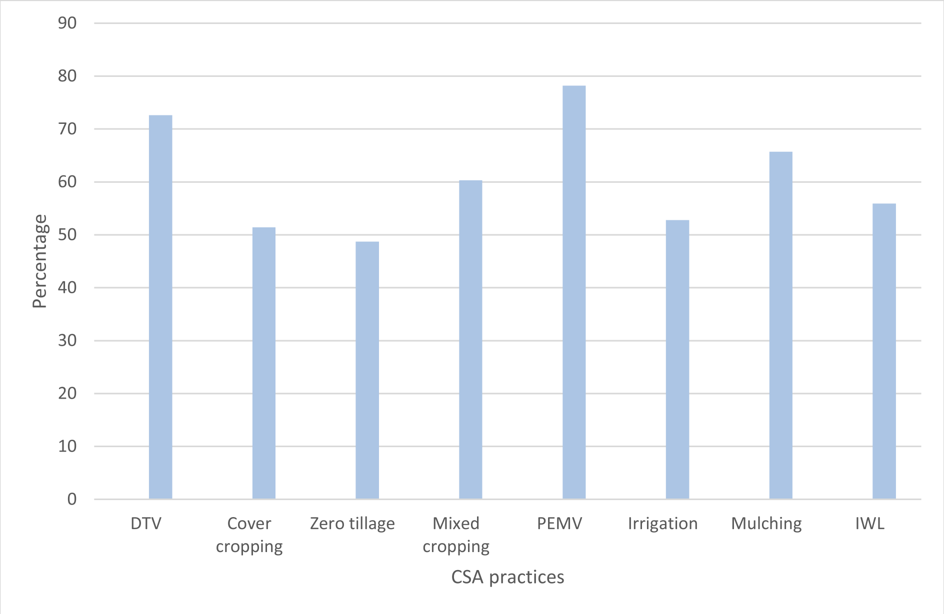

Fig. 2. CSA adopted by rural farmers in North-West Province, South Africa.

within the households (adopters and non-adopters). The findings revealed that CSA adoption improved the productivity and income of smallholder maize in the study area.

4.1. Climate-smart agricultural practices (CSA) adopted by smallholder maize farmers

The farmers' understanding of climate change has a significant impact on the level of adaptation and the steps they take to combat the impacts of climate change on their outputs [6]. This suggests that the majority of smallholder maize farmers are cognizant of local climatic variations and are thus able to make informed decisions on adaptations to deal with climate change and its impact on their farms. The smallholder maize farmers in North-West Province have developed a wide variety of adaptation techniques to deal with the changing climatic conditions.

Fig. 2 depicts the distribution of CSA practices adopted by smallholder maize farmers in North-West Province of South Africa. The understanding of climate change among farmers significantly influences their degree of adaptation and the strategies they use to mitigate the consequences of climate change on their agricultural productivity and FNS [17]. Smallholder maize farmers in North West Province, South Africa have developed a diverse array of CSA practices to adapt to the negative impacts of climate change. This includes mulching (65.7 %), mixed cropping, zero tillage (60.3 %), planting cover crops (51.4 %), and irrigation (52.8 %).

4.2. Assessing the change in productivity and FNS (households' dietary diversity and households' food insecurity score) of smallholder maize farmers (adopters and non-adopters)

The data obtained over the preceding seven days' reveals that the households experienced a range of Household Dietary Diversity Scores (HDDS) from 2 to 11, with a mean value of 9.10. Additionally, the Household Food Insecurity Access Scale (HFIAS) ranged from 1 to 25, with a mean value of 3.41. These findings suggest that there is a certain level of food and nutrition

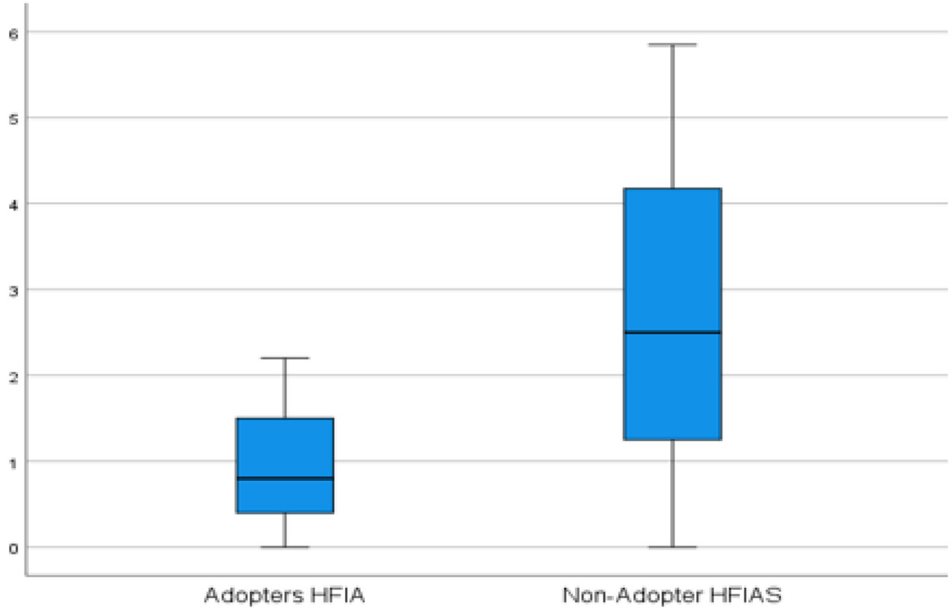

Fig. 3. HFIAS of smallholder maize farmers in North-West Province, South Africa (adopters and non-adopters of CSA).

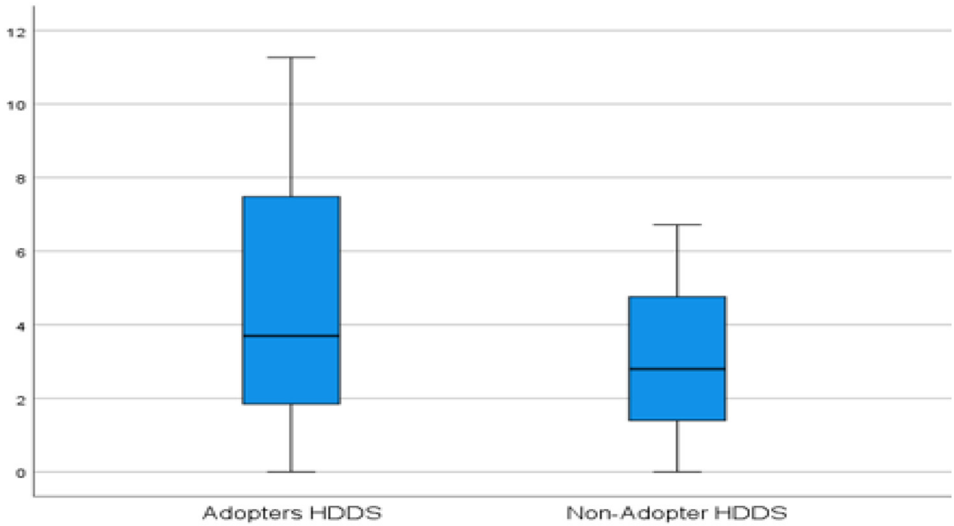

Fig. 4. HDDS of smallholder maize farmers in North-West Province, South Africa (adopters and non-adopters of CSA).

insecurity present among the families under study. As a result, Figs. 3 and 4 illustrate the distribution of HFIAS and HDDS among smallholder maize farmers, respectively, according to their adoption behavior towards Climate-Smart Agriculture (CSA) in South Africa. According to Fig. 3, the HFIAS values for adopters and non-adopters of smallholder maize farmers were 2.23 and 5.85, respectively. Similarly, Fig. 4 illustrates the HDDS values of 11.28 and 6.72 for adopters and non-adopters of smallholder maize farmers, respectively. The results suggest that the adoption of CSA practices greatly improves food-nutrition security in South Africa.

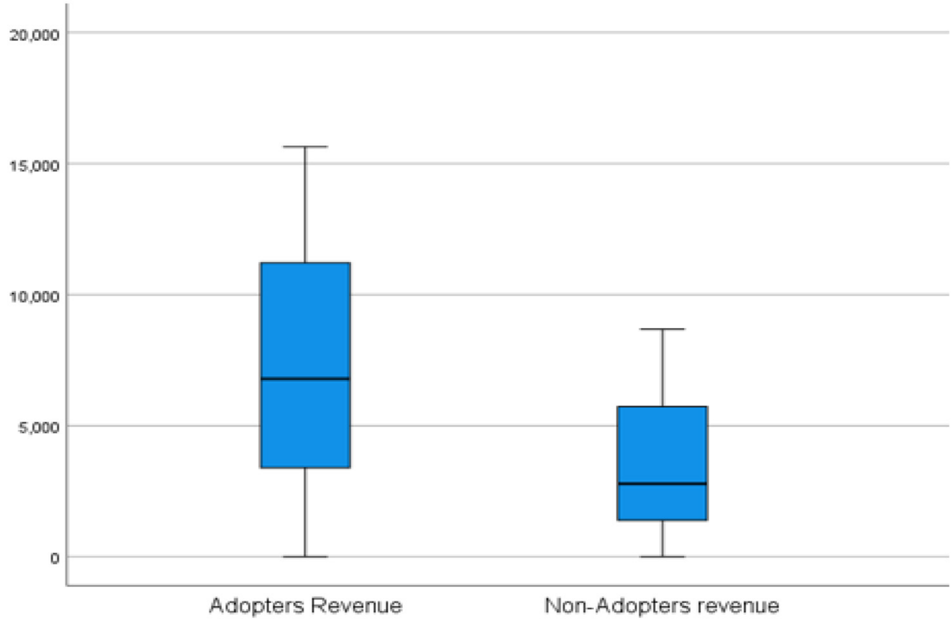

Fig. 5. Revenue of smallholder maize farmers in North-West Province, South Africa (adopters and non-adopters of CSA).

Typically, an increase in HDDS signifies an enhancement in the dietary quality and nutrition security of the family, whilst a decrease in HFIAS suggests an improvement in the household's food accessibility [5]. Furthermore, Fig. 5 denotes the productivity of smallholder maize farmers in North-West Province, South Africa. Following [15], smallholder maize farmers' revenue from farm produce was adopted as a proxy for their productivity. The mean revenues for adopters and non-adopter's smallholder maize farmers were estimated at R15654.09 and R8679.66 with the combined (both adopters and non-adopters) mean revenue designated at R11289.55. The result (Fig. 5) denoted a significant difference in the revenue categories of farmers (adopters and non-adopters of CSA).

Summarily, the result showed that smallholder maize farmers CSA adopters are better off in terms of HDDS and HFIAS than non-adopters. The predicts that CSA improved the households' FNS of smallholder maize farmers in North-West Province, South Africa.

Limitation

A number of limitations may have affected the study findings, and therefore their applicability to elsewhere outside of the North-West Province of South Africa.

- The sampled maize farmers may not be representative of the broader farming population of the country, making the findings less generalizable.
- Establishing a causal relationship between CSA adoption and increased productivity or food security can be challenging. Other factors, such as access to credit, education, and infrastructure, can also influence outcomes.
- Farmers participating in the study may provide biased information based on their perceptions of CSA practices, potentially over-estimating their effectiveness.

Ethical Statement

The Ethics Committee of the Faculty of Natural and Agricultural Sciences, North-West University, South Africa, authorized the ethical clearance (NWU-01267-23-A9) for the study.

Funding Statement

This study received no particular support from funding entities in the public, private, or non-profit sectors.

CRediT Author Statement

Abeeb Babatunde Omotoso and Abiodun Olusola Omotayo: Conceptualization, Data curation, Investigation, Methodology, Writing original draft, Software, Formal analysis, Supervision, Writing – review & editing; **Simon Letsoalo, Saidat Adebola Daud and Christopher Tshwene:** Review & editing.

Data Availability

Data on climate-smart agricultural practices, productivity and food security of smallholder maize farmers in South Africa (Original data) (https://www.figshare.com/articles/dataset/data_in_bried_on_CSA_HDDS_and_HFIAS_xlsx/24087975/2).

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Declaration of Competing Interest

The authors state that they have no known conflicting financial or personal interests that might have influenced the work described in this research.

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