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# Impact of Climate change adaptation strategies on Net farm income of Smallholder maize farmers in South Africa

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**Abstract**
In this paper, we examined the complementary relationships among the adopted climate change adaptation strategies (CCAS) and the impacts of adoption of net farm income of smallholder maize *(Zea mays L.)* farmers in South Africa. A multistage sampling technique was adopted to select smallholder maize farmers across 30 villages in South Africa. The data were analyzed using Endogenous Switching Regression Model (ESRM). The results show that mulching, crop rotation, agroforestry and crop diversification are major CCAS adopted by the farmers. The ESRM modelled the complementarity among the adopted CCAS and the effect of CCAS on the productivity of the smallholder maize farmers. The ESRM showed that CCAS has significant impacts on the net farm income of rural smallholder maize farmers in South Africa. This study concluded that the complementary relationships among the multiple CCAS adopted by smallholder maize farmers were influenced by institutional factors, socioeconomic attributes, and other farm variables. Consequently, we recommend policies and investment strategies tailored towards improving these identified factors are pertinent to ensure increased maize productivity in South Africa.
**Keywords:** Agriculture; Climate change; Food policy; Institutional factors; Socioeconomics; Sustainability

## Introduction

The adverse impacts of climate change on maize output are influenced by agricultural adaptations, farmer investment decisions, and policy choices (Abegaz et al., 2023; Omotoso et al., 2023). Being interrelated, these factors have had a detrimental impact on farming productivity if not well managed (Jennings et al., 2022). Various indicators of climate change, such as irregular rainfall, severe temperature stress, prolonged droughts, as well as flooding and temperature change, have been reported in the empirical literature, and have been shown to have varying impacts on South Africa's smallholder maize farming (Jennings et al., 2022). Smallholder maize farmers could directly perceive the effects of climate change on their enterprises, although the level of impact would vary according to their respective output levels and adaptation strategies (Jennings et al., 2022). Therefore, to achieve a sustainable output level, smallholder maize farmers are expected to adopt different adaptation techniques to cope with the threats on their productivity posed by climate change. 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. Thus, identifying the complementary relationships among the adopted climate change adaptation strategies, understanding the dynamics of the adaptation decisions of the smallholder maize farmers is essential in sustaining productivity in South Africa, especially in the North West province, which remains a key hub of maize production in the country (Abegaz et al., 2023; Omotoso et al., 2023).

## Material and Methods

Primary data was used for this study gathered via a field survey of smallholder maize farmers in South Africa's North-West province during the 2022 agricultural season. A multistage sampling technique was adopted in selecting 316 smallholder farmers across the four municipalities (Bojanala District, Ngaka Modiri Molema District, Dr Kenneth Kaunda District, and Dr Ruth Segomotsi Mompati District Municipality) in the province

## Results and Discussion

### Climate change adaptation strategies (CCAS) adopted by smallholder maize farmers

Figure 1 shows the distribution of CCAS adopted by smallholder maize farmers. The farmers' understanding of climate change has a significant impact on the level of adaptation and in the steps they take to combat the impacts of climate change on their outputs (Baiyegunhi et al., 2022). The smallholder maize farmers in North West have developed a wide variety of adaptation techniques to deal with the changing climatic conditions. These include mulching, varying planting and harvesting dates, mixed cropping, the use of improved plant varieties, agroforestry and crop rotation. Other strategies include the use of organic and inorganic fertilizers and minimal tillage

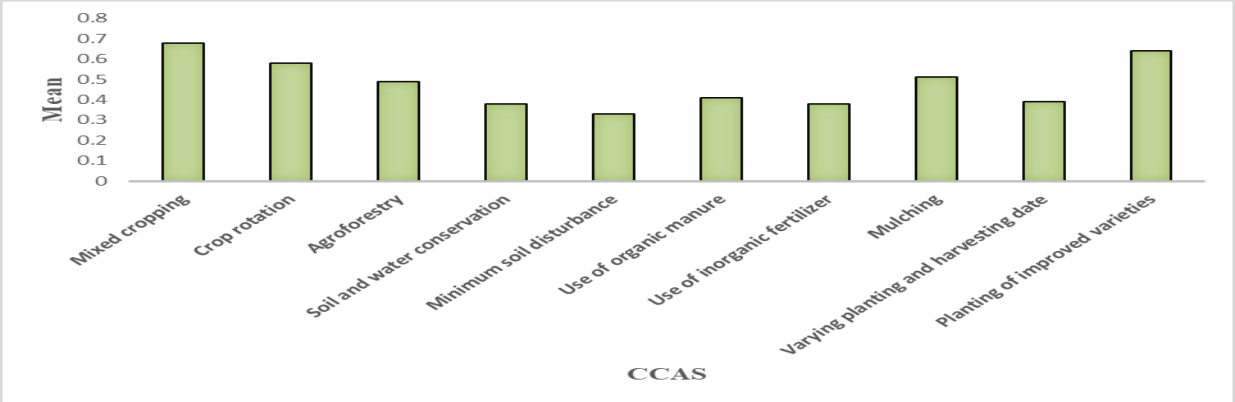


**Fig. 1.** Distribution of CCAS adopted by the smallholder maize farmers in South Africa

### Adaptation impact of ESRM on farmers' (adopter and non-adopter) net farm incomes

The ESRM estimates to determine CCAS adoption and the impacts of adoption on the net farm income of the sampled farmers are presented in Tables 1 and 2. The correlation coefficient, rho_1, in ESRM is positive and significant for the correlation between CCAS adoption and net farm income.

#### *i. Determinant of adoption of climate change adaptation strategies (CCAS) - First stage ESRM*

The second column Table 2 denotes the Probit regression, which determines the CCAS adoptions by the smallholder maize farmers. The Probit regression reveals that the coefficients of the household size, educational status, access to extension training on enhanced agricultural

production practices and access to climate information (through smartphones and radio) had a statistically significant influence on the adoption of CCAS. The coefficient of household size (β=-0.227; p > 0.05) had a negative significant influence on the adoption of CCAS.

**ii. Determinants of net farm income of adopter and non-adopter of CCAS**

Accordingly, the third and fourth columns of Table 2 present estimates from the second stage of ESRM on the determinants of net farm incomes of the adopter and non-adopter of CCAS. The coefficients of marital status, farm size, and educational status were significant in explaining variations in net farm income among the adopters of CCAS, whilst the coefficients of off-farm income, farm size, and farming experience are significant in explaining variations in net farm income among the non-adopters of CCAS. The coefficient of the smallholder farmers' marital status (β = 0.117; p>0.01) was positively significant in explaining the variation in net farm income of CCAS adopters in South Africa. According to (Maindi et al., 2020) married farmers have the ability to pool their resources, both financial and non-financial, to invest in the farm. This could enable larger-scale farming activities, adoption of new technologies, or the purchase of better inputs, ultimately impacting net farm income (Maindi et al., 2020).

**Table 1.** Maximum likelihood estimates of ESRM for the adoption of CCAS in South Africa

| | **Adaptation** | | **Net farm income** | | | |
|---|---|---|---|---|---|---|
| | | | **Adopters** | | **Non-adopters** | |
| **Variables** | Coef. | Std. Error | Coef. | Std. Error | Coef. | Std. Error |
| Gender | -0.216 | 0.164 | -0.505 | 0.416 | -0.604 | 0.713 |
| Age of household head | 0.668 | 0.756 | 0.389 | 0.615 | 0.364 | 0.669 |
| Educational status | 0.819** | 0.402 | 0.890*** | 0.167 | -0.188 | 0.371 |
| Household size | -0.227* | 0.101 | -0.731 | 0.878 | 0.136 | 0.442 |
| Marital status | -0.078 | 0.109 | 0.147** | 0.065 | -0.012 | 0.069 |
| Main occupation | 0.835 | 0.981 | -0.150 | 0.261 | 0.170 | 0.233 |
| Farm size | -0.831 | 0.798 | 0.057*** | 0.011 | 0.101*** | 0.023 |
| Years of farming experience | 0.538 | 0.904 | 0.062 | 0.120 | -0.362** | 0.197 |
| Off-farm income | -0.041 | 0.170 | -0.057 | 0.088 | 0.126* | 0.071 |
| Credit | 0.667 | 0.545 | -0.011 | 0.045 | -0.126 | 0.241 |
| Extension contacts | -0.515 | 0.976 | 0.041 | 0.059 | 0.070 | 0.092 |
| Smartphone | 0.516*** | 0187 | -0.962 | 1.091 | 0.147 | 0.822 |
| Radio | 0.038*** | 0.012 | 0.012 | 0.101 | 0.084 | 0.077 |
| Community meeting | 0.0261 | 0.110 | 0.016*** | 0.006 | 0.116 | 0.099 |
| Flyers/Posters | 0.184 | 0.099 | 0.116 | 0.103 | 0.093 | 0.105 |
| Local newspaper | 0.004 | 0.025 | 0.028 | 0.077 | 0.271 | 0.185 |
| Access to extension training | 0.097*** | 0.027 | | | | |
| Constant | 0.124*** | 0.017 | 0.578*** | 0.190 | 0.132*** | 0.038 |
| rho_1 | 0.851*** | 0.105 | | | | |
| Likelihood ratio test of independence | 27.67*** | | | | | |
| Number of observations | 316 | | 243 | | 73 | |

Note: *, **, and *** denotes 10%, 5%, and 1% significance level, respectively

**iii.** Average Treatment Effect (ATT) - Impacts of adoption of climate change adaptation strategies (CCAS) on net farm income (ESRM)

The result in Table 2 revealed the average treatment effect (ATT) of the impacts of CCAS on net farm income of adopters and non-adopter in South Africa. The ATT revealed that the adoption of CCAS significantly improved the net farm income of smallholder maize farmers in South Africa. The findings demonstrated that adoption of CCAS improved the net farm income of smallholder maize farmers by R3689.19/ha in the study area.

**Table 3.** Impact of adoption of CCAS on net farm income of smallholder maize farmers

| Categories | Expected net farm income | ATT | t-value |
|---|---|---|---|
| **Adopters** | 7891.94 | 3689.19*** | 5.29 |
| **Non-adopters** | 4202.75 | | |

Note: *** denotes significant at 1%

## Conclusions and Outlook

The results reveal that all of the adopted CCAS are mutually complementary. Likewise, the institutional factors such as access to extension service and climate information (through smartphones and radio broadcast) were found to enhance the probability of adopting mixed cropping, while access to climate information through newspapers and community meeting was found to increase the probability of the adoption of crop rotation, mulching and agroforestry. Additionally, the socioeconomic variables (such as age and household size) of some of the selected households, as well as certain farm variables (such as access to credit and farming experience), enhanced the complementarity between the adopted CCAS. The study outcomes indicates that to achieve FAO's sustainable agricultural goals and creating a world free hunger by 2030, South Africa's farmers must develop in terms of their resilience to climate change by adopting CCAS to augment their food productivity

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