# The determinants of adoption of Climate Smart Agricultural (CSA) Practices and its effects on smallholder maize farmer's welfare

**By**

**Khethiwe Naledi Mthethwa**

**Submitted in Fulfilment of the Academic Requirements for the Degree of**

**Master of Agriculture**

**Agricultural Extension and Rural Resource Management**

**School of Agricultural, Earth, and Environmental Sciences,**

**College of Agriculture, Engineering, and Science**

**The University of KwaZulu-Natal,**

**Pietermaritzburg**

**South Africa**

**January 2023**

## ABSTRACT

The smallholder farmers' maize production is highly vulnerable to climate change. Higher temperatures eventually reduce yields while encouraging the growth of weeds, pests, and diseases. Climate change is having a negative impact on agriculture, threatening global food security. Climate-Smart Agriculture (CSA) is considered as a strategy for transforming agri-food system into more environmentally friendly and climate-resilient practices. However, evidence on the socio-economic drivers of farmers' adoption of CSA practices and its effect on food security and yields remain limited. The study is set out to assess how CSA improves the welfare of smallholder maize farmers in the KwaZulu Natal local municipalities of uMshwathi and uKhahlamba. The study explored three specific objectives. The first objective was to assess the determinants of adoption and intensity of CSA Practices among smallholder maize farmers. The second was to evaluate the effect of CSA adoption on small-holder farmers' household food security and the third was to evaluate the distributional effect of CSA adoption on small-holder maize farmers' productivity in the study areas.

The study used a quantitative approach. A multistage random sampling was employed to select 99 respondents, 49 from Swayimane and 50 from Bergville. In assessing the determinants of adoption and intensity of CSA Practices among smallholder maize farmers, the study used the double hurdle count model. The Household Hunger Scale (HHS) was used to determine the food security status of the smallholder maize farmers while Ordered Regression Model (ORM), was used to evaluate the effect of CSA adoption on smallholder maize farmers' food status. The Conditional Instrumental Variable Quantile Treatment (IV-QTE) effect approach was used to assess the distributional effect of CSA adoption on smallholder farmers' maize yields.

The descriptive results indicated that farmers had experienced severe climatic conditions such as drought, pests, diseases, hailstorms, heavy rains (floods), soil infertility, and frost in their farming system. The first hurdle of the Probit model revealed that drought, on-farm income, and household size positively and significantly influenced the adoption of CSA practices. On the other hand, the primary source of income and educational level had a significant negative influence. The second hurdle of the Poisson model revealed that drought significantly impacted the intensity of CSA adoption, whereas marital status significantly negatively impacted CSA practices. The results show that 79% of the farmers experienced little or no hunger, while 13% experienced moderate hunger and only 8% experienced severe hunger. According to the LRM, the drought had a significant negative relationship with household food security, while the main source of income and age had a significant positive relationship. The empirical findings discovered that the impact of adoption was higher and significant at a lower tail quantile (0,5) yield distribution of 91.9%. Total household income and on-farm income were positively significant on yields at the lower quantile (0,5), whereas the main source of income was negatively significant. Total household income and on-farm income were positively significant to yields at the second quantile (0,25), while CSA adoption, smartphones, and the main source of income were negatively significant. Household size and on-farm income were positively significant to yields at the middle quantile (0,50), while CSA adoption and marital status were negatively significant. On-farm income and farmer association were positively significant on yields at quantile 0,75, while marital status was negatively affected. Variables such as total household income, on-farm income, and farmer association membership were positively significant in the upper quantile of 0.85.

Word of mouth, by which farmers share information with their family and friends, significantly improved the knowledge about climate change and adaptation. Most smallholder farmers experienced little to no hunger. The main source of income influenced the food security status of the smallholder farmers. The experience of drought contributed to food insecurity of smallholder farmers. While adoption of CSA practices did not considerably improve food security status but the contribution of CSA adoption towards food security cannot be ignored. Farming households with low yields benefit significantly more from CSA adoption.

The study suggests that when developing climate change adaptation programs, policymakers and climate change champions consider the socioeconomic factors of smallholder farmers. Local climate change organizations should collaborate to increase climate change awareness and adaptation programs. Public climate and adaptation education or training, localized meteorological observations, early warning systems, and mass media dissemination of climate change and adaptation information in locally understood languages is urgently required. To be more resilient to climate change effect, farmers should be encouraged to include a comprehensive diverse CSA package.

Keywords: Climate change impact, Climate Smart Agriculture (CSA), CSA adoption, smallholder farmers, Household Hunger Scale, Maize yields, IV-QTEQ

**DECLARATION 1**

I, Khethiwe Naledi Mthethwa, declare that:

i. The research reported in this dissertation, except where otherwise indicated, is my own original research.

ii. This dissertation has not been submitted for any degree or examination at any other university.

iii. This dissertation does not contain other person's data, pictures, graphs, or other information unless specifically acknowledged as being sourced from those people.

iv. This dissertation does not contain other authors' writing unless specifically acknowledged as being sourced out from them. Where other written sources have been quoted, then:

a) Their words have been re-written sources, but the general information attributed to them has been referenced.

b) Where their exact words have been used their writing has been placed inside quotation marks and referenced.

v. This dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, with the source(s) being detailed in the thesis and in the references section.

Student's signature:[redacted]........................................ Date: 01 January 2023

Khethiwe N Mthethwa

As the candidate's main supervisor, I, Dr Mjabuliseni Ngidi, agree to the submission of this dissertation for examination.

Supervisor's signature: [redacted]....... Date: 10/01/2023………………

Dr. Mjabuliseni SC Ngidi

## PUBLICATIONS

The following publications form part of the research presented in this study.

Publication 1 – Chapter 4.

Mthethwa, K.N., Ngidi, M.S.C., Ojo, T.O. and Hlatshwayo, S.I., 2022. The Determinants of Adoption and Intensity of Climate-Smart Agricultural Practices among Smallholder Maize Farmers. *Sustainability*, *14*(24), p.16926.

Publication 2 – Chapter 5.

Mthethwa, K.N., Ngidi, M.S.C., Ojo, T.O. and Hlatshwayo, S.I., 2022. The effect of Adoption of Climate-Smart Agricultural Practices among Smallholder Maize Farmers' food security. (Under preparation to be submitted to a journal).

Publication 3 – Chapter 6.

Mthethwa, K.N., Ngidi, M.S.C., Ojo, T.O. and Hlatshwayo, S.I., 2022. The distributional effect of Adoption of Climate-Smart Agricultural Practices among Smallholder Maize Farmers' yields (Under preparation to be submitted to a journal).

**ACKNOWLEDGEMENTS**

*Thanks be to God, who gives us this success through our Lord Jesus Christ- 1 Cor.15:57*

Dr. Mjabuliseni Ngidi, thank you so much for believing in me even when I did not believe in myself. Thank you for recognizing my potential when I doubted it. Throughout the research project, I greatly appreciated your constant supervision, support, guidance, motivation, feedback, data analysis, and advice.

Dr. Temitope Ojo, thank you for your invaluable assistance with statistical data analysis, guidance, motivation, and constructive comments throughout the study.

Simphiwe I, Hlatshwayo, am grateful for your mentorship, assistance, and guidance throughout the thesis. Your prompt responses to my inquiries kept me going.

My Dearest Mom, thank you so much for being a pillar of my success; I would not be here without your support, encouragement, and love.

My husband, Noyaba, please accept my heartfelt gratitude for your unwavering support throughout the study.

My daughter, Yamihle, thanks for giving me the reason and inspiration to fight for this accomplishment.

Prof. T Mabhaudhi, thank you for providing registration funding for my studies and the opportunities and courage you offered me to thrive.

Thanks to NRF for providing me with funding for my studies.

Lungelo Buthelezi and Nhlonipho Ngubane, Farmers from Bergville and Farmers from Swayimane, thank you for your time and assistance with data collection.

I want to thank all my family and friends who showed faith in me. Their support, love, and encouragement are much appreciated.

*I can do all things through Christ who gives me strength- Philippians 4:13*

## DEDICATIONS

This study is in memory of my late Father (Jabulani “Mjey” Frank Mthethwa). If he were still alive, I'm sure he'd be overjoyed about this achievement because he used to believe in and promote education. May his soul rest in peace forever.

TABLE OF CONTENT

ABSTRACT....i
DECLARATION 1....iii
PUBLICATIONS....iv
ACKNOWLEDGEMENTS....v
DEDICATIONS....vi
LIST OF TABLES....xi
LIST OF FIGURES....xii
ACRONYMS AND ABBREVIATIONS....xiii
CHAPTER ONE....15
GENERAL INTRODUCTION....15
1.1.Background....15
1.2. Statement of Research Problem....16
1.3. Significance of the study....19
1.4. Aims and objectives....20
1.5. Research Questions....20
1.6. Definition of terms....20
1.7. Outline of the thesis....21
1.8. References....23
CHAPTER TWO....26
LITERATURE REVIEW....26
2.1. Introduction....26
2.2. Characteristics of smallholder farmers and their farming systems....26
2.3. The importance of smallholder agriculture and its contribution to food security....27
2.4. Projections of climate change in Sub-Saharan African countries....29
2.5. The impact of climate change on smallholder farmer's livelihoods....30
2.6. Smallholder farmers adaptive capacity to climate change....31
2.7. Factors that influence  CSA adoption of smallholder farmers....33
2.7.1. Farmers' socio-demographic attributes....34
2.7.2. Institutional components....35
2.7.3. farmer's view of the innovation....36
2.7.4. Financial components....36
2.8. Determinants of CSA adoption and its intensity....37
2.9. The factors that influence household food security.....38
2.10. Effect of CSA adoption on smallholder household food security....39
2.11. Factors that influence maize yields on smallholder farmers' yields....40

2.12. The effect of CSA adoption on smallholder farmers' maize yields ........ 41
2.13. Review of analytical techniques of the study ........ 43
2.13.1. Household Hunger Scale ........ 43
2.13.2. Double-hurdle model (Probit and Logistic regression models) ........ 44
2.13.3. Logistic Regression model ........ 46
2.13.4. Ordered Regression model ........ 46
2.13.5. Conditional Instrumental Variable Quantile Treatment Effects (IV-QTE) ........ 47
2.14. Theoretical Framework: Vulnerability Framework ........ 48
2.15. Conceptual Framework ........ 49
2.16. Conclusion ........ 52
2.17. References ........ 53
CHAPTER THREE ........ 65
MATERIALS AND METHODS ........ 65
3.1. Introduction ........ 65
3.2. Description of the Study areas ........ 65
3.3. Data Collection Method ........ 67
3.4. Methods of data analysis ........ 67
3.5. Ethical Considerations ........ 69
3.6. References ........ 70
CHAPTER FOUR ........ 71
THE DETERMINANTS OF ADOPTION AND INTENSITY OF CLIMATE-SMART AGRICULTURAL PRACTICES AMONG SMALLHOLDER MAIZE FARMERS CHAPTER FOUR ........ 71
4.1. Introduction ........ 71
4.2. Methodology ........ 73
4.2.1. Description of the Study Area ........ 73
4.2.2. Data Collection Method ........ 73
4.3. Analytical Framework ........ 75
4.3.1. The determinants of CSA adoption on smallholder farmers ........ 75
4.3.2. The Intensity of CSA Use among Smallholder Maize Farmers ........ 76
4.4. Description of Variables and Statistics ........ 77
4.5. Results ........ 78
4.5.1. Descriptive Analysis of the Results ........ 78
4.5.2. Empirical Analysis of the Results ........ 84
4.6. Discussion ........ 86
4.7. Conclusions and Policy Recommendations ........ 89

CHAPTER FIVE ..... 95
THE EFFECT OF CLIMATE SMART AGRICULTURE (CSA) ADOPTION ON SMALLHOLDER FARMERS' HOUSEHOLD FOOD SECURITY. ..... 95
5.1. Introduction ..... 95
5.2. Methodology ..... 97
5.2.1. Description of the Study areas ..... 97
5.2.2. Data Collection Method ..... 97
5.3. Analytical Framework ..... 98
5.3.1. Computing Household Hunger Scale (HHS) ..... 98
5.3.2. Ordered probit regression (Effect of CSA adoption on food security) ..... 98
5.4. Description of variables ..... 99
5.5. Results ..... 101
5.5.1. Descriptive Analysis of Results ..... 101
5.6. Discussion ..... 105
5.7. Conclusion and policy recommendation ..... 106
5.8. References ..... 108
CHAPTER SIX ..... 111
THE DISTRIBUTIONAL EFFECT OF CLIMATE SMART AGRICULTURE (CSA) ADOPTION ON SMALLHOLDER FARMERS' HOUSEHOLD MAIZE YIELDS ..... 111
6.1. Introduction ..... 111
6.2. Methodology ..... 113
6.2.1. Description of the Study areas ..... 113
6.2.2. Data Collection Method ..... 113
6.3. Analytical Framework ..... 114
6.3.1. Distributional impact of the CSA on yield based on Conditional IV-QTE ..... 114
6.4. Description of variables ..... 116
6.5. Results ..... 117
6.5.1. Descriptive Analysis of Results ..... 117
5.2.2. Imperial Result analysis ..... 120
6.6. Discussion ..... 122
6.7. Conclusion and policy recommendation ..... 124
6.8. References ..... 126
CHAPTER SEVEN ..... 130
CONCLUSION AND RECOMMENDATIONS ..... 130
7.1. Summary ..... 130
7.2. Conclusion ..... 131

7.3. Recommendations and policy implications ........................................................ 132
7.4. Limitations of the study and suggestions for further research ................................ 133
APPENDIX A: CONSENT LETTER........................................................................ 134
APPENDIX B: QUESTIONNAIRE.......................................................................... 137
APPENDIX C: ETHICAL CLEARANCE .................................................................. 142

## LIST OF TABLES

**Table 1**: The 29 CSA practices and their categories. ............................................................73
**Table 2**:Description of variables (own source). .....................................................................77
**Table 3**:Demographic characteristics of smallholder maize farmers. ....................................78
**Table 4:** Probit regression of determinants of CSA adoption among the farmers' first hurdle. ...........................................................................................................................84
**Table 5:** Poisson regression of determinants of intensity of CSA adoption among the farmers' second hurdle. ..............................................................................................................86
**Table 6:** Summarizes the descriptive variables' names, variable type and measurement, and an expected outcome (Source: Own analysis) ............................. **Error! Bookmark not defined.**
**Table 7:** The coping strategies used by farmers to deal with hunger in 7 days before the data was collected (Source: Own analysis) .................................... **Error! Bookmark not defined.**
**Table 8:** The determinants of household food security (binary logistic regression model) .......................................................................................... **Error! Bookmark not defined.**
**Table 9:** The effect of CSA adoption on household food security (Ordered probit model) .......................................................................................... **Error! Bookmark not defined.**
**Table 10:** Summarizes the descriptive variables' names, variable type and measurement, and an expected outcome (Source: Own analysis) .......................................................116
**Table 11:** Yields quantities ....................................................................................119
**Table 12:** Distributional impact of the CSA on yield based on Conditional IV-QTE ..........120
**Table 13**: Distributional impact of the CSA on yield based on Conditional IV-QTE ..........121

## LIST OF FIGURES

**Figure 1**:Conceptual Framework ........................................................................................51
**Figure 2:**The map showing KZN Map with uMgungundlovu ad UThukela District Municipality Source: https://List_of_municipalities_in_KwaZulu_Natal (Accessed on 20 August 2022). Note: B represent Bergville, S represent Swayimane.....................................66
**Figure 3**:Natural hazards affecting maize production (Source: Own source).........................80
**Figure 4:**Short-term CSA practices adopted by smallholder maize farmers to cope with natural hazards in the 2019–2022 season...........................................................................................81
**Figure 5:**Potential practices to cope with hazards (Source: Own source). .............................82
**Figure 6:**Long-term climate-smart practices adopted by sampled smallholder maize farmers. ..........................................................................................................................................83
**Figure 7:**The different short-term CSA practices adopted by smallholder maize farmers to cope with natural hazards in the 2019-2020 season (Source: Own analysis)**Error! Bookmark not defined.**
**Figure 8:**Long-term Climate Smart Practices adopted by sampled smallholder maize farmers (Source: Own analysis)..........................................................**Error! Bookmark not defined.**
**Figure 9**: HHS Indicator (Source: Own analysis)..................**Error! Bookmark not defined.**
**Figure 10:**Local harvest units ...........................................................................................119
**Figure 11:**Perception of yields obtained and farmers' efficiency ........................................120

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **AIC** | Akaike Information Criterion |
| **BIC** | Bayesian information criterion |
| **CSA** | Climate-Smart Agriculture |
| **CSI** | Coping Strategy Index |
| **CSAT** | Climate-Smart Agricultural Technologies |
| **DAFF** | Department of Agriculture, Forestry, and Fisheries |
| **DHM** | Double-Hurdle Model |
| **DTMV** | Drought-Tolerant Maize Varieties |
| **FAO** | Food and Agriculture Organization |
| **FIES** | Food Insecurity Experience Scale |
| **FGD** | Focus Group Discussions |
| **GDP** | Gross Domestic Product |
| **GESS** | Growth Enhancement Support Scheme |
| **GHG** | Greenhouse Gases |
| **HDD** | Household Diversity Scores |
| **HFCS** | Household Food Consumption Scores |
| **HFIAS** | Household Food Insecurity Access Scale |
| **HHS** | Household Hunger Scale |
| **IBI** | Index-Based Insurance |
| **IFAD** | International Fund for Agricultural Development |
| **IMR** | inverse mill ratio |
| **IV-QTE** | Instrumental Variable Quantile Treatment Effect |
| **LGM** | Logit Regression Model |
| **NBRM** | Binomial Regression Model |
| **NGO** | Non-Profit Organization |
| **ORM** | Ordered Regression Model |
| **SA** | South Africa |
| **SAA** | Sub-Saharan Africa |
| **SCT** | Social Cash Transfer |
| **SDGs.** | Sustainable Development Goals |
| **SPSS** | Statistical Package for Social Science |
| **VIF** | Variance Inflation Factor |

| | |
|---|---|
| **ZINB** | Zero-Inflated Negative Binomial |
| **ZIP** | Zero-Inflated Poisson |

# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1.Background

The world is struggling to meet the 2030 deadline of SDG 2, which is to end malnutrition, ensure nutrition and adequate food for all, and eliminate all forms of hunger (FAO et al., 2021). Global hunger is rapidly increasing, rising from 804 million in 2016 to nearly 821 million in 2017. In 2019, 690 million people worldwide were suffering from hunger, while 135 million people in 55 countries and territories were suffering from acute food insecurity, with Africa accounting for 73 million of this figure (Ayinde, 2020). The COVID-19 pandemic and the measures many countries took to contain it added to the existing challenges in 2020, undermining efforts to reduce hunger and malnutrition in the region (FAO et al., 2015). While South Africa (SA) is food secure on a national level, the majority of South Africans are food insecure at the household level (Haymson et al., 2017). In 2020, the number of South Africans experiencing moderate to severe food insecurity increased to nearly 23.6%, while the number of South Africans experiencing severe food insecurity increased to nearly 14.9% (StatsSA, 2021). Individuals residing in rural areas and informal settlements are generally the most food insecure in the country (Ngidi and Kajombo, 2017).

Smallholder agriculture in South Africa has been identified as a vehicle for achieving poverty reduction, rural development goals, and beneficial food and nutrition security outcomes (Pienaar and Traub, 2015). Because smallholder farmers are the engines of many economies, the negative effects of climate change can have unfavorable consequences for affected countries and farming households. They can play an important role in generating income for Africa's rural poor, particularly in South Africa. Despite this potential, smallholder farmers are characterized by limited land access, capital, technologies, and market orientation (Chamberlin, 2008); Food and Agricultural Organization (FAO), 2015). Furthermore, smallholder farmers are more vulnerable to climate change due to poor management skills and limited access to quality irrigation systems. As a result of these characteristics, smallholder farmers rely more on stable crops such as maize, beans, and sweet potatoes, which can be grown in unfavorable conditions (Kom et al., 2022).

Maize (Zea mays L) is an essential source of staple food for many smallholder farmers (Adeagbo et al., 2021; Jimoh et al., 2022). A million smallholder farmers are estimated to be growing maize for subsistence farming (Hernández Dáz-Ambrona et al., 2013; Harvey et al., 2018). Despite its significance, maize yields remain low (Agbugba et al., 2020). Since maize is sensitive to rising temperatures and erratic rainfall patterns, extreme climate changes have a negative impact on its production. High temperatures and drought have a negative impact on maize production, flowering, and yields (Hernández Daz-Ambrona et al., 2013). Building resilient agriculture for smallholder farmers necessitates using Climate Smart Agriculture (CSA), which can assist them in dealing with the effects of climate change.

According to FAO (2014), agriculture must be "climate-smart" to feed the world while ensuring sustainable rural development. CSA is a strategy for creating the technical, policy, and investment conditions for long-term agricultural development and food security in the face of climate change (FAO, 2014). It contributes to national food security and development goals by focusing on three goals: increasing agricultural productivity and incomes in a sustainable manner, adapting to and building resilience to climate change, and reducing or eliminating greenhouse gas emissions where possible (FAO, 2014). Several studies (Wekesa et al., 2018; Antwi-Agyei et al., 2021) found that implementing CSA practices improves food security. These studies also stated that implementing various CSA practices helps mitigate the effects of climate change and improve nutrient availability. According to Antwi-Agyei et al. (2021), most farmers use CSA practices to reduce pests and diseases, increase yields, and increase income. However, the adoption of CSA technologies is a primary concern.

According to the research of Branca and Perelli (2020); Ogunyiola (2022), despite CSA investment by global development communities, the potential for sustainability, economic benefit, and adoption of CSA practices among smallholder farmers remains low. Most CSA practices are thought to be costly and out of reach for smallholder farmers (Mccarthy, 2011; Zougmoré et al., 2016). CSA adoption is affected by heterogeneous farming systems, limited finance, high agricultural input costs, and technology (Ogunyiola et al., 2022). Previous research has found that socioeconomic factors such as age, education, farm size, and farm ownership influence whether smallholder farmers can implement CSA effectively ( Kolawole et al., 2014; FAO, 2015; Westermann et al., 2018).

### 1.2. Statement of Research Problem

South Africa is food secure on a national level, but there are many individuals and households in the country who are food insecure (Haymson et al., 2017). South Africans experiencing moderate to severe food insecurity increased to nearly 23.6% in 2020, while those experiencing severe food insecurity increased to nearly 14.9%. (StatsSA, 2021). Maize is the most important crop in South Africa's smallholder agricultural livelihoods (Muzangwa et al., 2017). In southern Africa, maize is the primary source of carbohydrates and the largest domestically produced field crop (Agri, 2017). Maize planting area in the non-commercial agricultural sector is estimated to be 297 460 ha, a 0.49% increase over the previous season's 296 000 ha. The expected maize crop for this sector is 543-545 tons, which is 1.03% less than the previous season. The Eastern Cape accounts for roughly 40% of non-commercial maize production, followed by KwaZulu-Natal (27%). (SAGL, 2020). It has low yields, with average yields of less than 1 tonne per hectare. Low and erratic rainfall is a major constraint to maize growth. Temperature increases and rainfall patterns caused by climate change have an impact on maize growth. Temperatures above 35°C are unquestionably detrimental to maize's vegetative and reproductive growth, from sprouting to grain filling (Serna, 2022).

CSA has been documented as a well-recognized method for adjusting agricultural output to the new conditions brought on by climate change in the literature. While CSA activities are recommended to improve sustainable agriculture and reduce poverty, most studies have reported and emphized that CSA adoption remains low (McCarthy et al ., 2011, Atta-Aidoo et al., 2022; Mthethwa et al., 2022; Zougmoré et al., 2016) . These studies further provide possible reasons for low adoptions, according to earlier research (McCarthy et al., 2011; Zougmoré et al., 2016), the bulk of CSA technologies are costly and out of reach for most smallholder farmers in Africa. Some difficulties include insufficient institutional support, insurance plans, and funding mechanisms, and unreliable legal frameworks, such as tenure rights and land management frameworks, which might reduce farmers' willingness to embrace CSA (Harvey et al., 2014; Neufeldt et al., 2013; Scherr et al., 2012). Smallholder farmers are vulnerable to harsh climatic conditions caused by climate change, resulting in unstable livelihoods and productivity. Smallholder farmers rely heavily on indigenous knowledge to overcome the challenges they face in their farming systems. They cannot adopt CSA practices to improve their productivity due to their diverse characteristics, such as low illiteracy levels, old age and lack of stable sources of income, lack of access to information, small land sizes, lack of technologies, and poor managerial skills. This negatively impacts their crop productivity and, thus, their food security.

The agricultural programs and policies have failed to successfully implement CSA and facilitate its maximum adoption. These policies are perceived to have rules, norms, and standards which are impossible for smallholder farming as they will bring additional costs. In addition, the policymakers develop policies based on data collected at a national level, not at a household level, and their implementation is not monitored. Commercial farmers benefit more from government policies since they have resources, information, and a market. This implies that smallholder farming is not perceived to build resilience to Climate change, increase yields and contribute significantly to food security.

The study areas (uMshwathi and uKhahlamba local Municipalities in KwaZulu Natal) are primarily dominated by rural households engaged in agricultural activities that rely heavily on maize production. These study areas have high levels of food insecurity and are vulnerable to the effects of climate change. Previous studies reported that socioeconomic factors such as age, education, farm size, and farm ownership affect whether smallholder farmers can effectively implement CSA ( Kolawole et al., 2014; FAO, 2015; Westermann et al., 2018). Most studies on adopting CSA practices in South Africa concentrate on factors affecting a specific CSA practice (Kom et al., 2022; Mazibuko, 2018). For instance, Abegunde et al. (2020) studied the determinants of adopting CSA Practices in Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa. However, the study did not differentiate between long-term and short-term adaptation strategies and did not focus on a specific crop. Farmers are frequently presented with various technologies that can be used as complements or substitutes to mitigate and adapt to climate change when planting certain crops. Therefore, there is a need for a deeper understanding of whether these factors influence CSA implementation in KwaZulu Natal Maize farming since maize is a common and stable crop for smallholder farmers in the study areas. Furthermore, the study also seeks to understand the different types of short-term and long-term CSA practices adopted by smallholder farmers to mitigate climate change impacts.

Most studies on CSA adoption found that the determinants of CSA adoption, which are classified as institutional, technical, and socioeconomic factors, have the greatest impact on household food security (Wekesa et al., 2018; Abegunde et al., 2020). These factors have either positive or negative effect and they also determine the intensity of CSA adoption. The studies further explained that farmers that employing a comprehensive diverse package that includes all the category practices have the most significant impact on their state of food security. However, these studies generally examined the effect of CSA adoption on food security using the Household Food Insecurity Access Scale (HFIAS). This implies that there is a knowledge gap of studies that uses Household hunger Scale (HHS) as a measure of food security, therefore it is against this backdrop that the study seeks to investigate the contribution of CSA adoption on smallholder farmers' food security as determined by HHS. The HHS focuses on food quantity and does not assess dietary quality. Although several studies have been conducted to estimate the impact of CSA adoption on yields, there is still a lack of information on expected and counterfactual differences in productivity. In this context, this paper aims to assess the distributional effect of CSA adoption on maize smallholder farmers' yields in the study areas.

### 1.3. Significance of the study

Improved CSA adoption among smallholder farmers can help them build resilience and increase yields in the harsh climatic conditions of climate change. As a result, their ability to adapt and intensify CSA practices is crucial to improving their food security and yields. However, they face numerous challenges that make CSA practices difficult to implement. Adopting CSA practices is one of the strategies that could address food insecurity and increase yields, but it is still in its early stages. Understanding how CSA adoption can improve food security and yields is critical. There is a need to engage with smallholder farmers, give them the attention they require, and understand their production system and how to improve it, as well as how to address the challenges they face. As a result, the study identifies the factors that influence CSA adoption as well as the impact of CSA adoption on household food security and yields.

Generally, studies on adopting CSA practices in South Africa concentrate on factors affecting a specific CSA practice (Kom et al., 2022; Mazibuko, 2018). For instance, Abegunde et al. (2020) investigated the factors that affect the adoption of CSA practices in smallholder farming households. However, the study did not differentiate between long-term and short-term adaptation strategies and did not focus on a specific crop. Farmers are often presented with various technologies that can be used as complements or substitutes to mitigate and adapt to climate change when planting certain crops. Therefore, there is a need for a deeper understanding of whether these factors influence CSA implementation in KwaZulu Natal maize farming because maize is a common and stable crop for smallholder farmers. Additionally, most studies on CSA adoption found that the determinants of CSA adoption, which are classified as institutional, technical, and socioeconomic factors, have the greatest impact on household food security (Wekesa et al., 2018; Abegunde et al., 2020). These factors have either positive or negative effect and they also determine the intensity of CSA adoption. The studies further explained that farmers that were employing a comprehensive diverse package which includes all the category practices have the most significant impact on their state of food security. However, these studies generally examined the effect of CSA adoption on food security using the Household Food Insecurity Access Scale (HFIAS). This implies that there is a knowledge gap of studies that uses Household hunger Scale (HHS) as a measure of food security.

### 1.4. Aims and objectives

The adoption of CSA practices is projected to help farmers increase their agricultural productivity and build the resilience of smallholder farmers to cope with the impact of climate change. Also, socioeconomic characteristics are expected to impact the probability of CSA adoption and the number of CSA used by the farmers in this study. Therefore, the study aims to assess whether adopting CSA practices can improve farmers' welfare regarding household food security status and maize productivity (yields).

The specific objectives were to:

- To evaluate the determinants of adoption and intensity of Climate-Smart Agricultural Practices among smallholder maize farmers.
- To investigate the effect of CSA adoption on smallholder farmers' household food security in KwaZulu Natal.
- To determine CSA adoption's distributional impact on smallholder farmers' maize yields.

### 1.5. Research Questions

- What are the factors that influence smallholder farmers to adopt CSA practices?
- Does CSA adoption have an impact on household food security status?
- What is the distributional impact of CSA adoption on smallholder farmers' maize yields

### 1.6. Definition of terms

**Adoption**- The act or fact of taking up, following, or employing something

**Climate Smart Agricultural Practices-** an integrated approach to managing landscapes—cropland, livestock, forests, and fisheries—addresses the interconnected challenges of food security and climate change.

**Smallholder farmers**- The term 'smallholder' is often interchangeably used with 'small-scale,' 'resource-poor,' and sometimes 'peasant farmer.' Globally, one of the more general approaches used to define smallholder farmers would be to assess the common characteristics of these farmers, such as their land and capital access, exposure to risk and input technologies, and market orientation (Chamberlin, 2008) (FAO (Food and Agricultural Organization) 2015). However, in South Africa, the term "small-scale" is generally used to refer to the total number of farmers or households participating in any agricultural production (DAFF,2012). According to (FAO,2015), This broader group of smallholder producers should be subdivided into emerging and smallholder farmers, where emerging refers to those approximately 200 000 farmers selling their produce, while the smallholder relates to all the other products for household consumption.

**Welfare**- A statutory procedure or a social effort aimed at improving the essential physical and material well-being of those in need

**Climate change-** Refers to long-term changes in temperature and weather patterns. These changes could be natural, such as variations in the solar cycle. However, since the 1800s, human activities have been the primary cause of climate change, primarily due to the use of fossil fuels such as coal, oil, and gas.

**Determinants-** a factor that decisively affects the nature or outcome of something.

**Adoption Intensity-**is the proportion of total cultivated land under a given technology or CSA practices.

**Food security**- Food security, as defined by the United Nations Committee on World Food Security, means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

**Farmers' productivity (yields)-** more commonly used in the literature is 'yields,' defined as production per unit area of cultivated land.

### 1.7. Outline of the thesis

The overall structure of the study consists of five chapters , including this introductory section. The second chapter discusses the study's literature review, which includes a description of theoretical and empirical evidence on the determinants of CSA adoption and its impact on households' food security status and yields. The methods and materials are described in Chapter 03, which includes the study area, data collection methods, and conceptual framework. The remaining chapters are made up of three studies, each of which addresses a specific objective regarding the impact of CSA adoption on farmers' welfare. The final chapter presented the findings' conclusions, policy implications, and recommendations for future research. The following details an important aspect of the research.

**CHAPTER FOUR:** ***The determinants of adoption and intensity of Climate-Smart Agricultural Practices among smallholder maize farmers***

The double-hurdle model framework includes the first-stage adoption of climate change adaptation strategies based on the same set of covariates, determining the intensity of CSA adoption

**CHAPTER FIVE:** ***The effect of CSA adoption on smallholder farmers' household food security in KwaZulu Natal.***

The HHS and CSI models were used to assess the household food security status in the study area. The ordered probit regression model was used to determine the effect of CSA adoption on the food security of smallholder farmers' households in the study area, and Logistic Regression was used to determine the factors influencing food Security

**CHAPTER SIX:** ***The Distributional effect of CSA adoption on smallholder farmers' maize productivity (yields).***

A conditional IV-QTE was used to evaluate the distributional impact of the CSA on yield.

**CHAPTER SEVEN:** ***Conclusions and Recommendations*****:** Finally, the study presented conclusions and policy implications for the study

## 1.8. References

Abegunde, V.O., Sibanda, M. and Obi, A., 2019. Determinants of adopting climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), p.195.

Adeagbo, O.A., Ojo, T.O. and Adetoro, A.A., 2021. Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria. Heliyon, 7(2), p.e06231.

Agbugba, I., Christian, M. & Obi, A., 2020. Economic analysis of smallholder maize farmers: Implications for public extension services in Eastern Cape. *South African Journal of Agricultural Extension,* 48**,** 50-63.

Antwi-Agyei, P., Abalo, E.M., Dougill, A.J. and Baffour-Ata, F., 2021. Motivations, enablers and barriers to adopting climate-smart agricultural practices by smallholder farmers: Evidence from Ghana's transitional and savannah agro-ecological zones. *Regional sustainability*, *2*(4), pp.375-386.

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

Branca, G. and Perelli, C., 2020. 'Clearing the air: common drivers of climate-smart smallholder food production in Eastern and Southern Africa. *Journal of Cleaner Production*, *270*, p.121900

Chamberlin, J., 2008. It's Small World After All: Defining Smallholder Agriculture in Ghana (Vol. 823). Intl Food Policy Res Inst.

Department of agriculture, forestry and fisheries, Republic of South Africa (DAFF,RSA). Development of smallholder farmers through cooperative development.(2012).Available online: http://www.daff.gov.za (Accessed on 21 July 2022)

FAO, IFAD, PAHO, WFP, and UNICEF. 2021. Latin America and the Caribbean – Regional Overview of Food Security and Nutrition 2021: Statistics and trends. Santiago, FAO. https://doi.org/10.4060/cb7497en

Food and Agriculture Organization (FAO). *Climate Smart Agriculture Source Book*. 2013. Available online: www.fao.org accessed on 12 September 2022.

Food and Agriculture Organization (FAO). The economic lives of smallholder farmers. (2015). Available online: http// www.fao.org (Accessed 29 June 2022).

Food and Agriculture Organization (FAO). The economic lives of smallholder farmers. (2014). Available online: http// www.fao.org (Accessed 30 June 2022)

Harvey, C.A., Saborio-Rodríguez, M., Martinez-Rodríguez, M.R., Viguera, B., Chain-Guadarrama, A., Vignola, R. and Alpizar, F., 2018. Climate change impacts and adaptation among smallholder farmers in Central America. *Agriculture & Food Security*, *7*(1), pp.1-20.

Haysom, G., Crush, J. and Caesar, M., 2017. No. 03: The Urban Food System of Cape Town, South Africa.

Hernández Díaz-Ambrona, C.G., Gigena, R. and Mendoza, C.O., 2013. Climate change impacts on maize and dry bean yields of smallholder farmers in Honduras. *Iberoamerican journal of development studies*, *2*(1), pp.4-22.

Jimoh, L.O., Akintunde, O.K., Kehinde, A.L., Agboola, T.O. and Alabi, A.A., 2021. Structure, Conduct and Performance of Maize Marketing in Irewole Local Government Area, Osun State. *Nigerian Journal of Basic and Applied Sciences*, *29*(2), pp.59-66.

Kolawole, O.D., Wolski, P., Ngwenya, B. and Mmopelwa, G., 2014. Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana. *Climate risk management*, *4*, pp.43-58.

Kom, Z., Nethengwe, N.S., Mpandeli, N.S. and Chikoore, H., 2020. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. *GeoJournal*, pp.1-24.

McCarthy, N., Lipper, L. and Branca, G., 2011. Climate-smart agriculture: smallholder adoption and implications for climate change adaptation and mitigation. *Mitigation of Climate Change in Agriculture Working Paper*, *3*(1), pp.1-37.

Ngidi, M. and Kajombo, R. (2017). Livelihoods, Food and Nutrition Security Baselines: Four Livelihood Zones in KwaZulu-Natal Province. South African Vulnerability Assessment Committee Report. Pretoria.

Ogunyiola, A., Gardezi, M. and Vij, S., 2022. Smallholder farmers' engagement with climate-smart agriculture in Africa: role of local knowledge and upscaling. *Climate Policy*, *22*(4), pp.411-426.

Pienaar, L. and Traub, L., 2015. Understanding the smallholder farmer in South Africa: Towards a sustainable livelihood's classification (No. 1008-2016-79955).

StatsSA. (2021). *Measuring Food Security in South Africa: Applying the Food Insecurity Experience Scale*.

Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, *7*(1), pp.1-14.

Westermann, O., Förch, W., Thornton, P., Körner, J., Cramer, L. and Campbell, B., 2018. Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agricultural Systems*, *165*, pp.283-293. Scherr, S.J., Shames, S. and Friedman, R., 2012. From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security*, *1*(1), pp.1-15.

Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A., Ericksen, P., Said, M. and Jalloh, A., 2016. Toward climate-smart agriculture in West Africa: a review of climate change impacts, adaptation strategies and policy developments for the livestock, fishery, and crop production sectors. *Agriculture & Food Security*, *5*(1), pp.1-16.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Introduction

Agriculture is the foundation of the economy in Sub-Saharan Africa (SSA). About 70% of the population rely on rainfall to maintain agricultural productivity (Vincent and Cull, 2013). Notwithstanding, climate change has changed climate activity and expanded the force and repetition of shocking climate activity like droughts and floods, which have the most significant bearing, especially on the poor communities in rural areas (Shaw and Kristjanson,2013). Research studies propose that climatic conditions change negatively (Marin, 2010). High inconstancy in precipitation and temperature brought by climate change opens farmers to climate dangers and influences agricultural productivity on which their livelihoods are reliant (Shiferaw et al., 2014). The precipitation and temperature fluctuations affect food security and productivity (Unganai and Murwira, 2010). This literature review explores climate change and the various impacts, adaptation strategies, factors influencing the adoption of Climate Smart Agriculture, and the impact of adopting CSA practices on food security and productivity amongst smallholder maize farmers in SSA.

## 2.2. Characteristics of smallholder farmers and their farming systems

In this study, the following expressions: Peasant farmers, emerging farmers, small-scale farmers, resource-poor farmers, subsistence farmers, and emerging farmers are used interchangeably with smallholders (Ntshangase, 2014; Mdlalose, 2016). According to Chamberlin (2008), smallholder farmers have less than two hectares of land and a limited resource base. Smallholder agriculture is a diverse practice in which farmers grow crops and raise livestock for their families. (Gautam and Andersen, 2016, Shackleton et al., 2001). They grow more stable crops but diversify their output to achieve healthier diets. Maize, beans, sweet potatoes, potatoes, and vegetables such as cabbage, carrot, beetroot, spinach, and onion are among the crops grown (Sibhatu et al., 2015). Some smallholder farmers also have native apple, peach, pear, and avocado trees.

According to Hove and Game (2018), it is dominated by old and uneducated smallholder farmers who are hesitant to use sophisticated modern technology and rely on traditional/indigenous knowledge in almost all agronomic practices. Almekinders (2000) and McGuire and Sperling (2016) classified smallholder agriculture as an informal production system. This includes using self-saved native crop seeds, informal crop markets, and informal storage and preservation of indigenous knowledge. Furthermore, Gill et al. (2016) stated that an informal production system involves using smallholder farmers' knowledge, experiences, and skills to manage, improve, plant, harvest, and store crops. Fertilizers, genetically modified crops, and mechanization are being used less.

As diverse as smallholder farming is, it is vulnerable to unpredictable weather patterns and climate change, necessitating a greater reliance on drought-tolerant crops. According to Ncube (2018), it primarily depends on dryland farming due to erratic rainfall patterns. The majority of smallholder farmers lack access to proper irrigation systems. Drought-resistant crops include maize, beans, potatoes, and indigenous crops. It is highlighted that smallholder farmers are recognized as essential sources of indigenous crops, also known as Neglected and Underutilized Species (NUS). Indigenous crops are well known for their drought and heat stress tolerance, necessitating fewer inputs for growth and adaptation to semi-arid and arid conditions (Mabhaudhi et al., 2017).

Smallholder farmers produce primarily for household consumption (Tshuma, 2014). Many studies conducted in rural areas have confirmed this (Jari and Fraser, 2009; Cousins, 2010; Sibhatu et al., 2015). According to these studies, most smallholder farmers' foods are produced in bulk for consumption rather than sale due to the high population density in developing-country rural areas. Some smallholder farmers, however, sell the surplus to generate income. According to Soukand et al. (2020), smallholder farmers rely highly on informal markets to sell their produce due to insufficient linkages with formal markets.

### 2.3. The importance of smallholder agriculture and its contribution to food security

Smallholder agriculture is the engine of rural economic growth and the primary source of income for most smallholder farmers (Komba and Muchapondwa, 2012). (International Fund for Agricultural Development (IFAD),2010) estimates that there are about 500 million smallholder farms worldwide; in Asia and sub-Saharan Africa, smallholder farmers produce up to 80% of the food consumed and support up to two billion people. According to Dinar et al. (2008), the agricultural sector in South Africa contributes 3.4% to the GDP. It employs 30% of the labor force, and in the third quarter of 2010, primary agriculture contributed about 3% to South Africa's GDP, with a nominal value of R667 billion (Chamuka, 2011).

Significant progress remains to be made in rural areas of SSA, where a large proportion of the population is extremely poor (52% of the provincial population in SSA) and undernourished. One in every four people in SSA is considered undernourished (FAO, 2015). A 30% reduction in the occurrence of hunger in SSA between 1990 and 2015, but significant differences persist in the SSA in individual countries. For example, South Africa (S.A.) is food secure by national standards; most South Africans are considered food insecure at the household level (Haymson et al., 2017). A large proportion of the poor in SSA (82%), according to Beegle et al. (2016), continue to live in provincial areas, earning most of their livelihood through farming. Approximately 92% of rural families in SSA are involved in farming in some way, and the average African country-dwelling family earns approximately 75% of its livelihood from farming (Davis et al., 2017).

Regardless of smallholder farmers in SAA being the most vulnerable and experiencing the most food insecurity, they can be the causative agent for development and neediness easing. As per the FAO (2015), nations that have figured out how to achieve farming efficiency have prevailed concerning diminishing undernourishment. Even though farmers in SAA are the most vulnerable and face the most food insecurity, they can be the driving force behind development and poverty alleviation. According to the FAO (2015), nations that have figured out how to achieve farming efficiency have reduced undernourishment.

Studies have shown that rural development is critical for poverty reduction and encourages utilization and output connectedness in the general economy, particularly in countries where rural poverty accounts for a sizable portion of total poverty (Ravallion and Datt 1996, 2002; Hazell and Haggblade 1990). There is a widespread understanding that smallholder farmers account for a significant portion of the world's agrarian workforce and contribute significantly to total food output. They are especially significant in proportional terms in low- and middle-income countries, and their ultimate number and weight within a given economy/country will, in general, be negatively correlated with financial development (Davis et al., 2017).

Smallholder homesteads represent just 12% of the world's farmland, and they render livelihoods to greater than two billion individuals and create about 80% of the food in SSA (FAO, 2015). Therefore, smallholders are primal to worldwide food security and nourishment. In SSA, smallholders are the significant financial driver in the farming domain. They supply 80% of the food, possess around 60% of the land, and comprise an enormous piece of the general economy. In 2007–2017, smallholders imparted up to 18–25% of SSA's gross domestic product(GDP) and utilized 40–65% of the workforce (World Bank, 2017). In addition, an increase in capacity building and learnability of smallholder farmers could reduce provincial poverty, further develop food security and sustenance at various levels, and add to the accomplishment of different Sustainable Development Goals (SDGs).

A study analyzed eight hundred smallholder farms spanning twenty-five locations in the European Union and one hundred farms across five areas in Africa (Gillman (2019). The study showed that smallholder farms produce more food than measurements show. The author proposes that the underestimation presumably comes from the insights that do not consider food utilized on the farm to take care of family, companions, or animals (Gillman, 2019). Food developed on farms regularly meets between 25% and 40% of that homestead's essentials. The author further proposed that if the genuine worth of smallholder farms was better perceived, they could attain more legislative and financial help (Gillman, 2019).

## 2.4. Projections of climate change in Sub-Saharan African countries

Temperature changes can characterize climate change in Sub-Saharan Africa. Projected temperature change is less intense than the worldwide land region. African summer temperatures are projected to increase until 2050 at about 1.5°celcius over the 1951–1980 standard and stay at this level until the century's end (NASAC, 2015 ). In the high-emanation situation, which displays a four °C globe, warming proceeds until the century's end, with month-to-month summer temperatures over SSA toppling 5°celcius more than the 1951–1980 standard by 2100. Geologically, this warming is consistently conveyed, albeit inland areas in the subtropics warm the most (NASAC, 2015 ).

Heat extremes are also a factor induced by climate change. This is characterized as temperatures 3 and 5 standard deviations over the verifiable standard. By 2100, the multi-model means that 75% of mid-year months would experience higher temperatures, significantly higher than the worldwide normal (Coumou and Robinson, 2013). During the 2071–2099 period, about 60% of SSA summer months are proposed to be more sweltering, with particular expansions in tropical West Africa (about 90%)(Collier et al., 2008). Precipitation changes are projected to be apparent from climate change. A dipole trend of high precipitation levels in tropical East Africa and very low levels in Southern Africa arises in the two seasons, with two increments and diminishes of 10–30%(Collins et al., 2013). As opposed to worldwide models, immediate territorial environment models project no change or even very low levels of precipitation for East Africa, particularly during the prolonged precipitation periods (Laprise and Herna´ndez-Dı´az, 2013)

Sillmann et al. (2013) extended changes of 5 to - 15% in total wet-day rainfall for tropical western Africa, with this projection being indefinite, particularly on the storm-reliant Guinea coast. Exceptionally wet days show considerably more intense increments (Laprise et al., 2013). This is 50–100% in eastern tropical Africa and 30–70% in western tropical Africa. In southern Africa, total wet-day rainfall is proposed to diminish by 15–45% and very wet-day rainfall to increment by around 20–30% over specific locations in the area. Fluctuations in aridity and potential evapotranspiration can result from climate change (Coumou and Robinson, 2013).

The prolonged equilibrium concerning demand and supply is a major causal factor of the environment and agrarian frameworks that can flourish in a specific region. The aridity index is a marker that recognizes 'dry' districts, which are locales with an underlying precipitation deficiency (Zomer et al., 2008). The aridity index is characterized as total yearly precipitation divided by expected evapotranspiration. The yearly average of month-to-month future evapotranspiration increases under global warming as it is fundamentally temperature impelled. This is seen throughout Sub-Saharan Africa, aside from areas projected to see a solid expansion in precipitation (Schellnhuber et al., 2013).

Proposed aridity fluctuations display the most intense disintegration toward more dry situations in southern Africa. In southwestern Africa, the displacement toward more parched situations is projected because of a decrease in precipitation. Temperature-impelled expansions aggravate this in evapotranspiration (Collier et al., 2008). Ocean level rise is another impact of climate change, and predictions of future ocean level rise are seen not to be consistent across the globe. In light of the overwhelmingly tropical area of the SSA, predictions of local ocean level ascent along Sub-Saharan coastlines will generally be more elevated than the worldwide mean by around 10% (NASAC, 2015). The ocean level is proposed to ascend between 0.4m and 1.15m in a 4°C globe, with a median ascent of 0.65m. Ocean-level ascent in a 2°C globe is considered lower, with a scope of 0.2–0.7m and a median ascent of 0.4m (NASAC, 2015).

### 2.5. The impact of climate change on smallholder farmer's livelihoods

Smallholder farmers are among the most disadvantaged and vulnerable groups affected by climate change and variability due to their socioeconomic position (IFPRI, 2007; ASFG, 2013).

The impact of climate change and variability threatens smallholder farmers due to limited access to information, technology, and reliance on climate-sensitive agriculture (Morton, 2007; Mutekwa, 2009; Oxfam, 2007). They are among the most disadvantaged and vulnerable to climate change and variability due to their socioeconomic status (IFPRI, 2007; ASFG, 2013). Climate change and variability threaten smallholder farmers as their livelihoods depend on rainfed.

According to Komba and Muchapondwa (2012), increasing temperatures directly threaten smallholder farmers' production systems by causing heat stress on plants, reducing water availability, and lowering overall productivity. The changing climate negatively impacts overall productivity; soil fertility due to the very hot temperatures accompanied by dry winds leading to erosion, plant wilting, and poor production (DEDEA, 2013). According to the EEA (2009), the soil is critical for providing nutrients for plant growth, carbon storage, and water cycle regulation. Changes in precipitation patterns and temperature have a negative impact on soil quality, resulting in a loss of soil organic matter (Soils Matter, 2013). Rising air temperatures have a negative impact on soil fertility because they accelerate the natural decomposition of organic matter and increase the rates of other soil processes (Altieri and Koohafkan, 2008). They are leading to soil degradation, which threatens crop production. Due to low illiteracy levels, most smallholders find it difficult to access information and new technologies on soil management (Wanyama et al., 2010). The increasing temperature as an impact of climate change in S.A. may encourage the spread of plant and human diseases. In addition, disruptions to human well-being and agricultural and natural ecosystems may trigger new and emerging infection epidemics and environmental toxins (DEA 2010).

### 2.6. Smallholder farmers adaptive capacity to climate change

In Africa, smallholder farmers have embraced distinctive adaptive alternatives to develop further their adaptive capacity in the face of climate change. Tabi et al. (2012), while evaluating rice cultivation in the Volta district of Ghana, found that downpour-dependent marsh rice farmers practiced diverse adaptive techniques. i.e., the utilization of manures, water control, shifting the planting dates, herbicide usage, and the utilization of advanced yielding and infection-safe assortments). Kuwornu et al. (2013), in an investigation conducted in northern Ghana, revealed that smallholder farmers embraced both short and long adaptive alternatives to work on their adaptive ability to climate change.

Molua and Lambi (2006), in an investigation conducted in Cameroon, revealed that the short-term adaptation procedures carried out by smallholder farmers to combat climate change were; altering the date of farming tasks, expanding planting location, undertaking customary and spiritual functions, changing crops, shifting the area used, and farming of short season local varieties. The FAO (2006) revealed that the significant native adaptation systems carried out by smallholder farmers were diminishing food consumption, changing crops, decreasing individual expenses, selling land, discarding good harvests, and re-planting.

Various investigations across Africa reveal differing discoveries concerning the short-term adaptive decisions chosen by smallholder farmers in their response to climate change. Many studies revealed that incorporating livestock to supplement crop output is a primal native procedure (Easterling et al.,2007; Boko et al.,2007; Gbetibouo, 2009). Many studies uncovered that changing planting timing is quite possibly the main native system embraced by smallholder farmers to combat climate change (Molua and Lambi,2006; Easterling et al., 2007; Boko et al., 2007).

Agroforestry activities such as dispersed trees on croplands, further developed fallows, home nurseries, and cocoa, coffee, and banana forests were reasonable and climate-smart adaptive decisions used by smallholder farmers across Africa to combat the effects of climate change (Thorlakson, 2011, Rao et al.,2011, Bishaw et al.,2013).

## 2.7. Climate Smart Agricultural (CSA) practices

Climate Smart Agriculture (CSA) was first introduced in an FAO meeting at the Hague gathering on Food security and environmental change in 2010. FAO characterized CSA as a farming movement that economically and productively expands productivity and wages (adaptation), decreases or eliminates ozone-depleting substances (alleviation), and improves the accomplishment of public food security and SDG objectives (FAO, 2010). This idea was intended to find harmony between food output and natural care-taking without disregarding either aspect.

The link between agriculture and climate change is genuine and possibly destructive. Within one frame, the farming value chain and land usage modification regarding deforestation represent 30% of the complete worldwide Greenhouse Gases (GHG) outflows, while within another frame, the adverse effects of climate change are prompting land degradation and food uncertainty (IPCC, 2007). Food security necessitates the inclusion of stronger output frameworks. Likewise, more productive and strong farming necessitates supervising natural and ecological assets (FAO, 2010). Incorporating such frameworks could produce critical mitigation benefits (FAO, 2010; World Bank, 2011). CSA endeavors to augment ecological and social productivity, strengthen farmers' ability to withstand climate change, and diminish agriculture's commitment to change by lessening GHG discharge and expanding soil carbon sequestration (FAO, 2010; World Bank, 2011).

CSA incorporates the Sustainable Development and Green Economy objectives and core values as it focuses on food security and the conservation of ecological assets. FAO (2013) puts forward that CSA considers the four elements of food security which are accessibility, availability, use, and dependability.

Climate-smart practices include effective methods, for example, mulching, inter-cropping, integrated pest, and infection control, minimum soil disturbance practices/ no-till, crops rotation, agroforestry, coordinated crop-livestock control, hydroponics, developed water control, better climate determination for farmers and innovative practices, like early warning frameworks (FAO, 2010; World Bank, 2011). It additionally involves accepting new advances, for example, expanding genetic attributes of yields to assist farmers in combatting an uncertain climate and establishing an empowering strategy for adaptive transformation (World Bank, 2011). Even further, CSA is fixated on the post-reap treatment of yield as it moves along the value chain to limit misfortunes and enable feasible utilization. Without CSA, outlying regions might be less suitable for arable cultivation because of land degradation through deforestation, soil disintegration, redundant culturing, and overgrazing (World Bank, 2011). In any case, there is an acknowledgment that CSA should center on smallholder farmers in non-industrial countries who are critical to improvement across the whole farming framework. Strategy backup and financing of the farming activities is one more consideration in the overall extent of the first idea of CSA (FAO, 2013).

### 2.7. Factors that influence  CSA adoption of smallholder farmers

The factors relating to the adoption of CSA by farmers are multi-layered. Academics have researched a few factors that impact CSA adoption. These elements can be characterized into four fundamental classes: socio-demographic qualities, institutional elements, farmers' impression of the innovation, and financial elements (Mozzato et al., 2018). Variables influencing hazard might be noticeable and undetectable, like perspectives toward the hazard. People's different perceptions of vulnerability might mirror the innovation adoption likelihood.

### 2.7.1. Farmers' socio-demographic attributes

Farmers' socio-demographic qualities include family heads' age, gender, educational levels, and family size. Family head's age has been revealed to have both optimistic and adverse consequences on adoption by various academics. Academics in Vietnam discovered antagonistic and optimistic connections concerning age and acceptance of CSA advances in rice output in various territories (Tran et al., 2019). In one region, the elderly farmers were bound to embrace CSA, while in Bac Lieu and Thai Binh regions, the more youthful farmers were bound to take on CSA (Tran et al., 2019). More experienced farmers have a higher probability of taking on CSA advances since they have collected capital or have more prominent admittance to credit, especially for innovations that need financial input. Likewise, more experienced farmers gain knowledge on how they adapt to climate change and fluctuation shocks and, in this manner, can more readily assess any newfound innovations dependent on experience contrasted with more youthful farmers. In certain regions, age can hinder innovation acceptance as a matured farmer has diminished physical capacity (Abegunde et al., 2019).

This means that more youthful farmers are more daring than established farmers. Hazard-opposed farmers will delay their acceptance of innovations. The family head's training and education level affect the innovation's acceptance (Abegunde et al., 2019). The explanation is that a more educated family head is relied upon to comprehend and acquire innovations in a more limited period than uninformed individuals. Likewise, the training level is expected to build the farmer's capacity to acquire, process, and utilize the data pertinent to technology adoption (Amadu et al., 2020).

The gender of the family head additionally assumes a part in technology acceptance and adoption. A few investigations report a higher pace of innovation acceptance among male-headed families, contrasted with female-headed families because of discrimination (Martey et al., 2020). In most cases, women have less admittance to outside data sources, administrations, and revenue due to social and cultural qualities (Amadu et al., 2020; Martey et al., 2020). In the cases of males being more open to technology adoptions, this can be explained by men in male-headed families in many social orders who control valuable assets like land, work, and capital, which are fundamental for acquiring innovation. In correlation, female-headed families have restricted acceptance because of the lack of admittance to assets (land, work, capital). Higher admittance to assets and data enables such families to take on technological innovations (Beyene et al., 2017; Martey et al., 2020).

### 2.7.2. Institutional components

Institutional elements include administrations like financial systems, protection, data dispersal, and having a place with a gathering of people. Innovation adoption ordinarily requires inputs such as compost and pesticides, to name a few. Credit access empowers the farmers to buy these different inputs, which optimistically affects technology adoption (Beyene et al., 2017). A few academics have discovered that admittance to credit advances the acceptance of hazardous innovations through a more relaxed liquidity limitation and improving the risk-bearing capacity. This positive impact is acknowledged when the credit is placed on resources for farming exercises instead of utilized for social purposes (Aryal et al., 2017). Low acceptance rates have been accounted for in nations where credit organizations oppress female-headed families, and in that capacity, they cannot support yield-raising innovations.

Obtaining data on innovations is another factor that decides the acceptance and adoption of innovation. It empowers farmers to get familiar with the presence and the successful utilization of innovation, in this way, working with its adoption (Andersson and Souza, 2014). Admittance to agricultural extension administrations emphatically affects innovation reception in light of the extension specialist's help in inducing mindfulness about technology and its capacity. Extension administrations assume a significant part in the execution and dispersion of technology and overcome any issues among farmers and innovation (Andersson and Souza, 2014). Extension officers (scientists) and innovation clients (farmers) by dispersing data to farmers on the possible use and advantage of innovation. Extension specialists can scatter data that can offset the adverse consequences of the absence of formal schooling in farmers by adopting new technology (Mwangi and Kariuki, 2015). Admittance to data through extension empowers farmers to settle on educated choices as it lessens the vulnerability of an innovation's ability to be effective, thus might change a person's appraisal. Scattered data ought to be dependable and precise; otherwise, it can become an obstacle to adoption.

Participation in social gatherings upgrades social capital. This permits trust, thoughts, and data trade about new advancements (Mwangi and Kariuki, 2015). Farmers who partake more in local area-based associations have a higher probability of participating in social learning that centres on innovation, raising their probability of taking on the advances. Gatherings of people may adversely affect innovation reception, mainly where free-riding conduct exists (Bandiera and Rasul, 2006). As more individuals participate in the experimentation of new advances, others participate and complementary take advantage of the experimentation of others.

### 2.7.3. farmer's view of the innovation

Farmers are more inspired by the present moment than long-term benefits (Moges and Taye, 2017). Farmers' views of technology might give a superior comprehension of innovation reception since farmers manage the innovation and most likely see advances uniquely, in contrast to specialists and extension specialists (Bandiera and Rasul, 2006). These impressions of technology rely on their insight and information about the development and financial circumstance. The degree of information relies upon the farmer's level of schooling and training that they acquire on the innovation. An investigation in Ethiopia revealed that school level and admittance to training impacted farmers' discernment to embrace soil and water protection innovations (Moges and Taye, 2017).

Farmers' assessment of yield and absolute advantage experienced in twelve months affect the inclination for a specific innovation. Innovations that need fewer resources have a lower hazard premium and are more affordable. Thus, they have a higher likelihood of being taken on. Then again, innovations that require new abilities are tedious and expensive to learn and thus may have a slower adoption. Along these lines, the degree of interest relies upon the net financial advantages of the innovation as compared to different alternatives (Bandiera and Rasul, 2006).

### 2.7.4. Financial components

Financial and socio-economic factors, for example, farm magnitude, the earnings of the family head, ownership of income-producing infrastructure, and livestock, impact technology adoption. A few investigations revealed a negative impact of homestead size on technology adoption (Aryal et al., 2018). Small farm size might offer a motivating force to embrace input-intensive technology, for example, labor-concentrated or land-saving innovation. Farmers with a small land size are highly likely to take on land-saving innovations like nursery innovation and no grazing as an option, in contrast to expanded farming output (Mwangi and Kariuki, 2015). Families with smaller land sizes can select to attempt new improvements contrasted with those with larger land sizes. Resource proprietorship emphatically impacts innovation reception. Authors detailed that farmers with more resources had a higher probability of having cash, hardware, and materials required for new advancements ( Rosenstock et al., 2019). Resources produce the earnings vital for acquiring inputs related to adopting new advancements. Non-agricultural earnings permit farmers to meet capital expenses related to innovation and diminish the danger of exploring different avenues regarding innovation (Dahlin and Rusinamhodzi, 2019).

### 2.8. Determinants of CSA adoption and its intensity

The agriculture sector, particularly in developing countries, suffers the most from the effects of climate change. The lack of enthusiasm for climate-smart agriculture (CSA) practices raises concerns about the factors influencing adaptation determinants. The findings of a study by Zakaria et al. (2020) on the factors influencing the adoption of climate-smart agricultural technologies (CSAT) by rice farmers in Northern Ghana showed that, of the farmer-level attributes, only expertise in rice farming had a significantly positive impact on the rate of CSAT adoption. A farmer's CSAT adoption intensity will rise by 2.4% for every extra year of expertise in rice farming. Farmers will likely become aware of new technologies' advantages as they cultivate rice. This finding is in line with earlier studies that found that farming experience was a key predictor of adopting agricultural technologies to raise farmer output. The findings also indicated that the magnitude of the farm and the proximity from it to the marketplace (the"farm-market distance") had a substantial positive effect on farmers' intensity of CSAT adoption, while the "home-farm distance" had a substantial negative impact.
The cost of running a farm production is significant, and farmers who expand their operations might not be able to pay for CSAs at their current pay. As a result, a farmer is more likely to be able to employ more CSA to boost production on smaller farm sizes since this has a lower cost. According to the respondents in the study by Zakaria et al. (2020), farmers who could not use CSA because of the heavy price of the technology tended to expand their farms, increasing their overall output. The consequences are that the chance of intensity of adopting CSATs will decrease if both farm-market-distance and home-farm-distance rise by even 1 km. The issue may arise from the difficulty extension agents have in reaching smallholder farmers whose farms are far from their homes and the nearest market, hindering their adoption of more advanced production systems. Compared to farmers who did not receive such instruction, farmers who received it were 49.8% more likely to adopt CSA. Also significant at 1% was the variable accessibility to research scientists.

Consequently, farmers with access to research scientists had a 57.3% higher likelihood of adopting CSATs than farmers without. Access to mass media boosted the rate of farmers adopting CSATs by 34.5%. (i.e., radio and television). Farmers who had access to radio and television had exposure to broadcast agricultural programs, which educated them about planting times, strategies for coping with climate change, credit resources, and input and output channels to help them embrace the available CSATs. Farmers' adoption of climate-smart farming methods increased significantly when they had accessibility to information. Therefore, they need to be exposed to these sources of information and allocate support to modernize these facilities (Birthal et al. 2015). National and global agricultural institutions play a significant part in improving farmers' understanding of CSATs to confront climate risks and disruptions in the agriculture sector.

## 2.9. The factors that influence household food security.

Food is one of the most important service delivery areas for a household's well-being and development. Against this backdrop, the literature suggests that rural South African households face high food insecurity. Thus far, an investigation into the causes of household-level food insecurity is required. Gatobu et al. (2021) studied the socio-economic factors influencing household food security in West Pokot County, Kenya. This study's findings reveal that smallholder farmers in West Pokot County cannot fully engage in farming activities due to inadequate financial resources. Obtaining sufficient funding to buy farming input has an impact on agricultural production. Smallholder farmers could not purchase more seeds, fertilizers, and other inputs due to a lack of funds. Yahya and Xiaohui (2014) also claimed that smallholder farmers' efforts to ensure food security at home are hampered by their lack of access to resources like land and finance. Abu and Soom (2016) discovered that the family head's income had a favorable effect on food security. Limitations like a lack of financial availability were some things working against Nigerians attaining food security. Education, conceived in terms of the abilities and skills employed in farming, was another societal component. The results revealed that few sample respondents had taken part in capacity-building and training in this area. The majority of those surveyed reported having little to moderate agricultural expertise and relying on their neighbors and relatives for knowledge on agricultural production. Since they make decisions regarding household expenditures, the level of education of the head of the household is crucial. Food security at home is anticipated to benefit from education.

The proportion of households with access to food rises with education level. This is anticipated because people will be able to implement more cutting-edge farming technologies on their farms as their level of education rises, increasing their production. The level of formal education gained aids farmers in effectively using production information since a more educated individual learns more and, in turn, is a better producer (Gatobu et al., 2021). Furthermore, Enyedi and Volgyes (2016) insist that education is crucial for agricultural transformation since it improves farmers' capacity for information reception, decoding, and comprehension. The usage of more advanced technologies in agriculture and, consequently, farm productivity is thought to be influenced by the education level of farmers. The likelihood that the home will have enough food increases with the level of education of the head of the household.

The household head's education might increase awareness of the potential benefits of upgrading agriculture with technical inputs, enable them to comprehend fertilizer package instructions, and diversify household revenues, improving home food availability (Gatobu et al., 2021). According to Amaza et al. (2009), having more education makes a person a better producer because they can use the data they acquire about production more effectively. The usage of new technologies in agriculture and farm productivity is thought to be influenced by education levels. An education degree influences the possibility of increasing food security, livelihood activities, and poverty levels (Gatobu et al., 2021).

### 2.10. Effect of CSA adoption on smallholder household food security

Climate-smart agriculture (CSA) is one approach to improving food security in a changing climate. Since 2010, the Department and an NGO have promoted CSA with farmers through climate field schools. Adopting CSA by smallholder farmers can increase output, resulting in improved food security outcomes. Wekesa et al. (2018) studied the effect of climate-smart agricultural practices on household food security in smallholder production systems at the micro-level with evidence from Kenya. This study used the Household Food Consumption Scores (HFCS) and Household Diversity Scores (HDDs). It revealed that the maximum overall impact on the welfare of farmers, as determined by HFCS and HDDs, was a comprehensive CSA package containing crop management procedures, field management techniques, farm risk mitigation practices, and soil management. This suggests that compared to their rivals who decided not to utilize any CSA practices, farmers who utilized this package were 56.83% and 25.44% more food secure. Therefore, if farmers adopt climate-smart technologies included in this package, they may have greater food security.

This program covers a wide range of field and soil conditions and mitigates soil deterioration for stable production, making it highly complete. So, for farmers to gain the most from CSAs, they must use as many of them as possible. The likelihood of using this package was discovered to be favorable influenced by gender, farm size, and farm assets. Its use was more frequent on larger, privately owned plots for households headed by men with more farmland. Thus, if used in conjunction and to a greater extent, CSAs have the potential to reduce food insecurity among smallholder farmers. Farmers should be urged to implement larger CSA packages that include at least one member in each of the four categories of crop management, field management, risk reduction strategies, and specific soil management methods to have a more significant impact on the state of food security,

## 2.11. Factors that influence maize yields on smallholder farmers' yields

Climate variability has a high impact on rain-fed food crop production. Most of the population in developing countries relies on rain-fed seasonal maize, the backbone of the country's economy. It is critical to investigate the factors that influence maize yields. Using various machine learning approaches, Ditta et al. (2020) investigate the relative influences of multiple biophysical, socio-economic, and crop management features in determining maize yield variability. Soil fertility status was assessed in 180 farms and correlated with survey data on maize yield, socio-economic conditions, and agronomic management. Farm size, total labor, soil factor, seed rate, fertilizer, and organic manure were identified as influential factors.

The study by Tamane et al. (2016) explored the effect of soil nutrient status, agronomic practices, and socio-economic factors on maize yield attained by smallholder farmers in the Dedza District of Malawi. The results revealed that households using improved varieties combined with improved management practices such as NPK, urea, and animal manure were obtaining higher yields of maize. Regarding soil factors, boron (B) and nitrogen (N) which are critically deficient in the area, were significantly associated with maize yield increase. Lastly, Weeds, seed spacing, plant density, and fertilizer application all played a significant role in maize yield.

The weather and non-weather factors influence crop production in the O.R. Tambo District Municipality, South Africa (Masiza et al., 2021). The findings show that key agrometeorological variables such as surface moisture content, growing degree-days, and precipitation influence maize yield even in ideal weather conditions, while seed variety, fertilizer application rate, soil pH, and machinery ownership also play a role.

The study was conducted in southern Ethiopia to assess smallholder farmers' productivity and technical efficiency and to identify factors that influence productivity and technical efficiency. The results showed that labor, fertilizer, and oxen power significantly impacted maize productivity. The mean technical efficiency was discovered to be 40%, indicating a significant technical inefficiency among smallholder farmers in maize production. Essential factors that significantly affected the technical efficiency were agro-ecology, oxen holding, farm size, and use of high-yielding maize varieties (Geta, et al., 2013).

## 2.12. The effect of CSA adoption on smallholder farmers' maize yields

Climate change has a significant impact on the maize production of smallholder farmers. Higher temperatures can reduce yields while encouraging the growth of weeds, pests, and diseases. The adoption of CSAs is proposed as a solution to build resilience for smallholder farmers to grow crops in changing climatic conditions. The effect of CSA adoption on smallholder maize yields is a critical area for empirical research. Tiri et al. (2020) investigated the distributional effects of adopting drought-tolerant maize varieties (DTMVs) on the productivity outcomes of rural farming households in Nigeria. The empirical findings revealed that adoption significantly impacts the distribution of maize yield and farming households' welfare. Adoption has a more significant impact on the lower tails of yield distributions, implying that the strategic roles of DTMV adoption in increasing productivity and reducing poverty are stronger among poor farming households. These findings highlight the importance of effectively targeting and disseminating improved agricultural technologies in increasing maize yield and improving rural farmers' welfare outcomes in Nigeria.

Pangapanga-Phiri and Mungatana (2021) investigated the factors that influence the adoption of CSA practices and their impact on the technical efficiency of maize production in drought-affected households. Their study revealed that drought episodes increase the adoption of organic manure by 76% and soil and water conservation by 29%. The study reveals that households are 63% technically efficient, implying that they can increase current maize production by 37%. Furthermore, the study found that using organic manure and inorganic fertilizers on the same farm improves maize production technical efficiency by 18%, with the effect being more noticeable in drought-affected households.

Kichamu-Wachira et al. (2021) studied the effects of climate-smart agricultural practices on crop yields, soil carbon, and nitrogen pools in Africa by using a meta-analysis of 60 studies. The study's results revealed that crop yields are substantially higher with CSA management than under traditional management. For instance, crop yields were boosted by 63.5% and 5.8%, respectively, by green manure and crop residue retention. This is consistent with earlier research that showed agricultural residue retention techniques significantly boost crop yields. Their research also backs up the assertion that using conservation tillage (i.e., no-tillage and decreased tillage) alone does not significantly affect yields compared to traditional management (Corbeels et al., 2020).

Different CSA management techniques may affect yield depending on how much fertilizer they supply to the soil. The study demonstrated that nitrogen fertilizer significantly impacted how CSA affected crop production. Green manure and crop residue retention were observed to boost crop yields at low levels of fertilizer addition (1-99 kg N ha1). However, conservation tillage had an effect at high levels of fertilizer addition (>100 kg N ha1). This supports earlier research that indicated green manure increased productivity with less fertilizer (Lu, 2020). Their analysis also suggests that farmers may need to use nitrogen fertilizer at levels more significant than 100 kg N ha1 for conservation tillage (on its own) to increase yields.

The findings indicate that the CSA practice's implementation duration impacts crop performance and yields. Other studies have shown that the cumulative effects of unpredictable weather patterns on agricultural yields may account for the absence of a substantial yield response in the longer-term CSA (Kichamu-Wachira et al., 2021). In tests lasting longer than three years, their study also noticed a decline in yields under crop residue retention, which may be related to the inhibition of seedling emergence brought on by heavy crop residue retention. According to the findings of their meta-analysis, CSA activities increase soil carbon concentration. For example, they increase soil organic carbon concentration by including agricultural residue retention as carbon inputs. It has been discovered that the degradation of crop residue retention encourages microbial growth, raising soil organic carbon. On the other hand, conservation tillage's capacity to lessen soil disturbance and the pace at which soil organic matter decomposes also enhances soil organic carbon stores (Kichamu-Wachira et al., 2021).

Because CSA methods improve soil quality and crop productivity, they support climate mitigation and adaptation. For instance, according to the research, conservation tillage combined with either crop residue retention or green manure increased soil organic carbon concentration and yield, most likely due to the synergistic effects of added organic matter and minimum soil disturbance. The concentration of accessible soil organic carbon increased due to the higher carbon substrate concentrations in green manure and crop residue retention (Kichamu-Wachira et al., 2021). Even though heavy fertilizer addition is marketed as a technique to increase yields by supplying nutrients to the soil, the findings show that combined CSA practices provided greater yields and soil organic carbon content returns than traditional practices at low fertilizer levels (Kichamu-Wachira et al., 2021).

## 2.13. Review of analytical techniques of the study

### 2.13.1. Household Hunger Scale

The Household Hunger Scale HHS is a household food hunger indicator derived from research to adapt the United States household food security survey module for use in a developing country context and from research to assess the validity of the Household Food Insecurity Access Scale (HFIAS) for cross-cultural use. The HHS uses four weeks (30-days) recall period for collecting household food security status data. A 4-week call period is assumed to reduce the risk of biasness due to problems with accurate recalling. A recall period of more than four weeks will not capture the full extent of the experience, and fluctuations in food accessibility are common within a month ( Ballard, 2011). Many studies do not commonly use the HHS. However, this indicator differs from other household food insecurity indicators in that it was developed and validated specifically for cross-cultural use (Nkegbe et al., 2017). In most studies, Gebreyesus et al. (2015), Desiere et al. (2015), Mohammadi et al. (2012), Becquey et al. (2010) calculate the food security status using the HFIAS. The HHS focuses on the food quantity dimension of food access, while the common HFIAS Measures the dietary quality.

Regassa and Stoecker (2012) used the HHS to count household hunger, and the results show that 29·0 % and 5·6 % of households fell into the moderate and severe household hunger categories. The model was used to calculate the factors influencing food security in northern Ghana. According to the estimates, crop producers, multiple crop producers, yield, and commercialization are key policy variables influencing food security. Based on the findings, stakeholders should increase efforts to improve farm household productivity and provide necessary market infrastructure to boost commercialization, as these are critical to ensuring food security (Nkegbe,2017).

In Southern Ethiopia, researchers investigated small-holder farmers' coping strategies for enduring household food insecurity and hunger. The findings revealed that approximately 54% of households were experiencing mild to severe food insecurity, with approximately 19% falling into the household hunger category (as measured by the Household Hunger Scale) for more than six months of the year. The study suggested promoting income-generating activities, improving microfinancing efficiency, creating employment opportunities in local areas to discourage unskilled labor migration, and farm diversification (Regassa,2012).

### 2.13.2. Double-hurdle model (Probit and Logistic regression models)

The double-hurdle model, introduced by Cragg (1971), expresses that an individual's decision on the extent of adopting the technology is the result of two processes. A double-hurdle count data model with the inverse mill ratio (IMR) as a regressor was used to estimate the factors influencing farmers' adoption of adaptation strategies while accounting for selection bias.

#### 2.14.2.1. Probit regression Model-First hurdle

In the Probit regression model, the decision to adopt the technology can be modeled as a dependent unobservable variable representing an individual's decision’s discrete decision whether or not to adopt the innovation. Furthermore, the independent variables hypothesized to affect the individual's decision to adopt the innovation takes the value of 1 if the household adopts CSA and 0 if otherwise in the Probit Regression Model. Aman et al. (2014) applied a double hurdle model to analyse the determinants of the commercialization decision and level of commercialization. In the first hurdle, the Probit Regression Model revealed that gender, distance to the nearest market, and cultivated land played a significant role in smallholder commercialization decisions. The study recommends designing appropriate intervention mechanisms focusing on the abovementioned factors to improve the performance of horticultural crop commercialization.

Adetomiwa et al. (2020) conducted an empirical investigation into the impact of the Fadama III group participation program on the food security status of rural households in South West, Nigeria. Gender (p0.10), occupation (p0.01), extension contacts (p0.01), and awareness (p0.05) all had a significant influence on the decision to participate in the Fadama III program in South West Nigeria. Gender, farm size, non-farm income, membership in the association, and income from the Fadama III program were significant positive determinants of the food security status of Fadama III program participants, while gender and non-farm income were significant positive determinants of the food security status of non-participants in South West, Nigeria, where household size was a significant negative determinant. Since participation in the Fadama III program leads to improved food security, such community development programs should be designed to accommodate many potential farmers to improve their well-being and food security.

Sulaiman et al. (2021) assess the Fadama III development project's impact on poor rural farmers in Kano state's Danbatta local government area. The results show that marital status, education level, and farming experience all have a 21%, 37%, and 65% influence on treatment (participation) in the Fadama III project, respectively, whereas household size does not influence treatment (participation) in the Fadama III project. Furthermore, 71% of the time, the observed heterogeneities could predict treatment (participation). Furthermore, household income and productivity have increased; thus, the study recommends training sessions in order to employ strategies that reflect best management practices in order to ensure sustainability in agricultural productivity, adequate support of storage facilities, awareness creation of insurance policies, and finally, improvement in agricultural productivity in agricultural technologies to increase crop yields.

#### 2.14.2.2. Poisson regression-Second hurdle

An inverse Mills ratio (*IMR)* predicted from the first-stage probit regression is added as a regressor to account for the selection bias in the second hurdle. The results show that the IMR was statistically significant, indicating selection bias. The null hypothesis (no selection bias) is rejected because the coefficient is significant. As a result, many studies use a double-hurdle model to account for a selection bias problem. Zondi (2021) evaluated the effect of the commercialization of indigenous crops on smallholder farmers' household food security. The Poisson regression model (with endogenous treatment model) was used to analyze the study's findings. Extension services, marital status, household size, and having a member living with HIV significantly positively influenced smallholder farmers' household food security. It was concluded that there is still room for improvement and much work to be done to reduce the growing number of food-insecure smallholder farmers. Furthermore, it was suggested that the government intervene by providing trained extension officers to assist smallholder farmers in overcoming their challenges.

Ndlovu et al. (2021) investigated the factors influencing the level of value chain participation and the implications for smallholder farmers in KwaZulu-Swayimane Natal's area. Purposive sampling was used to collect primary data from farming households. The data were analyzed using descriptive statistics and the hurdle model. According to the Poisson regression model results, the respondent's age, marital status, farm income, household size, cooperative, market information, radio, extension officer, and formal education significantly influenced smallholder farmers' participation decisions in agricultural value chains. The results further showed that off-farm income, marital status, cooperatives, access to credit, access to irrigation schemes, radio, extension officers, contact with non-government organizations, and formal education significantly influenced the level of value chain participation of the smallholder farmers. It can be concluded that the level of endowment in the physical, financial, and human resources influence participation. Further, the farmer's connectivity with the external world outside the village improves the outcomes and level of success. It is recommended that a market-led approach to farmer development be adopted to improve the commercial prospects of farmers while bolstering food security.

### 2.13.3. Logistic Regression model

Logistic regression is a multivariate regression and permits an analysis where several independent variables forecast a dependent variable in the presence or absence of an outcome based on the values of a set of predictor variables. The main advantage of Logistic Regression is the usability of each type of variable. For example, variables may be either continuous or discrete or any combination of both types, and there is no need to have normal distributions (Lee, 2005). By nature, Logistic Regression analysis is not affected by dependent and independent variables being qualitative, quantitative, or categorical. Therefore, Logistic Regression is beneficial to the research for interpreting binary and categorical data, especially (Agresti, 1996). Abegunde et al. (2019) used the Logistic regression model to assess the determinants of CSA adoption by smallholder farming households. The findings indicate that educational status, farm income, farming experience, farmland size, contact with agricultural extension, media exposure, agricultural production activity, membership in an agricultural association or group, and perception of the impact of climate change are statistically significant and positively correlated with the level of CSA adoption. While off-farm income and farm-to-homestead distance were statistically significant, they were negatively correlated with CSA adoption level. Mncube (2022) used the Logistic Regression model to determine the factors influencing social cash transfer (SCT) programs among smallholder farmers. The age and gender of the household head positively influenced social cash transfer programs by using both the odd ratio and marginal models. The marginal model, however, reflects contrasting results for the gender of the household head, as SCTs favor male-headed households over female-headed households. The study further presents contradictory results, indicating a positive and significant influence of educational level and access to credit on access to SCTs

### 2.13.4. Ordered Regression model

McKelvey and Zavoina (1971, 1975) proposed the extended ordered probit regression model to analyze ordered, categorical, non-quantitative choices, outcomes, and responses. Greene and

Hensher (2010) define the model platform as an underlying random utility or latent regression model. It understands that various response variables are indexed. This model has rarely been used to assess CSA adoption's impact on food security. The model has been commonly applied in vehicle crash severities studies. For example, Shen *et al.* (2021) used an extended ordered probit model to investigate the factors influencing bus-crash severity levels in the U.K. The marginal effect of variables confirms that variables such as road-section, frontal-impact-crash, wet-road, junction-exit, and main-way increase the likelihood of severe injuries. Furthermore, the influence of lower-speed-limit, roundabout, urban-crash, parking-crash, and moderate-speed-limit variables increases the likelihood of minor injuries. This study also identifies the factors that have inconsistent effects on the outcome of bus and passenger-car accidents. To improve bus safety, authorities must carefully consider the heterogeneity and specificities of the factors influencing bus crash severity and develop appropriately targeted policies.

In the study of Lamondia *et al*. (2014), they applied an extended probit regression model to investigate factors influencing non–distance-based definitions of long-distance travel and leisure travel. According to the findings of ordered probit analysis, education and income increased most types of long-distance travel, whereas having a spouse or children decreased some types of long-distance travel. In general, limited factors had the same effect on work and non-work travel and modes of transportation. The factors also differed depending on the type of trip. Even for estimating the frequency of non-work trips, commute and employment factors were useful. The findings imply that future data collection for long-distance travel can be tailored to the specific definition under consideration.

### 2.13.5. Conditional Instrumental Variable Quantile Treatment Effects (IV-QTE)

The IV-QTE approach is used to control for selection bias caused by both observed and unobserved factors. The model is commonly used in studies evaluating the impact of new technology on farmers' welfare, including their production and income.

The model was used by Tiri et al. (2020) to address the study objective of examining the impact of the Growth Enhancement Support Scheme (GESS) subsidy program on the welfare of smallholder maize farmers in Kano State. The findings show that the impact of the GESS subsidy was statistically higher at the lower tail of the income distribution, and the proportion of the poor who benefited the most from the GESS program varied by age, years of education, market participation, and area cultivated.

Dakyong (2020) used IV-QTE to estimate the impacts of cultivating Nerica on welfare along the income distribution. The results show that Nerica adoption increases households' expenditure across the entire distribution of income. The quantile treatment effects are statistically different from the average treatment effects, suggesting substantial heterogeneity in the impacts of the adoption of Nerica on welfare. We also find that, in absolute terms, the impact for farmers located in the upper half of the income distribution is the largest. However, farmers at the bottom of the income distribution also experienced a large proportional increase in welfare

Alia et al. (2018) used the same model to estimate the impacts of cultivating Nerica on welfare along the income distribution. The study finds that Nerica adoption increases households' expenditure across the entire income distribution. The quantile treatment effects are statistically different from the average treatment effects, suggesting substantial heterogeneity in the impacts of the adoption of Nerica on welfare. We also find that, in absolute terms, the impact for farmers located in the upper half of the income distribution is the largest.

Olagunju et al. (2020) used the IV-QTE to investigate the distributional impacts of drought-tolerant maize varieties on productivity and welfare outcomes and revealed that adoption significantly impacts the distribution of maize yield and farming households' welfare. In particular, the effects of adoption are larger at the lower tails of the distributions of yield and welfare outcomes, suggesting that the strategic roles of DTMV adoption in raising productivity and reducing poverty are better among poor farming households.

## 2.14. Theoretical Framework: Vulnerability Framework

The global climate change increases the need to address the consequences of the change's impact. These changes raise questions such as: who and what is vulnerable to multiple climate changes and where? Research that has been conducted revealed that in Sub-Saharan countries, smallholder farmers are the most vulnerable group to climate change. Smallholder farmers are characterized by being heterogeneous, and they rely on rainfed for most of their livelihoods. Therefore, the study adopts the vulnerability framework to evaluate the impact of climate change on smallholder farmers and how they adapt to climate change.

The vulnerability framework concerns itself with investigating the vulnerability of human and ecological frameworks to climate change and their capacity to adjust to changes such as climatic hazards (Brooks, 2003). The hazard should be explicitly stated, as this will provide more relevant insight into a system's vulnerability and adaptive capacity. Once the risk or hazard has been acknowledged, the appropriate adaptive response can be utilized to address the environmental hazard, which may occur over a wide range of timescales and require an assortment of reactions. Additionally, a framework might be able to adjust to particular sorts of risks but not to other risks (Brooks, 2003). This study acknowledges the impact of smallholder farmers on climate change by looking at how climate change affects smallholder farmers' maize production, which is highly identified as their stable crop.

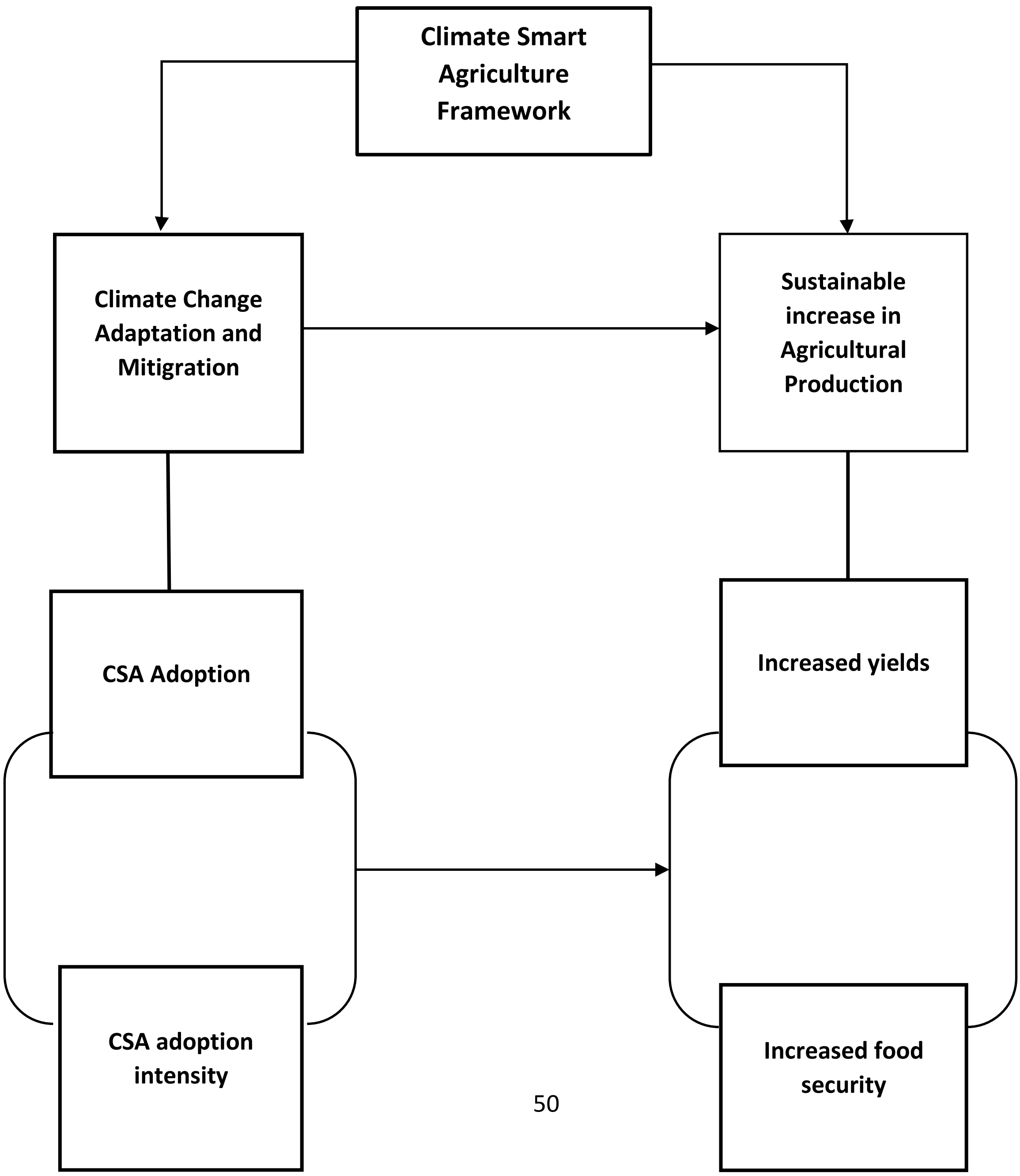
The developing collections of writing on vulnerability and adaptability contain a comprehensive list of terms. This includes vulnerability, sensitivity, resilience, adaptation, adaptive capacity, risk, hazard, and coping (IPCC, 2001; Adger et al., 2002; Burton et al., 2002). The framework demonstrates that vulnerability is not only described by exposure to hazards alone but also in the sensitivity and resilience of the system experiencing such hazards. The theory of the framework suggests that if the system has a high ability to adjust, it has a low susceptibility to risks (IPCC,2007).

In this study, Climate Smart Agricultural Practices (CSA) have been identified as a strategy to help farmers build resilience and adapt to climate change. As defined by FAO, CSA's primary focus is increasing agricultural productivity, adaptability, and resilience to climate change. In this study, resilience was derived from the ability of smallholder farmers to adopt CSA practices and improve maize yields and food security status. Different factors that affect smallholder farmers to adopt and intensify CSA were identified, and their impact on food security and maize yields were determined. The factors include drought, gender, marital status, smartphone, access to market information, farmer association, the main source of income, household size, age, and level of education.

### 2.15. Conceptual Framework

Various research methodologies are used to estimate the specific objectives listed in this dissertation. Climate Smart Agricultural Practices framework contributes to achieving sustainable development goals. It integrates the three dimensions of sustainable development by jointly addressing food security and climate challenges. It comprises three main pillars: 1. sustainably increasing agricultural productivity and incomes; 2. adapting and building resilience to climate change; 3. reducing and removing greenhouse gas emissions, where possible. It is, therefore, important to understand how socio-economic and institutional factors interact to enhance or constrain the adoption of CSA by smallholder farmers, which in turn affects household food security and yields.

The conceptual framework provided in this study shows that smallholder farmers are affected by many factors; academics have researched a few factors that can be characterized into four fundamental classes, including socio-demographic qualities, institutional elements, farmer impression of the innovation, and financial elements (Mozzato et al., 2018). Variables influencing the adoption of CSA, food security and yields might be noticeable and undetectable, like perspectives toward the adoption of CSA. People's different inclinations for vulnerability might mirror the innovation adoption likelihood. It was conceptualized that these factors affect CSA adoption. These factors' positive influence on smallholder farmers leads to increased CSA adoption, which leads to more resilience for smallholders to withstand harsh climatic conditions resulting in increased yields and food security. Figure 1 illustrates the interrelationship among the critical variables in the study.



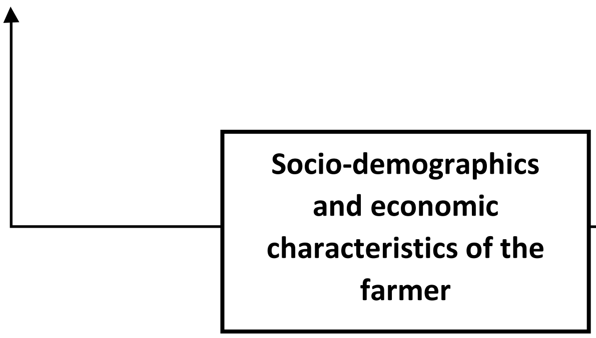



**Figure 1**: Conceptual Framework

characteristics. It was carried out to show the mean averages, standard deviations, and percentages of the various factors influencing CSA adoption and the intensity of CSA adoption among smallholder farmers. Internal, external, and socio-demographic factors influence CSA adoption and intensity among smallholder farmers. In order to meet the objectives, the study used a variety of econometric analytical tools. The double-hurdle model (DHM) was used to identify factors influencing CSA adoption among smallholder farmers. The DHM was ideal for the study because it assumed that smallholder farmers' adoption of CSA practices could be modelled as a two-step decision process. First, smallholder farmers decide whether or not to participate in CSA practices, and then they decide how many CSA practices to adopt. The model was also used to account for sample selection bias.

The Household Hunger Scale (HHS) was used to assess the food security status of households in the study area. This HHS collects household food security status data over a four-week (30-day) recall period. A 4-week call period is assumed to reduce the risk of bias due to recalling problems. To compute the HHS score, a new variable was created that recorded the response to each frequency-of-occurrence question from three frequency categories. The new variable was coded as 1 for "rarely," 2 for "sometimes," 3 for "often," and 0 for households that answered no to each corresponding occurrence question. The HHS score was calculated by adding the values of the new variables for each household. The HHS indicator is created using these values. To tabulate the HHS indicator, the HHS score was subjected to two different value cuts (>1 and >3). The three Household Hunger Categories are a 0-1 HHS score, which indicates little to no hunger in the household, and a 2-3 HHS score, which indicates moderate hunger. An HHS score of 4-6 denotes severe hunger in the household ( Ballard, 2011).

The study employed a Logistic Regression model to identify the factors influencing food security among smallholder farmers. Logistic regression is a type of multivariate regression analysis that allows for predicting the presence or absence of an outcome based on the values of a set of predictor variables. The main advantage of logistic regression is the usability of each variable type. The Extended ordered probit regression model was used to assess the effect of CSA adoption on smallholder household food security. This model was more helpful in this study because it recognizes the indexed nature of different response variables. The detailed model specifications for the analytical tools are found in Chapter 5.

The study on the impact of CSA adoption on smallholder farmers' yields used Conditional IV-QTE to correct for endogeneity and sample selection. The model was used to account for CSA adoption endogeneity, which can significantly overestimate or underestimate the impact of CSA adoption on yields. Similarly, the complete model specification is provided in Chapter 6 to avoid information duplication.

### 2.16. Conclusion

Climate change will adversely influence agricultural productivity in Africa, where most smallholder farmers depend on rain-fed crops such as maize yields for their livelihoods and family food security. In order to upgrade the ability to withstand changing climates with trivial external investment, advancing customary adaptive techniques that are achievable to these asset-restricted smallholder farmers is critical. Accessibility and availability of important, convenient, and dependable climate data empower farmers to prepare successfully and settle on educated choices regarding innovations. These methodologies, if they can be utilized, can act to assemble farming communities that can withstand changing climatic conditions. This literature review explored climate change concerning smallholder maize farmers in Sub-Saharan countries.

## 2.17. References


Abegunde, V.O., Sibanda, M. and Obi, A., 2019. Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), p.195.

Abu, G.A. and Soom, A., 2016. Analysis of factors affecting food security in Benue State, Nigeria's rural and urban farming households. *International Journal of Food and Agricultural Economics (IJFAEC)*, *4*(1128-2016-92107), pp.55-68.

Adetomiwa, K., Mayowa, O.O., Adebayo, A.I. and Victor, O.O., 2020. Impact assessment of Fadama III Group Participation on the food security status of rural households in South West, Nigeria. *Journal of Agriculture and Sustainability*, *13*.

Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M. and Adger, N., 2002. Adaptation to climate change: Setting the Agenda for Development Policy and Research. *Progress in Development Studies*, *3*(3), pp.179-195.

Agresti, A. and Hitchcock, D.B., 2005. Bayesian inference for categorical data analysis. *Statistical Methods and Applications*, *14*(3), pp.297-330.

Al-Hassan, R.M., Kuwornu, J.K., Etwire, P.M. and Osei-Owusu, Y., 2013. Determinants of choice of indigenous climate-related strategies by smallholder farmers in Northern Ghana. *British Journal of Environment and Climate Change*, *3*(2), p.172.

Alia, D.Y., Diagne, A., Adegbola, P. and Kinkingninhoun, F., 2018. Distributional Impact of Agricultural Technology Adoption on Rice Farmers' Expenditure: The Case of Nerica in Benin. *Journal of African Development*, *20*(2), pp.97-109.

Allen, K., 2003. Vulnerability reduction and the community-based approach: A Philippines study. In *Natural disaster and development in a globalizing world* (pp. 186-200). Routledge.

Almekinders, C., 2000. The importance of the informal seed sector and its relation with the legislative framework. *GTZ-Eschborn*.

Altieri, M.A. and Koohafkan, P., 2008. *Enduring farms: climate change, smallholders and traditional farming communities* (Vol. 6). Penang: Third World Network (TWN).

Aman, T., Adam, B. and Lemma, Z., 2014. Determinants of smallholder commercialization of horticultural crops in Gemechis District, West Hararghe Zone, Ethiopia. *African journal of agricultural research*, *9*(3), pp.310-319.

Amaza, P., Abdoulaye, T., Kwaghe, P. and Tegbaru, A., 2009. Changes in household food security and poverty status in prosab area of Southern Borno State, Nigeria. *IITA, Ibadan, Nigeria*.

Andersson, J.A. and D'Souza, S., 2014. From adoption claims to understand farmers and contexts: A literature review of Conservation Agriculture (C.A.) adoption among smallholder farmers in southern Africa. *Agriculture, ecosystems & environment*, *187*, pp.116-132.

Archer, E.R., 2010. Climate change–a critical emerging issue. DEA.

ASFG (2013).Supporting smallholder farmers in Africa: A framework for an enabling environment. International NGOs are working together with Africa's smallholder farmer, London.

Ballard, T., Coates, J., Swindale, A. and Deitchler, M., 2011. Household hunger scale: indicator definition and measurement guide. *Washington, DC: Food and nutrition technical assistance II project, FHI*, *360*, p.23.

Bandiera, O. and Rasul, I., 2006. Social networks and technology adoption in northern Mozambique. *The economic journal*, *116*(514), pp.869-902.

Barham, B.L. and Weber, J.G., 2012. The economic sustainability of certified coffee: Recent evidence from Mexico and Peru. *World Development*, *40*(6), pp.1269-1279.

Baruah, B., 2017, February. Renewable inequity? Women's employment in clean energy in industrialized, emerging and developing economies. In *Natural resources forum* (Vol. 41, No. 1, pp. 18-29). Oxford, U.K.: Blackwell Publishing Ltd.

Becquey, E., Martin-Prevel, Y., Traissac, P., Dembélé, B., Bambara, A. and Delpeuch, F., 2010. The household food insecurity access scale and an index-member dietary diversity score contribute valid and complementary information on household food insecurity in an urban West-African setting. *The Journal of nutrition*, *140*(12), pp.2233-2240.

Beegle, K., Christiaensen, L., Dabalen, A. and Gaddis, I., 2016. *Poverty in a rising Africa*. World Bank Publications

Beyene, A.D., Mekonnen, A., Kassie, M., Di Falco, S. and Bezabih, M., 2017. Determinants of adoption and impacts of Sustainable Land Management and Climate Smart Agricultural Practices (SLM-CSA): Panel data evidence from the Ethiopian highlands.

Brooks, N., 2003. Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for climate change research working paper*, *38*(38), pp.1-16.

Burton, I., Huq, S., Lim, B., Pilifosova, O. and Schipper, E.L., 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. *Climate policy*, *2*(2-3), pp.145-159.

Chamberlin, J., 2008. *It's Small World After All: Defining Smallholder Agriculture in Ghana* (Vol. 823). Intl Food Policy Res Inst.

Collier, P., Conway, G. and Venables, T., 2008. Climate change and Africa. *Oxford Review of Economic Policy*, *24*(2), pp.337-353.

Collins, M., Knutti, R., Arblaster, J., Dufresne, J.L., Fichefet, T., Friedlingstein, P., Gao, X., Gutowski, W.J., Johns, T., Krinner, G. and Shongwe, M., 2013. Long-term climate change: projections, commitments, and irreversibility. In *Climate change 2013-The physical science basis: Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change* (pp. 1029-1136). Cambridge University Press.

Corbeels, M., Naudin, K., Whitbread, A.M., Kühne, R. and Letourmy, P., 2020. Limits of conservation agriculture to overcome low crop yields in sub-Saharan Africa. *Nature Food*, *1*(7), pp.447-454.

Coumou, D. and Robinson, A., 2013. Historic and future increases in the global land area affected by monthly heat extremes. *Environmental Research Letters*, *8*(3), p.034018.

Coumou, D. and Robinson, A., 2013. Historic and future increases in the global land area affected by monthly heat extremes. *Environmental Research Letters*, *8*(3), p.034018.

Cousins, B., 2010. What is a 'smallholder'? Class-analytic perspectives on small-scale farming and agrarian reform in South Africa. In *Reforming land and resource use in South Africa* (pp. 102-127). Routledge.

Cragg, J.G., 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica: Journal of the Econometric Society*, pp.829-844.

Dahlin, A.S. and Rusinamhodzi, L., 2019. Yield and labor relations of sustainable intensification options for smallholder farmers in sub-Saharan Africa. A meta-analysis. *Agronomy for Sustainable Development*, *39*(3), pp.1-18.

Dahlin, A.S. and Rusinamhodzi, L., 2019. Yield and labor relations of sustainable intensification options for smallholder farmers in sub-Saharan Africa. A meta-analysis. *Agronomy for Sustainable Development*, *39*(3), pp.1-18.

Dakyong, T.G., 2020. *Impact of growth enhancement support scheme on productivity, welfare and income distribution of smallholder maize farmers in Kano* (Doctoral dissertation, Sokoine university of agriculture).

DEDEA (2013). Limpopo green economy plan: Including provincial climate change response. Available online:https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf. Accessed on 10 May 2015).

DEDEA. Limpopo green economy plan: Including provincial climate change response.Available online: https://www.environment.gov.za/sites/default/files/docs/limpopogreen_economyplan.pdf.2013. Accessed on 10 May 2015.

Desiere, S., D'Haese, M. and Niragira, S., 2015. Assessing the cross-sectional and inter-temporal validity of the Household Food Insecurity Access Scale (HFIAS) in Burundi. *Public Health Nutrition*, *18*(15), pp.2775-2785.

Dinar, A., Hassan, R., Mendelsohn, R. and Benhin, J., 2012. *Climate change and agriculture in Africa: impact assessment and adaptation strategies*. Routledge.

Dutta, S., Chakraborty, S., Goswami, R., Banerjee, H., Majumdar, K., Li, B. and Jat, M.L., 2020. Maize yield in smallholder agriculture system—An approach integrating socio-economic and crop management factors. *PloS one*, *15*(2), p.e0229100.

Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.F., Schmidhuber, J. and Tubiello, F.N., 2007. Food, fibre and forest products. *Climate change*, *2007*, pp.273-313.

EEA (2009). Soil and climate change. Available online: http://www.eea.europa.eu/themes/soil/climate. Accessed on 2015, May 2.

Enyedi, G. and Volgyes, I. eds., 2016. *The effect of modern agriculture on rural development: comparative rural transformation series*. Elsevier.

Food and Agriculture Organization. (2013). Multiple dimensions of food security. The state of food insecurity in the world. Rome, Italy.

Food and Agriculture Organization. (2015). The state of food insecurity (SOFI) in the world .Available online: www.fao.org.za. Accessed on 31 August 2022.

Food and Agriculture Organization. The state of food and agriculture. Rome: FAO. 2016. Available online:http://www.fao.org/3/a-i6030e.pdf. Accessed on 03 April 2021

Gatobu, C.K., Omboto, P. and Mining, P., 2020. Socio-Economic Factors that Influence Household Food Security in West Pokot County, Kenya.

Gatobu, C.K., Omboto, P. and Mining, P., 2020. Socio-Economic Factors that Influence Household Food Security in West Pokot County, Kenya.

Gautam, Y. and Andersen, P., 2016. Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of rural studies*, *44*, pp.239-249.

Gbetibouo, G.A., 2009. *Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa* (Vol. 849). Intl Food Policy Res Inst.

Gebreyesus, S.H., Lunde, T., Mariam, D.H., Woldehanna, T. and Lindtjørn, B., 2015. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia?. *BMC nutrition*, *1*(1), pp.1-10.

Geta, E., Bogale, A., Kassa, B. and Elias, E., 2013. Productivity and efficiency analysis of smallholder maize producers in Southern Ethiopia. *Journal of Human Ecology*, *41*(1), pp.67-75.

Gift, N.M., 2014. Analysis of marketing channels used by smallholder crop farmers in Vryheid (Abaqulusi) Muni cipality, Kwazulu-Natal. *Unpublished Dissertation*.

Gill, T.B., Bates, R., Bicksler, A., Burnette, R., Ricciardi, V. and Yoder, L., 2013. Strengthening informal seed systems to enhance food security in Southeast Asia. *Journal of Agriculture, Food Systems, and Community Development*, *3*(3), pp.139-153.

Gillman, S., 2019. Small farms produce more food than statistics show. *Horizon: The E.U. Research & Innovation Magazine*.

Greene, W.H. and Hensher, D.A., 2010. *Modeling ordered choices: A primer*. Cambridge University Press.

Hassan, R.M. and Nhemachena, C., 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, *2*(311-2016-5521), pp.83-104.

Haysom, G., Crush, J. and Caesar, M., 2017. No. 03: The Urban Food System of Cape Town, South Africa.

Hazell, P.B. and Haggblade, S., 1990. *Rural-urban growth linkages in India* (Vol. 430). World Bank Publications.

Hove, M. and Gweme, T., 2018. Women's food security and conservation farming in Zaka District-Zimbabwe. *Journal of Arid Environments*, *149*, pp.18-29.

http://wdi.worldbank.org/table/4.2. Accessed on 27 September 2022

International Food Policy Research Institute (IFPRI) The Future of Small Farms for Poverty Reduction and Growth. 2020. Discussion Paper 42. Available online: http://www.ifpri.org/sites/default/files/pubs/2020/dp/vp42 Accessed on 20 April 2015.

International Fund for Agricultural Development (IFAD) Rural Poverty Report (2010).Available online: http://www.ifad.org/rpr2011/. Accessed on 03 May 2015.

Jari, B. and Fraser, G.C.G., 2009. An analysis of institutional and technical factors influencing agricultural marketing amongst smallholder farmers in the Kat River Valley, Eastern Cape Province, South Africa. *African Journal of Agricultural Research*, *4*(11), pp.1129-1137.

Kabir, K.H., Billah, M.M., Sarker, M.A. and Miah, M.A.M., 2015. Adaptation of farming practices by smallholder farmers in response to climate change. J Agric Ext Rural Dev 7 (2): 33–40.

Kichamu-Wachira, E., Xu, Z., Reardon-Smith, K., Biggs, D., Wachira, G. and Omidvar, N., 2021. Effects of climate-smart agricultural practices on crop yields, soil carbon, and nitrogen pools in Africa: a meta-analysis. *Journal of Soils and Sediments*, *21*(4), pp.1587-1597.

Komba C and Muchapondwa E (2015).Adaptation to climate change by smallholder farmers in Tanzania. Discussion Paper Series, 15: 12

Komba, C. and Muchapondwa, E., 2018. Adaptation to climate change by smallholder farmers in Tanzania. In *Agricultural adaptation to climate change in Africa* (pp. 129-168). Routledge.

LaMondia, J.J., Aultman-Hall, L. and Greene, E., 2014. Long-distance work and leisure travel frequencies: Ordered probit analysis across non–distance-based definitions. *Transportation Research Record*, *2413*(1), pp.1-12.

Laprise, R., Hernández-Díaz, L., Tete, K., Sushama, L., Šeparović, L., Martynov, A., Winger, K. and Valin, M., 2013. Climate projections over cordex Africa domain using the fifth-generation Canadian Regional Climate Model (CRCM5). *Climate Dynamics*, *41*(11), pp.3219-3246.

Lee, S., Won, J.S., Jeon, S.W., Park, I. and Lee, M.J., 2015. Spatial landslide hazard prediction using rainfall probability and a logistic regression model. *Mathematical Geosciences*, *47*(5), pp.565-589.

Lu, X., 2020. A meta-analysis of the effects of crop residue return on crop yields and water use efficiency. *PLoS One*, *15*(4), p.e0231740.

Mabhaudhi, T., Chimonyo, V.G., Chibarabada, T.P. and Modi, A.T., 2017. Developing a roadmap for improving neglected and underutilized crops: A case study of South Africa. *Frontiers in plant science*, *8*, p.2143.

Marin, A., 2010. Riders under storms: contributions of nomadic herders' observations to analysing climate change in Mongolia. *Global Environmental Change*, *20*(1), pp.162-176.

Martey, E., Etwire, P.M. and Abdoulaye, T., 2020. Welfare impacts of climate-smart agriculture in Ghana: Does row planting and drought-tolerant maize varieties matter?. *Land use policy*, *95*, p.104622.

Masiza, W., Chirima, J.G., Hamandawana, H., Kalumba, A.M. and Magagula, H.B., 2021. Linking agricultural index insurance with factors that influence maize yield in rain-fed smallholder farming systems. *Sustainability*, *13*(9), p.5176.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. eds., 2001. *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press.

McGuire, S. and Sperling, L., 2016. Seed systems smallholder farmers use. *Food Security*, *8*(1), pp.179-195.

McKelvey, R.D. and Zavoina, W., 1971. Ibm Fortran-Iv program to perform N-chotomous multivariate probit analysis. *Behavioral Science*, *16*(2), p.186.

Mdlalose, N., 2016. *Marketing of fresh produce by smallholder farmers: A case study of uThungulu District Municipality, KwaZulu-Natal, South Africa* (Doctoral dissertation).

Mncube, N.L., 2022. *Investigating the contribution of social cash transfers to the food security situation of agricultural-based rural households of Nhlazuka, Richmond Municipality, South Africa* (Doctoral dissertation).

Moges, D.M. and Taye, A.A., 2017. Determinants of farmers' perception to invest in soil and water conservation technologies in the North-Western Highlands of Ethiopia. *International Soil and Water Conservation Research*, *5*(1), pp.56-61.

Mohammadi, F., Omidvar, N., Houshiar-Rad, A., Khoshfetrat, M.R., Abdollahi, M. and Mehrabi, Y., 2012. Validity of an adapted Household Food Insecurity Access Scale in urban households in Iran. *Public health nutrition*, *15*(1), pp.149-157.

Molua, E.L. and Lambi, C.M., 2006. The economic impact of climate change on agriculture in Cameroon (CEEPA Discussion Paper No. 17). *Pretoria: Centre for Environmental Economics and Policy in Africa, University of Pretoria*.

Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences*, *104*(50), pp.19680-19685.

Mozzato, D., Gatto, P., Defrancesco, E., Bortolini, L., Pirotti, F., Pisani, E. and Sartori, L., 2018. The role of factors affecting the adoption of environmentally friendly farming practices: can geographical context and time explain the differences emerging from literature?. *Sustainability*, *10*(9), p.3101.

Mutekwa, V.T., 2009. Climate change impacts and adaptation in the agricultural sector: The case of smallholder farmers in Zimbabwe. *Journal of Sustainable Development in Africa*, *11*(2), pp.237-256.

Mwangi, M. and Kariuki, S., 2015. Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and sustainable development*, *6*(5).

Ncube, B., 2018. Constraints to smallholder agricultural production in the Western Cape, South Africa. *Physics and Chemistry of the Earth, Parts A/B/C*, *106*, pp.89-96.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2021. Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane KwaZulu-Natal. *Land Use Policy*, *109*, p.105611.

Nkegbe, P.K., Abu, B.M. and Issahaku, H., 2017. Food security in the Savannah Accelerated Development Authority Zone of Ghana: an ordered probit with household hunger scale approach. *Agriculture & Food Security*, *6*(1), pp.1-11.

Nyong, P.A. and Martin, N.T., 2019. Enhancing agricultural sustainability and productivity under changing climate conditions through improved agroforestry practices in smallholder farming systems in sub-Saharan Africa. *African Journal of Agricultural Research*, *14*(7), pp.379-388.

O'Riordan, T., Cooper, C.L. and Jordan, A., 1998. Institutional frameworks for political action.[In]: RAYNER, S. & MALONE, E.(eds.) Human choice and climate change. Volume 1. The societal framework.

Olagunju, K.O., Ogunniyi, A.I., Awotide, B.A., Adenuga, A.H. and Ashagidigbi, W.M., 2020. Evaluating the distributional impacts of drought-tolerant maize varieties on productivity and welfare outcomes: an instrumental variable quantile treatment effects approach. *Climate and development*, *12*(10), pp.865-875.

Oxfam (2007).Adapting to climate change: What's needed in poor countries, and who should pay. Oxfam Briefing Paper 104, Oxfam International.

Parry, M., Arnell, N., McMichael, T., Nicholls, R., Martens, P., Kovats, S., Livermore, M., Rosenzweig, C., Iglesias, A. and Fischer, G., 2001. Millions at risk: defining critical climate change threats and targets. *Global environmental change*, *11*(3), pp.181-183.

Rao, K.P.C., Ndegwa, W.G., Kizito, K. and Oyoo, A., 2011. Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental agriculture*, *47*(2), pp.267-291.

Ravallion, M. and Datt, G., 1996. How important to India's poor is the sectoral composition of economic growth?. *The World Bank Economic Review*, *10*(1), pp.1-25.

Ravallion, M. and Datt, G., 2002. Why has economic growth been more pro-poor in some states of India than others?. *Journal of development economics*, *68*(2), pp.381-400.

Regassa, N. and Stoecker, B.J., 2012. Household food insecurity and hunger among households in Sidama district, southern Ethiopia. *Public Health Nutrition*, *15*(7), pp.1276-1283.

Rosenstock, T.S., Nowak, A. and Girvetz, E., 2019. *The climate-smart agriculture papers: investigating the business of a productive, Resilient and Low Emission Future* (p. 321). Springer Nature.

Shackleton, C.M., Shackleton, S.E. and Cousins, B., 2001. The role of land-based strategies in rural livelihoods: the contribution of arable production, animal husbandry and natural resource harvesting in communal areas in South Africa. *Development Southern Africa*, *18*(5), pp.581-604.

Shaw, A. and Kristjanson, P.M., 2013. Adaptation by agricultural communities to climate change through participatory and supply chain inclusive management.

Shen, J., Gu, H., Feng, X., Yu, M. and Zheng, C., 2021. Investigation of factors contributing to bus-crash severity based on extended hierarchical ordered probit model with heteroscedasticity. *Journal of Transportation Safety & Security*, pp.1-21.

Shen, J., Gu, H., Feng, X., Yu, M. and Zheng, C., 2021. Investigation of factors contributing to bus-crash severity based on extended hierarchical ordered probit model with heteroscedasticity. *Journal of Transportation Safety & Security*, pp.1-21.

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B.M. and Menkir, A., 2014. Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather and climate extremes*, *3*, pp.67-79.

Sibhatu, K.T., Krishna, V.V. and Qaim, M., 2015. Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), pp.10657-10662.

Sibhatu, K.T., Krishna, V.V. and Qaim, M., 2015. Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), pp.10657-10662.

Sillmann, J., Kharin, V.V., Zwiers, F.W., Zhang, X. and Bronaugh, D., 2013. Climate extremes indices in the CMIP5 multi-model ensemble: Part 2. Future climate projections. *Journal of geophysical research: atmospheres*, *118*(6), pp.2473-2493.

Singh, R. and Singh, G.S., 2017. Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology and Environment*, *2*(5), pp.296-316.

Smit, B. and Pilifosova, O., 2003. Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), p.9.

Soils Matte. Does climate change affects soil?. 2013. Available online: https://soilsmatter.wordpress.com/2013/10/23/does-climate-change-affect-soil/. Accessed on 04 May 2021).

Soukand, R., Stryamets, N., Fontefrancesco, M.F. and Pieroni, A., 2020. The importance of tolerating interstices: Babushka markets in Ukraine and Eastern Europe and their role in maintaining local food knowledge and diversity. *Heliyon*, *6*(1), p.e03222.

StatsSA. (2021). *Measuring Food Security in South Africa: Applying the Food Insecurity Experience Scale*.

Sulaiman, S.M., Yahaya, A., Muhammad, M.A. and Muhammad, A.D., 2021. I am evaluating Fadama III Development Project in Kano State, Nigeria: Using Difference in Difference Estimation with Propensity Score Matching Approach. *International Journal of Economics, Management, and Accounting*, pp.499-517.

Tabi, F.O., Adiku, S.G.K., Ofori, K., Nhamo, N., Omoko, M., Atika, E. and Mayebi, A., 2012. Perceptions of rain-fed lowland rice farmers on climate change, their vulnerability, and adaptation strategies in the Volta Region of Ghana. In *Technologies and Innovations for Development* (pp. 169-182). Springer, Paris.

Tamene, L., Mponela, P., Ndengu, G. and Kihara, J., 2016. Assessment of maize yield gap and major determinant factors between smallholder farmers in the Dedza district of Malawi. *Nutrient cycling in agroecosystems*, *105*(3), pp.291-308.

Thorlakson, T. and Neufeldt, H., 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture & Food Security*, *1*(1), pp.1-13.

Tiri, G.D., Gilead, I.M. and Roselyne, A., 4.0 Impact of Growth Enhancement Support Scheme on Income Distribution of Smallholder Maize Farmers in Kano State: An IV-QTE approach. *Impact Of Growth Enhancement Support Scheme On Productivity, Welfare And Income Distribution Of Smallholder Maize Farmers In Kano State, Nigeria*, p.115.

Tran, N.L.D., Rañola, R.F., Sander, B.O., Reiner, W., Nguyen, D.T. and Nong, N.K.N., 2020. Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. *International journal of climate change strategies and management*, *12*(2), pp.238-256.

Tshuma, M.C., 2014. Understanding the small-scale agricultural sector as a precondition for promoting rural development in South Africa. *African journal of Agricultural research*, *9*(31), pp.2409-2418.

Ubisi, N.R., 2016. *Smallholder farmers' perceptions and adaptation to climate change interventions and support systems in Limpopo province, South Africa* (Doctoral dissertation).

Unganai, L.S. and Murwira, A., 2010, August. Challenges and opportunities for climate change adaptation among smallholder farmers in southeast Zimbabwe. In *2nd International Conference: Climate, Sustainability, and Development in Semi-arid Regions, Ceará Convention Center, Fortaleza* (pp. 16-20).

Vincent, K. and Cull, T., 2013. Climate change and food security in Southern Africa: Implications of theoretical development for the promotion of sustainable equitable development, 1. *Kulima Integrated Development Solutions (Pty) Ltd Johannesburg, South Africa*.

Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, *7*(1), pp.1-14.

World Bank, 2011. Increased Productivity and Food Security, Enhanced Resilience and Reduced Carbon Emissions for Sustainable Development: Opportunities and Challenges for a Converging Agenda-Country Examples.

World Bank. 2017. World development indicators. Washington, DC. Available online:

Yahya, H.P. and Xiaohui, Z., 2014. Constraints to women smallholder farmers' efforts in ensuring food security at household level: A case of Msowero ward of Morogoro region Tanzania. *International Journal of Economics and Finance*, *6*(5), p.47.

Zomer, R.J., Trabucco, A., Bossio, D.A. and Verchot, L.V., 2008. Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agriculture, ecosystems & environment*, *126*(1-2), pp.67-80.

Zondi, N.T.B., 2021. *Impact of commercialization of indigenous crops on household food security of smallholder farmers in Limpopo Mpumalanga provinces, South Africa* (Doctoral dissertation).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1. Introduction

This study evaluates the contribution of Climate Smart Agricultural practices to small-scale farmers to adapt to climate change in KwaZulu-Natal Province, South Africa. The specific objectives of this study are to understand how farmers perceive climate change and how it affects their farming systems. This chapter outlines how and why the information was gathered to ensure that the data collected is trustworthy. The chapter will describe the study areas, data collection methods, and the detailed analytical tool covered in chapters 4,5, and 6 since the study adopted a manuscript study format.

## 3.2. Description of the Study areas

The research was carried out in Swayimane and Bergville in the KwaZulu Natal Province. These areas were chosen because farmers in these villages rely on maize for household consumption, animal feed, and a source of income. Furthermore, these areas were chosen due to farmers' long relationships with active agricultural organizations from the public, private, and non-governmental sectors. Swayimane is located in the UMshwathi Local Municipality of the uMgungundlovu District Municipality, east of Pietermaritzburg. The area's population is 6,856 (53% females); most families are female, and all black Africans speak IsiZulu as their first language. Their primary source of income is subsistence farming (StatisticsSA, 2021). Because of the climatic and weather conditions, the study area has rich agricultural soils. As a result, agriculture has become a source of income for most residents in the area (Ndlovu et al., 2020). Most households in the study area are headed by women and are food insecure due to high levels of unemployment and poverty (Khumalo, 2014). Swayimane's average annual rainfall ranges from 694 to 994mm, making the soil fertile and the area suitable for farmers to plant crops such as sugar cane, madame, sweet potato, green mealies, cabbage, spinach, and other varieties of vegetables (Ndlovu et al., 2020).


**Figure 2:** The map showing KZN Map with uMgungundlovu ad UThukela District Municipality Source: https://List_of_municipalities_in_KwaZulu_Natal (Accessed on 20 August 2022). Note: B represent Bergville, S represent Swayimane

Bergville, on the other hand, is a small town in the Drakensberg Mountains that falls under the UThukela District Municipality in the uKhahlamba local municipality in KwaZulu Natal. (See Figure 1) Bergville has a population of about 4500 people. Because the birth rate or population growth is increasing daily, the population in this area is rapidly increasing with a higher poverty level. Because there are few job opportunities in Bergville, most of the population is illiterate, and most people make a living by farming. Farming becomes their only means of survival. The average annual precipitation in the area is 895mm. January-March and November-December are the rainy seasons. At the same time, dry spells occur between May and August. January is the wettest month, with 154 mm of rain. The driest month is June, with only 11 mm of rain, and crop production is nearly impossible during the dry, cold winter with frost. As a result, production is limited to the summer (Mpanza, 2008).

### 3.3. Data Collection Method

The study used a quantitative approach. A multistage random sampling was employed to select 99 respondents, 49 from Swayimane and 50 from Bergville. The sample size was calculated using statistical software on the 95% confidence interval and 5% margin of error based on the sampling frame of 310 maize farming households, with each household having an equal chance of being selected. Primary data was collected using semi-structured interview questionnaires to determine the farmer's short-term adaptive measures for the 2019/2020 maize production season. A questionnaire was also distributed to determine long-term adaptation strategies, which natural hazards endanger farmers' maize yields, how they deal with them, and what potential practices are needed in their farming system to increase production. Approximately 29 lists of practices were identified with the assumption that each could deliver on one or more CSA goals. Knowledge smart, carbon smart, nitrogen smart, water smart, weather smart, and energy smart were the six (6) packages considered for these practices. The adoption of practices was self-reported in yes/no questions.

Actual or realized yield refers to the harvest yield from a farmer's fields. Estimating crop production through farmer interviews entails asking farmers to estimate how much they harvested or expect to harvest for an individual plot, field, or farm. Harvest quantities are farmer estimates and are typically expressed in local harvest units rather than kilograms or tonnes. Conversion factors will be required to convert harvest quantities to standard units (Fermont and Benson, 2011). Estimating crop production through farmer interviews requires farmer recall from previous harvests (quantifying previous harvest yield) and farmer prediction (estimating the current yield based on the previous harvest) (Bihter et al., 2016). These yield estimation methods are less accurate and sometimes introduce additional biases. As a result, the use of simple mathematical models is advised (Ngoune Tandzi and Mutengwa, 2020). The GrainsSA yields estimation model was used in the study, and yields were estimated based on the total number of cobs each farmer received in the plot after harvesting.

### 3.4. Methods of data analysis

Excel and Statistical Software for Social Science (SPSS) version 24 were used to analyse the quantitative data. Descriptive statistics were used to provide the key socioeconomic characteristics of the smallholders sampled. It was carried out to demonstrate the mean averages, standard deviations, and percentages of the various factors influencing CSA adoption and the intensity of CSA adoption among smallholder farmers. Factors influencing CSA adoption and the intensity of CSA adoption among smallholder farmers are classified as internal, external, and socio-demographic. Variables such as the age of the household head, gender, household size, marital status, and educational level are socio-demographic factors. Internal factors or household assets include livestock ownership, off-farm income, family members with disabilities and HIV, labor, irrigation system, yield, and land. External factors include market information, agricultural assistance, social grants, and market distance.

In order to meet the objectives, the study used various econometric analytical tools. A double hurdle model (Probit and Poisson regression) were used to address the first objective. Where: the Probit regression model was used to determine factors influencing the adoption of CSA practices and the latter Poisson regression model was used to assess the intensity of CSA adoption on smallholder farmers. The Poisson regression model was used to correct for self-selection bias in the study of the effect of market participation on smallholder farmers' nutrition status. This model estimates the casual effect of market nutrition security status using the count outcome with the Poisson distribution of the error term (Danso-Abbeam et al., 2021). Chapter 6 contains in-depth information on the analytical tools.

The Household Hunger Scale (HHS) was used to assess the food security status of households in the study area. This HHS collects household food security status data over a four-week (30-day) recall period. The questions asked were the following: In the 30 days, was there ever no food to eat of any kind in your household because of lack of resources to get food? In the past 30 days, did any household member go to sleep at night hungry because there was not enough food? In the past 30 days, did any household member go all day and night without eating anything because there was not enough food? To compute the HHS score, a new variable was created that recorded the response to each frequency-of-occurrence question from three frequency categories.

The new variable was coded as 1 for "rarely," 2 for "sometimes," 3 for "often," and 0 for households that answered no to each corresponding occurrence question. The HHS score was calculated by adding the values of the new variables for each Household. The HHS indicator is created using these values. To tabulate the HHS indicator, the HHS score was subjected to two different value cuts (>1 and >3). The three Household Hunger Categories are a 0-1 HHS score, which indicates little to no hunger in the household, and a 2-3 HHS score, which indicates moderate hunger in the household. An HHS score of 4-6 denotes severe hunger in the household ( Ballard, 2011).

A Logistic Regression model was used in the study to determine the factors influencing food security among smallholder farmers. Logistic regression is a type of multivariate regression that allows for an analysis in which several independent variables forecast the presence or absence of an outcome based on the values of a set of predictor variables. The usability of each variable type is the main advantage of logistic regression. The Effect of CSA adoption on smallholder household food security was assessed using the Extended ordered probit regression model. Because it recognizes the indexed nature of different response variables, this model was more useful in this study. Chapter 5 contains the detailed model specifications for the analytical tools.

The study used Conditional IV-QTE to correct for endogeneity and sample selection on the impact of CSA adoption on the yields of smallholder farmers. The model was used to control for the endogeneity of CSA adoption, which can significantly overestimate or underestimate the impact of CSA adoption on yields. Similarly, to avoid information duplication, the complete model specification is provided in Chapter 6.

### 3.5. Ethical Considerations

Prior to the commencement of data collection, ethical clearance was sought and received from the Human Social Sciences Research Ethics Committee (see Appendix C). After receiving ethical clearance, questionnaires (Appendix B) were administered immediately, and participation for interviews were sent. All data collection tools were accompanied by the informed consent (Appendix A) which was to be signed as an acknowledgement that the participant's participation was free and consensual. All responses/ raw data were kept strictly confidential and encrypted within researcher's databases. Secondary data collected through literature review was also duly acknowledged.

### 3.6. References


Bihter, O., Bakal, H., Gulluoglu, L. & Arioglu, H., 2016. The effects of row spacing and plant density on yield and yield components of peanut grown as a double crop in mediterranean environment in Turkey. *Turkish Journal of Field Crops,* 22**,** 71-80.

Buke, W. J. 2009. "Fitting and Interpreting Cragg's Tobit Alternative Using Stata." *The Stata Journal* 9 (4): 584–592

Danso-Abbeam, G., Ojo, T.O., Baiyegunhi, L.J. and Ogundeji, A.A., 2021. Climate change adaptation strategies by smallholder farmers in Nigeria: does non-farm employment play any role? *Heliyon*, *7*(6), p. e07162.

Fermont, A. & Benson, T., 2011. Estimating yield of food crops grown by smallholder farmers. *International Food Policy Research Institute, Washington DC,* 1**,** 68.

Mpanza, T.P., 2008. *An evaluation of the perceived benefits and constraints of community gardens established by the KwaZulu-Natal Department of Agriculture and Environmental Affairs* (Doctoral dissertation).

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2021. Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane KwaZulu-Natal. *Land Use Policy*, *109*, p.105611.

Ngoune Tandzi, L. & Mutengwa, C. S., 2020. Estimation of Maize (Zea mays L.) Yield Per Harvest Area: Appropriate Methods. *Agronomy,* 10**,** 29.

Rubhara, T.T., Oduniyi, O.S., Mudhara, M. and Akwasi, A.M., 2020. Analysis of household food expenditure patterns. A case of Shamva district Zimbabwe. *Future of Food: Journal on Food, Agriculture and Society*, *8*(1).

StatsSA. (2020). *Mid-year population estimates* (Issue July).

# CHAPTER FOUR

# THE DETERMINANTS OF ADOPTION AND INTENSITY OF CLIMATE-SMART AGRICULTURAL PRACTICES AMONG SMALLHOLDER MAIZE FARMERS

CHAPTER FOUR

## 4.1. Introduction

Smallholder agriculture has been identified as a mechanism for achieving rural development goals in South Africa (Pienaar and Traub (2015) and achieving favorable food and nutrition security outcomes. Smallholder farmers are the drivers of many economies; therefore, climate change's adverse effects can have undesirable results for the affected countries and farming households. They can play an essential role in livelihood creation among the rural poor in Africa, particularly in South Africa. Even though smallholder farmers have this potential, they are characterized by limited land access, capital, technologies, and market orientation (Chamberlin, 2008; Food and Agricultural Organization (FAO), 2015). Moreover, smallholder farmers are more susceptible to climate change as they have poor managerial production skills and limited access to quality irrigation systems. Therefore, these characteristics of smallholder farmers lead them to rely more on stable crops, such as maize, beans, and sweet potatoes, because these crops can be grown under unfavorable conditions (Kom et al., 2022). Several smallholder farmers depend on maize (*Zea mays* L.) as one of the essential sources of food and nutrition (Adeagbo et al., 2021; Jimoh et al., 2022). An estimated one million smallholder farmers are growing maize for subsistence and local consumption (Adeagbo et al., 2021; Jimoh et al., 2022). However, extreme climate changes cause a negative impact on the production of maize because it is sensitive to rising temperatures and erratic rainfall patterns. High temperatures and drought conditions negatively impact the production, flowering, and yields of maize (Hernández Díaz-Ambrona et al., 2013). Building resilient agriculture for smallholder farmers requires adopting climate-smart agriculture (CSA), which can help them cope with the impact of climate change.

FAO (2014) indicated that agriculture must be "climate-smart" to feed the world in a way that can ensure sustainable rural development. CSA is an approach to develop long-term agricultural conditions for food security in the context of climate change (FAO, 2014). It contributes to national food security and development goals by focusing on three objectives: increasing agricultural productivity and incomes, increasing adaptability and resilience to climate change, and reducing or eliminating greenhouse gas emissions (FAO, 2014). Several studies (Wekesa et al., 2018; Antwi-Agyei et al., 2021) reported that adopting several CSA practices helps improve food security. These studies further explained that adopting numerous

CSA practices helps mitigate the impact of climate change and enhance nutrient availability. Antwi-Agyei et al. (2021) revealed that most farmers use CSA practices to reduce pests and diseases, obtain higher yields and increase income. However, a primary concern of CSA technologies is adoption. Most CSA technologies are costly and out of reach for many smallholder farmers in the country (Mccarthy,2011; Zougmoré et al.,2016; Ogunyiola,2022). Some difficulties include insufficient institutional support, insurance plans, and funding mechanisms, and unreliable legal frameworks, such as tenure rights and land management frameworks, which might reduce farmers' willingness to embrace CSA ( Scherr et al., 2012; Kolawole et al., 2014;  Harvey et al., 2018). CSA has been documented as a well-recognized method for adjusting agricultural output to the new conditions brought on by climate change in the literature. Although CSA practices are recommended to solve these problems, improve sustainable agriculture, and reduce poverty, it has been emphasized that smallholder farmers find it challenging to adopt and apply CSA-related technology.

Previous studies reported that socioeconomic factors such as age, education, farm size, and farm ownership affect whether smallholder farmers can effectively implement CSA ( Kolawole et al., 2014; FAO, 2015; Westermann et al., 2018). These socioeconomic characteristics are also expected to impact the probability of CSA adoption and the number of CSA used by the farmers in this study. Generally, studies on adopting CSA practices in South Africa concentrate on factors affecting a specific CSA practice (Kom et al., 2022; Mazibuko, 2018). For instance, Abegunde et al. (2020) investigated the factors that affect the adoption of CSA practices in smallholder farming households. However, the study did not differentiate between long-term and short-term adaptation strategies and did not focus on a specific crop. Farmers are often presented with various technologies that can be used as complements or substitutes to mitigate and adapt to climate change when planting certain crops. Therefore, there is a need for a deeper understanding of whether these factors influence CSA implementation in KwaZulu Natal maize farming because maize is a common and stable crop for smallholder farmers. This study set out to investigate the factors affecting the adoption and intensity of the adoption of CSA practices by maize farmers in the study areas.

Furthermore, the study also seeks to understand the different types of short-term and long-term CSA practices adopted by smallholder farmers to mitigate climate change impacts. The study structure consists of five sections, including this introductory section. The second section discusses the methodology used for this study, which includes a description of the study area, data collection methods, and conceptual framework. The third section summarizes the research findings, focusing on two key themes: the determinants of CSA adoption and the intensity of

CSA adoption among smallholder farmers. The fourth section discusses the findings of interviews, focus groups, and empirical frameworks. Finally, the conclusion provides a summary and critique of the findings and areas for future research.

## 4.2. Methodology

### 4.2.1. Description of the Study Area

The study area, sampling, and data collection technique are the same as in chapter three.

### 4.2.2. Data Collection Method

The study adopted both qualitative and quantitative approaches. This study used the primary data collected by using semi-structured interviews and questionnaires. 99 respondents were interviewed and randomly selected (49 from Swayimane and 50 from Bergville). A semi-structured interview with open-ended questions was administered through focus group discussions (FGDs) to find out about the farmer's short-term adaptive measures for the 2019/2020 maize production season. These semi-structured interviews focused on analyzing which natural hazards threaten farmers' maize yields, how they cope with them, and which potential practices are required in their farming system to increase their production. In addition, a questionnaire was given to find the long-term adaptation strategies. A total of 29 practices were identified assuming that each can deliver one or more CSA goals. These practices were grouped into five categories. These categories are knowledge smart, carbon smart, nitrogen smart, water smart, weather smart, and energy smart. Adoption of practices was self-reported in response to yes/no questions. Table 1 shows the 29 CSA practices and their categories identified in the study area.

**Table 1**: The 29 CSA practices and their categories.

| **Knowledge Smart** |
| --- |
| Belong to farmer associations |
| Get access to information on market prices of produce & inputs |
| Share one-on-one information with colleagues (farmer-to-farmer knowledge sharing) |
| Store seeds for next season/emergency (seed banking) |
| Have a backyard garden in addition to my farm |

| |
|---|
| **Carbon Smart** |
| Change the type of crop planted on this land in some seasons (crop rotation) |
| Plant different type of crops together (mix cropping) |
| Plant trees in and around my farm (afforestation) |
| Use plants and animal manure on my farm (organic manuring) |
| Use less heavy equipment on my farm (minimum tillage) |
| **Nitrogen Smart** |
| Use specific fertilizer/manure based on the type of soil (site-specific nutrient application) |
| Plant legumes among crops |
| Estimate the amount of fertilizer/manure needed at a time (precision fertilization) |
| **Water Smart** |
| Plant cover crops to maintain soil moisture |
| Harvest and store rainwater to be used on my farm |
| Engage in mulching to reduce excessive use of water |
| Plant in the early season to make use of rainwater |
| Regulate/control the water used in watering crops |
| **Weather Smart** |
| Use mobile phone to access weather information |
| Received weather information through the community information centre |
| Usage of radio/tv for weather information |
| Access to weather information on the internet |
| Use personal experience to predict weather events |
| Take index-based insurance (IBI) to protect my farm |
| Received education/training on how to access weather information by an organization |
| **Energy Smart** |
| Compost my residue after harvesting |
| Convert my residue into bioenergy |
| Use solar equipment in farming |
| Use of less fuel-consuming vehicles |

## 4.3. Analytical Framework

### 4.3.1. The determinants of CSA adoption on smallholder farmers

The adoption of CSA practices can be outlined as the stage at which a farmer decides to adopt one or more adaptive options to mitigate the effect of climate change. The double-hurdle model framework includes the first-stage adoption of climate change adaptation strategies based on the same set of covariates, determining the intensity of CSA adoption. The standard errors from separate estimations are valid for statistical inference if the error terms in the equations are assumed to be uncorrelated-conditional on all covariates. If there is no assumption of the error terms in the equation, the coefficient estimates from separate regressions will be biased (Asrat et al., 2018; Adeagbo et al., 2021). The same method used by Heckerman to test bias is used for testing conditionally uncorrelated errors. However, it is standard to enforce one justifiable exclusion restriction estimating the second stage but not technically necessary for identification. The coefficient estimates on inverse mill ratio (IMR) test the null hypothesis that the first- and second-stage errors are conditionally uncorrelated. The model must be estimated and estimated again to conduct valid inference unless the coefficient estimates are statistically significantly different from zero (Wooldridge, 2002). The second-stage parameters are estimated without the IMR if there is a failure in rejecting the null (De Luca and Perotti, 2011). A probit model of CSA for selection equations is estimated using a function of explanatory variable that is also likely to determine the CSA intensity. The IMR predicted by the first-stage probit regression is used as a regressor in the second hurdle to account for selection bias. The probit regression model has been used by many researchers in studies relating to adoption. Serote (2021) used the probit regression model to evaluate the factors influencing smallholder farmers' adoption of climate-smart irrigation technologies for sustainable crop production. Mutenje (2019) used the probit regression model to evaluate the cost-benefit analysis of CSA options in southern Africa. They were balancing gender and technology. Marenya (2017) used the probit regression model to predict minimum tillage adoption among smallholder farmers. In contrast, Ojo and Baiyegunhi (2020) used this model to evaluate the determinants of climate change adaptation strategies and their impact on the net farm income of rice farmers in southwest Nigeria.

According to Feder (1985), to determine the probability of CSA adoption by smallholder farmers, the underlying latent variable that captures the true farmer's socioeconomic characteristics is hypothesized. The regression Equation (1) indicates the latent variable $CSA^{*}{}_{i}$ :

$$CSA^{*}{}_{i} = X_i\beta + ei \quad ei \approx Y\ (1) \tag{1}$$

(first hurdle)

$$CSA^{*}{}_{i} = 1\ if\ CSA^{*}{}_{i} > 0$$

$$CSA^{*}{}_{i} = 0\ if\ CSA^{*}{}_{i} \leq 0. \tag{2}$$

$CSA^{*}{}_{i}$ Has a value of 1 if a smallholder farmer adopts climate change and 0 otherwise. A vector to be estimated is $\beta$. A probit model of $CSA^{*}{}_{i}$ , which follows random utility, is expressed as in Equation (2) (Wooldridge, 2002); a probit model of CSA which follows random utility is defined in Equation (3):

$$\text{Hr}\ (CSA_i = 1|B_i, \alpha) = \oint (B_i, \alpha) + ei \ . \tag{3}$$

$CSA^{*}{}_{i}$ Equals 1 for households that adopt climate-smart agriculture techniques and 0 otherwise. Xi represents the vector of independent variables, $\alpha$ is the vector of parameters to be estimated. The $\varphi$ is the standard normal cumulative distribution function, and $ei$ is a random error term hypothesized to be distributed generally with unit variance and zero means.

**4.3.2. The Intensity of CSA Use among Smallholder Maize Farmers**

The Poisson regression model (PRM), the negative binomial regression model (NBRM), the zero-inflated Poisson (ZIP), and the zero-inflated negative binomial (ZINB) are the most commonly used regression models to analyze count data. The PRM and NBRM regression models are standard for analyzing the response variables with nonnegative integers (Green, 2008; Kirui et al., 2010). The last two (ZIP and ZINB) are commonly used for cases with frequent zero counts. This study does not have more zeros than would be expected. Therefore, only the PRM is discussed because the response variable contained nonnegative integers with only a few zero counts. A Poisson model was used to estimate the determinants of CSA intensity. Poisson is a process of satisfying the assumptions of the probability distribution of the number of occurrences of the event in a fixed time interval (Anon, 2008). Studies by ( Bukchin & Kerret, 2020; Ojo & Baiyegunhi, 2020) have stated that farmers usually weigh the technology's benefits before adopting it. The study used the PRM because diagnostic tests revealed the absence of overdispersion and underdispersion. The density function of the PRM, as depicted in Equation (4), is given by

$$\text{Hr}(P = p) = \frac{e^{-\delta(P)}\delta i(p)^{P}}{\Phi(1+P)}, \tag{4}$$

where $\delta_i = \text{Exp}(\Omega + B^i\psi)$ and $P_i$ = 0, 1,…, $i$ is the number of CSA practices used by the farmers, and B is a vector of predictor variable $\Omega$ and is $\Psi$ the parameters to be estimated. The expected outcome is the number of CSA practices adopted by a farmer, expressed in Equation (5):

$$A\,(P_i = p_i) = \text{Kar}\left\{\frac{P_i}{p_i}\right\} = \delta_i = \text{Exp}\,(\Omega + B^i\,\Psi\,) \text{ for } i = 1, 2, ..., n. \qquad (5)$$

### 4.4. Description of Variables and Statistics

The study's quantitative data analysis was conducted using the IBM Statistical Package for Social Science (SPSS) version 28. The descriptive statistics provided the key socioeconomic characteristics of sampled smallholder farmers. According to the hypothesis of this study, the variables are drought, gender, marital status, once-off-farm income, smartphone, access to market information, membership in farmers' association, the primary source of income, household size, age, and level of education. These variables affect the adoption and intensity of the adoption of CSA practices. Table 2 summarizes the descriptive variables' names, variable types, measurements, and expected outcomes.

**Table 2**: Description of variables (own source).

| Variable | Description of Variable | Expected Outcome |
|---|---|---|
| Drought | Dummy (1 = Yes, 0 = otherwise) | + |
| Gender | Dummy (1 = Female, 0 = Male) | _ |
| Marital status | Continuous (1 = Single, 2 = Married, 3 = Divorced, 4 = Widowed) | + |
| Once-off-farm income | Measured in Rands/Kg | _ |
| Smartphone | Dummy ((1 = Owns, 0 = otherwise) | + |
| Access to market information | Dummy (1 = Yes, 0 = otherwise) | + |
| Member of farmers' association | Dummy (1 = Yes, 0 = otherwise) | + |
| The primary source of income | Measured in Rands/Kg | + |
| Household size | Measured in numbers | + |

| | | |
|---|---|---|
| Age | Measured in numbers | + |
| Level of education | Continuous (1 = No education, 2 = Primary, 3 = Secondary, 4 = Tertiary) | + |

Source: Survey data.

## 4.5. Results

### 4.5.1. Descriptive Analysis of the Results

#### 4.5.1.1. Demographic Characteristics of Smallholder Farmers in the Study Area

Table 3 shows that 80% of the respondents were female, and 20% were male. The results show that most (42%) respondents had received primary education, followed by 33% who had no formal education, 24% who had received secondary education, and only 1% who had acquired tertiary education. The results also show that most (72%) farmers are married, 19% are single, 8% are widowed, and only 1% are divorced.

**Table 3**:Demographic characteristics of smallholder maize farmers.

| Variable | Description | Percent (%) |
|---|---|---|
| Gender | Female | 80 |
| | Male | 20 |
| Level of education | No Education | 33 |
| | Primary Education | 42 |
| | Secondary education | 24 |
| | Tertiary education | 1 |
| Marital status | Single | 19 |
| | Married | 72 |
| | Divorced | 1 |
| | Widowed | 8 |
| The main source of income | No income | 9 |
| | Agricultural produce | 8 |
| | Social government grant | 38 |
| | Remittances | 1 |
| | Pension | 39 |

| | | |
|---|---|---|
| | Casual work | 1 |
| | Spaza | 2 |
| | Traditional healer | 2 |
| The second source of income | No income | 73 |
| | Full-time employment | 1 |
| | Part-time employment | 1 |
| | Sales of agricultural produce | 21 |
| | Casual work | 1 |
| | Spaza | 3 |

The results showed that approximately 39% of the respondents relied on pension grants, 38% on social government grants, and 8% on agricultural produce sales as their primary income source. Approximately 1% of the respondents had no source of income. When considering the second source of income, results show that most farmers (73%) did not have a second source of income. Approximately 21% indicated that their alternative income source was selling agricultural produce, and 3% owned spaza shops as an additional source of income. The results also revealed that household size was an average of 7, ranging between 1 and 30 members per household. Furthermore, the average age of participants was 56 years. This is in line with the literature, which reported that most farmers are older.

#### 4.5.1.2. Climate Change Impact (Natural Hazards) Experienced by Farmers in Their Maize Production in 2019–2020

Figure 3 shows the different natural hazards that affected farmers during the 2019–2020 production season of maize. These natural hazards affected mostly the quality and quantity of maize yields. The most common natural hazards that farmers experienced were pests, with 56% of them experiencing this hazard, followed by diseases, with 43% of the farmers have experienced diseases in their maize crops. Approximately 34% of the farmers were affected by drought. Only 22% were affected by soil infertility. Farmers also reported that their yields decreased through predators such as livestock, monkeys, rats, and birds.

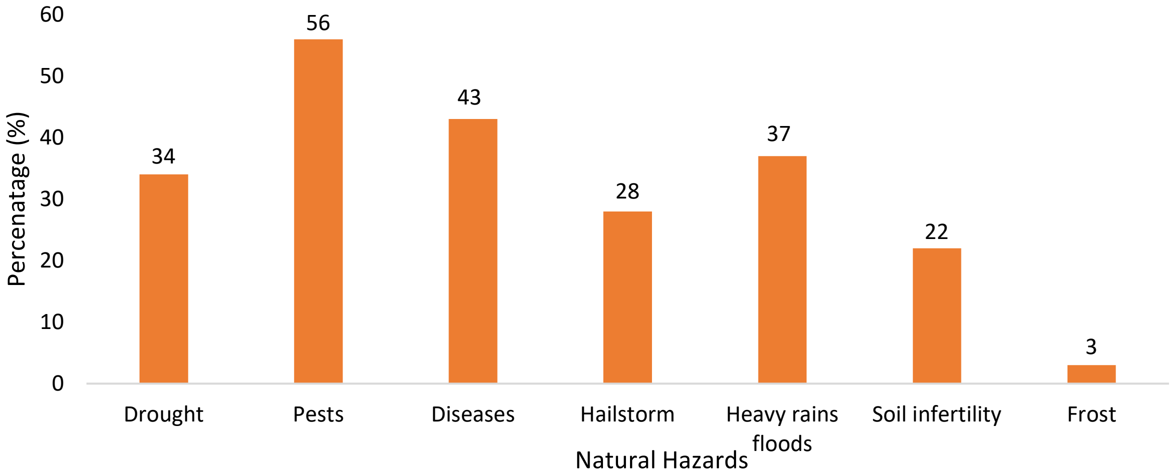



**Figure 3**:Natural hazards affecting maize production (Source: Own source).

#### 4.5.1.3. Short-Term CSA Practices Adopted by Smallholder Maize Farmers to Cope with Natural Hazards in the 2019–2020 Season

Figure 4 shows the different short-term CSA practices adopted by smallholder maize farmers to cope with natural hazards in the 2019–2020 production season. The results showed that approximately 71% of the farmers did not take any specific action to cope with the drought. In comparison, 6% thought it was impossible to take measures to deal with the water shortage, and only 1% used in-field rainwater-harvesting methods by which farmers dig rows (trenches) in the soil to absorb rainwater. Regarding the disease coping strategy, approximately 86% of the farmers applied chemicals to deal with diseases, 10% took no action, and only 2% removed the affected leaves or crops to prevent the spread of the disease. The results also showed that 80% of the farmers used chemicals to deal with pests, 10% took no action to adapt to pests, and 1% used greywater harvesting to cope with the problem precisely, water with soap previously used for laundry.

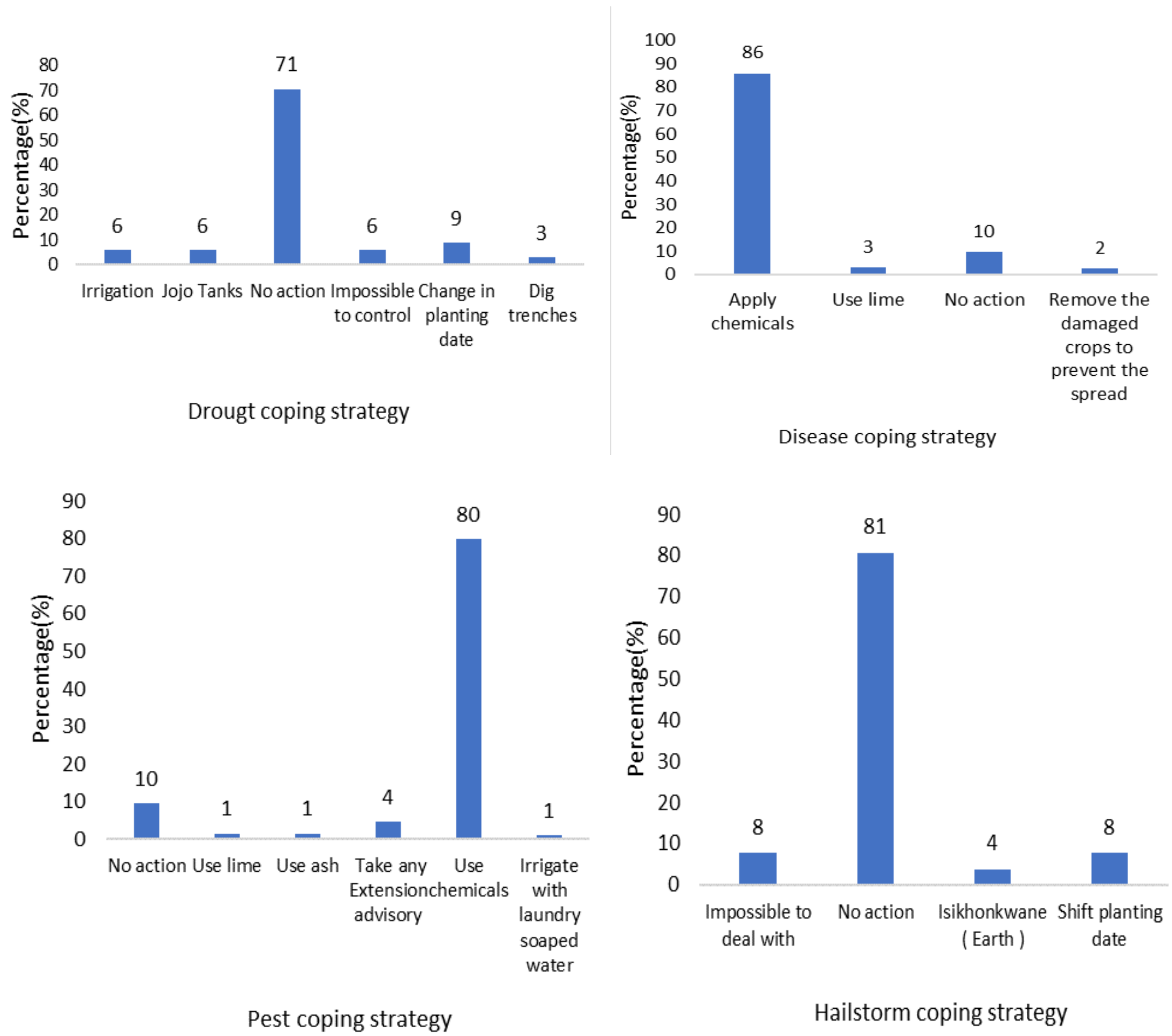



**Figure 4:**Short-term CSA practices adopted by smallholder maize farmers to cope with natural hazards in the 2019–2022 season.

Regarding the hailstorm adaptation strategy, approximately 81% of farmers took no action to adapt to hailstorms, 8% thought it was impossible to deal with hailstorms, and 8% shifted planting dates. Few farmers (4%) mentioned using "Isikhonkwane" meaning earth, to adapt to a hailstorm. Regarding the flood adaptation strategy, about 15% of the affected farmers did not take any actions to deal with floods, 2% dig trenches to channel water away from the plots, and only 1% thought it was impossible to adapt to floods. The results also showed that 3% of farmers were affected by frost, and all of them preferred planting earlier than usual so the crops could mature enough to withstand frost. As mentioned earlier, farmers reported that their yields are decreasing because of predators such as livestock, monkeys, rats, and birds. They are not putting any adaptation strategies to deal with predators except applying poison to rats.

#### 4.5.1.4. Potential Practices Which Farmers Can Put in Place to Adapt to Climate Change

Figure 5 shows the potential practices which farmers believe could be an aid to withstand natural hazards and increase production. The most preferred potential practice was the use of organic manure 24%. Approximately 21% of farmers prefer to add lime to neutralize soil PH, mix different fertilizers, and rely on extension advisory services, whereas 20% prefer using specifically recommended fertilizers.

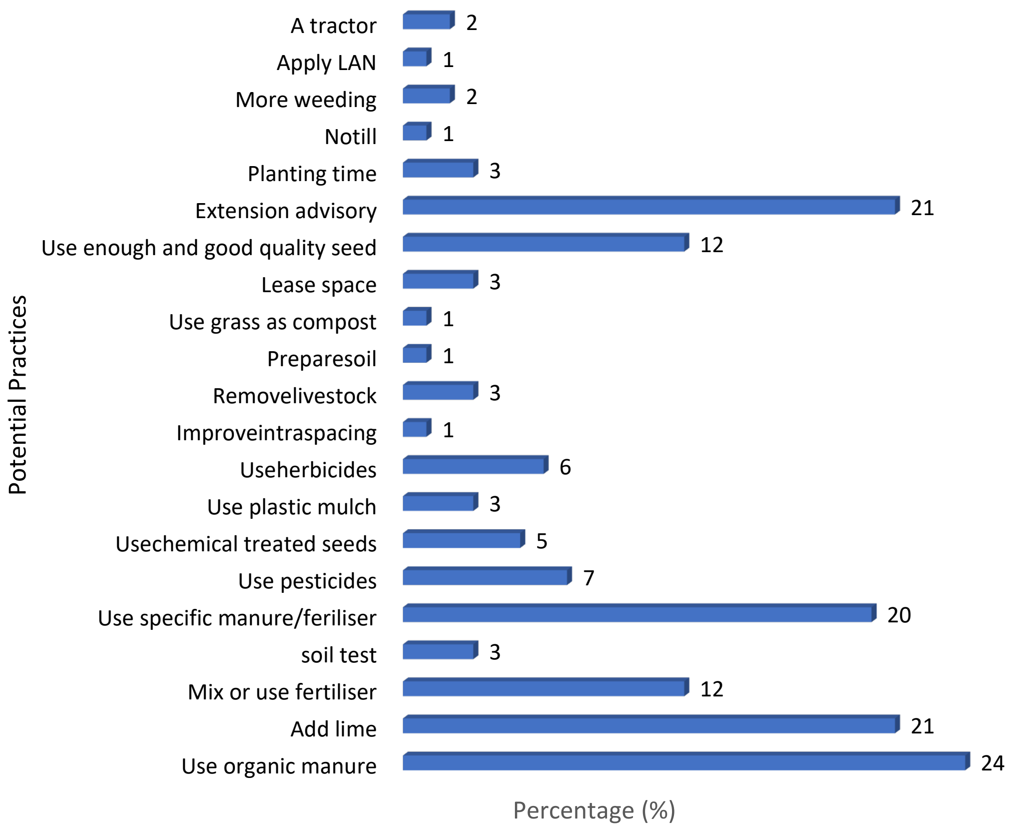



**Figure 5:** Potential practices to cope with hazards (Source: Own source).

#### 4.5.1.5. The Adaptation Strategies Employed by Smallholder Farmers over Ten Years of Maize Production

Figure 6 shows the long-term CSA practices employed by smallholder farmers as adaptation strategies over more than ten years of maize production. The results show that as far as knowledge of Smart practices is, the most adopted practice is sharing one-on-one information with colleagues, also known as word of mouth or farmer-to-farmer knowledge sharing, at 76%, and only 4% had access to agricultural credits. Regarding carbon-smart practices, 95% have adopted minimum tillage, followed by 91% of farmers who used plant and animal manure, also known as organic manure, and 90% used crop rotation. Approximately 78% of farmers produced different kinds of crops together on the same ground, also known as intercropping. The practice that farmers least adopted was afforestation; only 7% of farmers planted trees around their fields. Regarding nitrogen-smart practices, the results showed that most farmers (77%) preferred to plant legumes to improve soil fertility, 59% estimated the amount of fertilizer required, and only a few farmers (25%) used specific fertilizer.

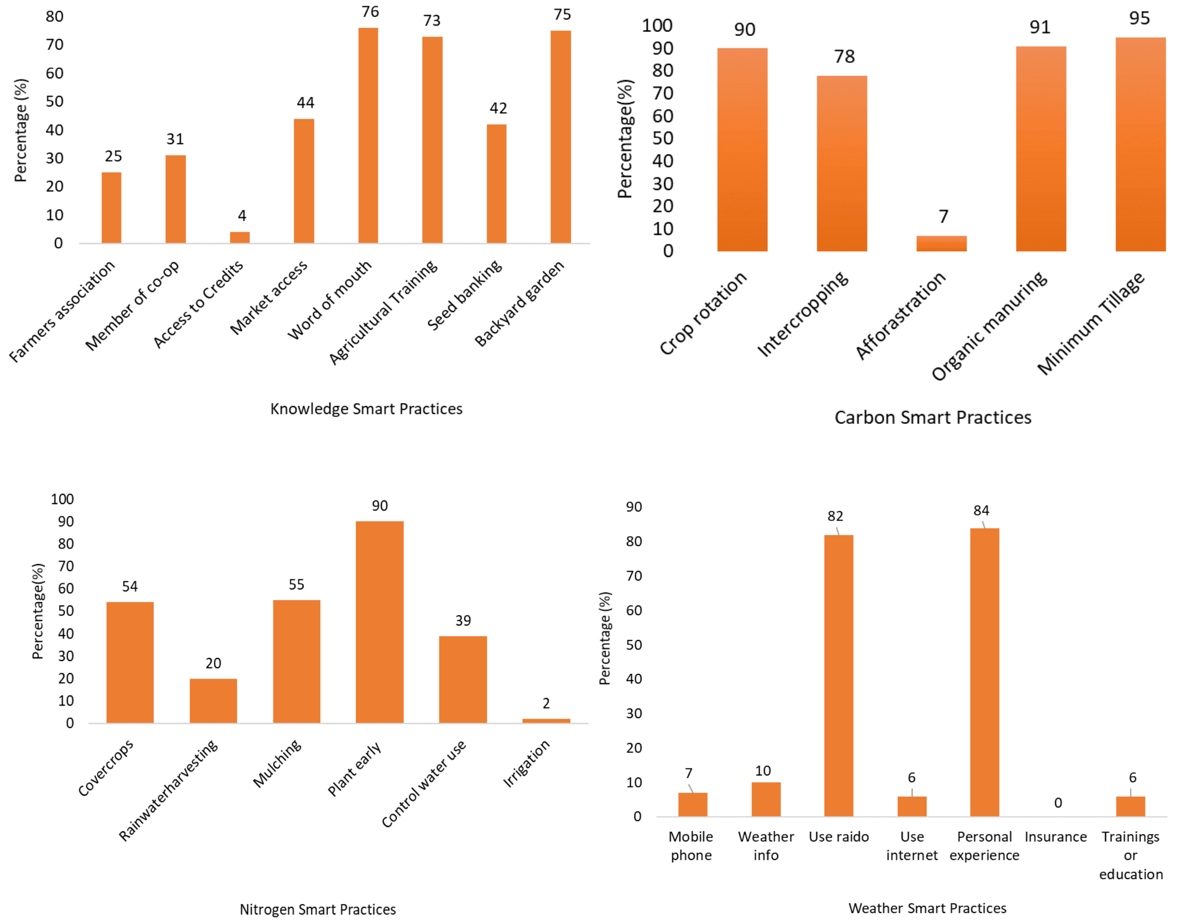



**Figure 6:** Long-term climate-smart practices adopted by sampled smallholder maize farmers.

The common practice farmers have adopted regarding water-smart practices is planting early in a season (90%) to use rainwater efficiently, followed by 54% of farmers who planted cover crops to maintain soil moisture and 55% who used mulch to reduce excessive use of water. Only 2% of the farmers use irrigation. Among weather-smart practices, about 43% of farmers used personal experience to predict weather events, and 42% used radio or TV for weather information. The results show that no farmers take index-based insurance to protect their crops from weather events. Regarding energy-smart practices, most farmers (74%) used compost.

### 4.5.2. Empirical Analysis of the Results

#### 4.5.2.1. Determinants of Adoption of Climate Change Adaptation Strategies among Maize Farmers Probit Model

Table 4 highlights the determinants of adopting climate change adaptation strategies among smallholder farmers in the sampled areas. The first-hurdle equation of a probit regression model revealed that drought, on-farm income, the main source of income, household size, and level of education were the main factors that significantly affected the adoption of CSA practices by smallholder farmers.

**Table 4:** Probit regression of determinants of CSA adoption among the farmers' first hurdle.

| CSA Adoption | Coef. | St. Err. | *p*-Value |
|---|---|---|---|
| Drought | 0.915 | 0.406 | 0.024 ** |
| Gender | −0.509 | 0.438 | 0.245 |
| Marital status | −0.414 | 0.259 | 0.110 |
| On-farm income | 0.000 | 0.000 | 0.050 * |
| Smartphone | 0.043 | 0.487 | 0.929 |
| Access to market info | 0.170 | 0.376 | 0.652 |
| Farmers' association | −0.504 | 0.406 | 0.214 |
| Main source of income | −0.269 | 0.116 | 0.021 ** |
| Household size | 0.109 | 0.053 | 0.040 ** |
| Age | −0.003 | 0.014 | 0.823 |
| Level of education | −0.521 | 0.244 | 0.033 ** |
| Total anum | 0.000 | 0.000 | 0.142 |
| Constant | 2.947 | 1.381 | 0.033 ** |
| Pseudo r-squared | 0.251 | | |
| Chi-square | 33.712 | | |
| Akaike crit. (AIC) | 126.597 | | |
| Bayesian crit. (BIC) | 160.334 | | |
| Prob > chi2 | 0.001 | | |

** $p < 0.05$, * $p < 0.1$.

The results revealed that drought had a positive and significant impact on the adoption of CSA. On-farm income showed a positive and statistically significant ($p < 0.05$) effect on the adoption of CSA among smallholder farmers. Unexpectedly, the results showed that the main source of income had a negative and significant impact on CSA adoption. Household size positively impacted CSA adoption and was statistically significant at the 5% level. Surprisingly, the results showed that education level negatively impacted the adoption of CSA practices methods and was statistically significant.

#### 4.5.2.2. Determinants of the Intensity of CSA Adoption

The results of the intensity of CSA adoption are presented in Table 5. An inverse Mills ratio (IMR) predicted from the first-hurdle equation was used as a covariate in the count data model (second hurdle of the Poisson model) to correct for selectivity bias. The results show that the IMR was statistically significant, indicating that selection bias was a problem. Because the coefficient was significant, the null hypothesis (no selection bias) is rejected. Hence, using a double-hurdle model for estimating determinants and level of adoption of CSA while correcting for a selection bias problem is justified. As shown in Table 5, the estimation of the Akaike information criterion (AIC) and Bayesian information criterion (BIC) are essential to indicate a better model in analyzing count data of the CSA adoption level of smallholder farmers. In this study, the Poisson regression model was used, the AIC value was 362.705, and the BIC value was 396.442. Surprisingly, a Poisson model revealed that only two variables significantly impacted the intensity of CSA adoption. Drought and marital status were the main factors that significantly affected the intensity of CSA adoption by smallholder farmers in KwaZulu Natal.

**Table 5:** Poisson regression of determinants of intensity of CSA adoption among the farmers' second hurdle.

| CSA Number | Coef. | St. Err. | *p*-Value |
|---|---|---|---|
| Drought | 0.731 | 0.190 | 0.000 *** |
| Gender | 0.091 | 0.217 | 0.673 |
| Marital status | −0.203 | 0.122 | 0.095 * |
| On-farm income | 0.000 | 0.000 | 0.173 |
| Smartphone | −0.097 | 0.263 | 0.713 |
| Access to market info | −0.027 | 0.198 | 0.893 |
| Farmers' association | −0.084 | 0.229 | 0.714 |
| Main source of income | −0.001 | 0.064 | 0.983 |
| Household size | 0.002 | 0.021 | 0.913 |
| Age | 0.002 | 0.007 | 0.736 |
| Level of education | −0.044 | 0.135 | 0.741 |
| IMR_01 | 2.280 | 0.559 | 0.000 *** |
| Constant | −0.752 | 0.881 | 0.394 |
| Pseudo r-squared | 0.181 | | |
| Chi-square | 74.528 | | |
| Akaike crit. (AIC) | 362.705 | | |
| Bayesian crit. (BIC) | 396.442 | | |
| Prob > chi2 | 0.000 | | |

*** $p < 0.01$, * $p < 0.1$.

Similar to the first double hurdle of the probit regression model, the second double hurdle of the Poisson regression model showed that drought positively influenced the intensity of CSA adoption by smallholder farmers and was statistically significant. The results also showed that a farmer's marital status had a negative and significant relationship with the intensity of CSA adoption.

### 4.6. Discussion

This study aimed to assess the determinants of CSA adoption and the intensity of CSA adoption among smallholder maize farmers. The descriptive results indicated that farmers had experienced severe climatic conditions such as drought, pests, diseases, hailstorms, heavy rains (floods), soil infertility, and frost. This proves that climate change is still a major agricultural production issue, especially within smallholder farming. These results align with most previous studies' findings that agriculture is prone to harsh climatic conditions (FAO, 2015; Kolawole et al., 2016; Godde et al., 2021).

The empirical results revealed a positive relationship between drought conditions and CSA adoption and the intensity of CSA adoption. Rainfall, dams/rivers, communal taps, wells, and boreholes are the primary water sources for most smallholder farmers. However, due to varying rainfall amounts, some water sources are seasonal, making it difficult for rural farmers to produce annually (Serote et al., 2021). These results imply that farmers go the extra mile searching for different practices to put in place to save and harvest water to cope during water-shortage seasons. The results seem plausible to findings by Kanjere et al. (2014), who emphasized that farmers need to adopt CSA practices to help access and maintain water to adapt to water shortages. On the contrary, Negera et al. ( 2022) found that farmers who have previously been affected by drought are less likely to adopt and intensify CSA practices because the cost of adopting CSA practices is higher when farmers experience crop failure due to severe climatic conditions.

On-farm income in this study refers to the revenue farmers generate through making sales of their agricultural produce. The positive relationship between on-farm income and CSA adoption revealed in this study implies that farmers who sell their products to make income adopt CSA practices more than farmers who grow primarily for household consumption and those who generate income outside farming. Similarly, the study by Onyeneke et al. (2010); Adeagbo et al.(2021) found that farmers who sell their produce invest a lot in adaptation practices with the mandate to increase production. Furthermore, Asrat et al. (2018) stated that farmers who obtain off-farm income are less likely to invest in adaptation methods because they are not solely dependent on farming.

This study's findings indicate a negative relationship between the main source of income and CSA adoption. This result is convincing, as most smallholder farmers' main sources of income in the study area were old age and child support, indicating that the farmers' ability to afford to invest in new technologies is low. Another possible explanation of the negative relationship could be based on the findings that only 8.1% rely on agricultural sales as their main source of income. The results indicate that farmers in this study are less likely to be adventurous in investing in CSA practices, as most do not expect any returns from production but only grow crops for household consumption. These results correspond to Onyeneke and Madukwe's

(2010) studies, which found that only a few smallholder farmers are commercially orientated and take their produce to the market; hence, they are less likely to adopt CSA practices. Furthermore, Hlatshwayo et al.(2022) stated that most households see social grants as their main source of income and neglect farming.

The study results show a positive relationship between adopting CSA practices and household size. These results imply that more people in the household means more labour and exposure to information sources and hence more ideas about climate change adaptation strategies. This is in line with Adeagbo et al. (2021); Agbenyo et al.(2022), who found that household size positively influences the likelihood of CSA practices adoption. On the contrary, Musafiri et al.(2022) found that large families were less likely to adopt labor-intensive CSA practices, and small family sizes adopted and hired labor to implement the innovations.

The educational level of the farmer decreased the adoption of CSA practices. The implication of results could be attributed to the fact that farmers with a low educational level have fewer information-comprehension skills and therefore are less aware of climate change and, hence, less likely to respond to the effects of climate change. These findings are consistent with the findings of the Department of Agriculture, Forestry, and Fisheries (DAFF) (2012), which stated that recent technological improvements and information necessitate a certain level of formal education and training because most technologies are frequently presented in complex academic language, making it difficult for illiterate farmers to use them. The findings by Kolawole et al.(2014); Salad et al. (2021) stated that the more educated the farmer becomes, the more likely it is that they will use scientific weather knowledge in farming decisions. Again, farmers with low levels of formal education are less likely to adopt CSA practices because they cannot search, process, interpret, and respond to new information on CSA practices. Higher levels of education tend to build innovativeness and improve the farmers' information processing, which is essential in adopting technological decision-making choices (Gido et al., 2015; Onyeneke et al., 2018).

Surprisingly, the results of this study show that a farmer's marital status has a negative relationship with the intensity of CSA adoption. The possible explanations could be that most married farmers with kids are more likely to invest in domestic work than in the garden, and the spouse opts for off-farm activities to sustain household livelihood. Therefore, there is less time and money invested in agricultural innovations. The findings of this study are consistent with previous studies that show that marital status increases access to alternative sources of income outside of farming, decreases the time and effort dedicated to farming activities, and decreases labor, endowment, and investment in adopting new technology (Marenya et al., 2017; Onyeneke et al., 2018). Moreover, Negera et al. (2022) found that a spouse's education negatively influences the adoption of new technologies, as an educated individual prefers white-collar employment to sustain livelihood rather than sustaining livelihood via CSA adoption. The findings of this study are contrary to the results of Salad et al.( 2021). They revealed that farmers' marital status had a positive relationship with the intensity of climate-smart agriculture practices because marriage promotes family life by allowing both women and children to participate in crop production and technology use.

## 4.7. Conclusions and Policy Recommendations

The adoption of CSA practices helps smallholder farmers increase their agricultural productivity but also helps to improve smallholder farmer resilience to the impact of climate change. This study assessed the factors affecting the adoption and intensity of CSA adoption among smallholder maize farmers. The findings showed that drought, on-farm income, and household size significantly influenced the adoption of CSA practices. In contrast, the main source of income and educational level had a significant negative influence. Drought also had a significant positive impact on the intensity of CSA adoption, whereas marital status had a significant negative effect. It is concluded that socioeconomic characteristics considerably influenced the likelihood of CSA adoption and the intensity of adoption by smallholder maize farmers. Improved education among smallholder farmers can improve CSA adoption. Word of mouth, by which farmers share information with their family and friends, significantly improved the knowledge about climate change and adaptation. The study recommends that numerous local organizations with a strong comparative advantage in agriculture, climate change, and adaptation collaborate to invest in increasing rural public awareness of climate change and adaptation. An investment in outcome-based accredited training that caters to all farmers' primary education levels will ensure that training activities significantly impact the outcome of competent farmers with skills and knowledge about climate change and adaptation. The study suggests that climate change awareness and adaptation information be disseminated through the media and in locally understood languages. The study only looked at the factors influencing CSA adoption and intensity among smallholder maize farmers in one province of KwaZulu-Natal. Further research should be carried out in all nine provinces of South Africa.

## 4.8. References

Abegunde, V.O., Sibanda, M. and Obi, A., 2019. Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), p.195.

Adeagbo, O.A., Ojo, T.O. and Adetoro, A.A., 2021. Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria. Heliyon, 7(2), p.e06231.

Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., Siaw, A., Asare, I. and Twumasi, M.A., 2022. Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, *19*(7), p.3804.

Antwi-Agyei, P., Abalo, E.M., Dougill, A.J. and Baffour-Ata, F., 2021. Motivations, enablers and barriers to the adoption of climate-smart agricultural practices by smallholder farmers: Evidence from the transitional and savannah agroecological zones of Ghana. *Regional Sustainability*, *2*(4), pp.375-386.

Asrat, P. and Simane, B., 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, *7*(1), pp.1-13.

Ayinde I.A, Otekunrin O.A, Akinbode S.O, Otekunrin O.A (2020). Food Security in Nigeria: Impetus for Growth and Development. Journal of Agricultural Economics and Rural Development, 6(2): 808-820.

Bukchin, S. and Kerret, D., 2020. Character strengths and sustainable technology adoption by smallholder farmers. *Heliyon*, *6*(8), p.e04694.

Chamberlin, J., 2008. It's Small World After All: Defining Smallholder Agriculture in Ghana (Vol. 823). Intl Food Policy Res Inst.

De Luca, G. and Perotti, V., 2011. Estimation of ordered response models with sample selection. *The Stata Journal*, *11*(2), pp.213-239.

Department of agriculture, forestry and fisheries, Republic of South Africa (DAFF,RSA). Development of smallholder farmers through cooperative development.(2012).Available online: http://www.daff.gov.za (Accessed on 21 July 2022)

Food and Agriculture Organization (FAO). The economic lives of smallholder farmers. (2014). Available online: http// www.fao.org (Accessed 30 June 2022)

Food and Agriculture Organization (FAO). The economic lives of smallholder farmers. (2015). Available online: http// www.fao.org (Accessed 29 June 2022)

Gido, E.O., Sibiko, K.W., Ayuya, O.I. and Mwangi, J.K., 2015. Demand for agricultural extension services among small-scale maize farmers: Micro-level evidence from Kenya. *The Journal of Agricultural Education and Extension*, *21*(2), pp.177-192.

Godde, C.M., Mason-D'Croz, D., Mayberry, D.E., Thornton, P.K. and Herrero, M., 2021. Impacts of climate change on the livestock food supply chain; a review of the evidence. *Global food security*, *28*, p.100488.

Goodman, S., 2014. National Security and the accelerating risks of climate change. *CNA Military Advisory Board, Alexandria, VA*.

Harvey, C.A., Saborio-Rodríguez, M., Martinez-Rodríguez, M.R., Viguera, B., Chain-Guadarrama, A., Vignola, R. and Alpizar, F., 2018. Climate change impacts and adaptation among smallholder farmers in Central America. *Agriculture & Food Security*, *7*(1), pp.1-20.

Hernández Díaz-Ambrona, C.G., Gigena, R. and Mendoza, C.O., 2013. Climate change impacts on maize and dry bean yields of smallholder farmers in Honduras. *Iberoamerican journal of development studies*, *2*(1), pp.4-22.

Hlatshwayo, S.I., Ojo, T.O., Modi, A.T., Mabhaudhi, T., Slotow, R. and Ngidi, M.S.C., 2022. The Determinants of Market Participation and Its Effect on Food Security of the Rural Smallholder Farmers in Limpopo and Mpumalanga Provinces, South Africa. Agriculture, 12(7), p.1072.

Jimoh, L.O., Akintunde, O.K., Kehinde, A.L., Agboola, T.O. and Alabi, A.A., 2021. Structure, Conduct and Performance of Maize Marketing in Irewole Local Government Area, Osun State. *Nigerian Journal of Basic and Applied Sciences*, *29*(2), pp.59-66.

Kolawole, O.D., Motsholapheko, M.R., Ngwenya, B.N., Thakadu, O., Mmopelwa, G. and Kgathi, D.L., 2016. Climate variability and rural livelihoods: How households perceive and adapt to climatic shocks in the Okavango Delta, Botswana. *Weather, Climate, and Society*, *8*(2), pp.131-145.

Kolawole, O.D., Wolski, P., Ngwenya, B. and Mmopelwa, G., 2014. Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana. *Climate risk management*, *4*, pp.43-58.

Kom, Z., Nethengwe, N.S., Mpandeli, N.S. and Chikoore, H., 2020. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. *GeoJournal*, pp.1-24.

Marenya, P.P., Kassie, M., Jaleta, M., Rahut, D.B. and Erenstein, O., 2017. Predicting minimum tillage adoption among smallholder farmers using micro-level and policy variables. *Agricultural and Food Economics*, *5*(1), pp.1-22.

Mazibuko, N.L., 2018. Selection and implementation of Climate Smart Agricultural Technologies: performance and willingness for adoption (Doctoral dissertation).

McCarthy, N., Lipper, L. and Branca, G., 2011. Climate-smart agriculture: smallholder adoption and implications for climate change adaptation and mitigation. *Mitigation of Climate Change in Agriculture Working Paper*, *3*(1), pp.1-37.

*Models for Count Data*. (2008). 277–286. Available online: https://doi.org/10.1007/978-3-540-71918-2_16 (Accessed on 19 July 2022)

Mpanza, T.P., 2008. An evaluation of the perceived benefits and constraints of community gardens established by the KwaZulu-Natal Department of Agriculture and Environmental Affairs (Doctoral dissertation).

Musafiri, C.M., Kiboi, M., Macharia, J., Ng'etich, O.K., Kosgei, D.K., Mulianga, B., Okoti, M. and Ngetich, F.K., 2022. Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter?. *Heliyon*, *8*(1), p.e08677.

Mutenje, M.J., Farnworth, C.R., Stirling, C., Thierfelder, C., Mupangwa, W. and Nyagumbo, I., 2019. A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics*, *163*, pp.126-137.

Negera, M., Alemu, T., Hagos, F. and Haileslassie, A., 2022. Determinants of adoption of climate smart agricultural practices among farmers in Bale-Eco region, Ethiopia. *Heliyon*, *8*(7), p.e09824.

Ogunyiola, A., Gardezi, M. and Vij, S., 2022. Smallholder farmers' engagement with climate smart agriculture in Africa: role of local knowledge and upscaling. *Climate Policy*, *22*(4), pp.411-426.

Ojo, T.O. and Baiyegunhi, L.J.S., 2020. Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in southwest Nigeria. *Land Use Policy*, *95*, p.103946.

Onyeneke, R.U. and Madukwe, D.K., 2010. Adaptation measures by crop farmers in the southeast rainforest zone of Nigeria to climate change. *Science World Journal*, *5*(1).

Onyeneke, R.U., Igberi, C.O., Uwadoka, C.O. and Aligbe, J.O., 2018. Status of climate-smart agriculture in southeast Nigeria. *GeoJournal*, *83*(2), pp.333-346.

Organisation for economic co-operation and development (OECD) . Adoption of Technologies for Sustainable Farming Systems.2001. Available online: https://www.oecd.org (Accessed on 01 July 2022)

Pienaar, L. and Traub, L., 2015. Understanding the smallholder farmer in South Africa: Towards a sustainable livelihood's classification (No. 1008-2016-79955).

Salad, A.F., Zziwa, S., Talengera, D., Nabatanzi, L., Makumbi, O., Najjuma, V. and Nafula, M., 2021. Adoption intensity of climate smart agricultural practices in arabica coffee production in Bududa District.

Scherr, S.J., Shames, S. and Friedman, R., 2012. From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security*, *1*(1), pp.1-15.

Schreinemachers, P., Simmons, E.B. and Wopereis, M.C., 2018. Tapping the economic and nutritional power of vegetables. *Global food security*, *16*, pp.36-45.

Serote, B., Mokgehle, S., Du Plooy, C., Mpandeli, S., Nhamo, L. and Senyolo, G., 2021. Factors Influencing the Adoption of Climate-Smart Irrigation Technologies for Sustainable Crop Productivity by Smallholder Farmers in Arid Areas of South Africa. *Agriculture*, *11*(12), p.1222.

Statistics South Africa (Stats SA). Category Archives: Food Security and Hunger. 2021. Available online: http://www.statsa.gorv.za (accessed on 20 August 2022).

Steinfeld, B., Scott, J., Vilander, G., Marx, L., Quirk, M., Lindberg, J. and Koerner, K., 2015. The role of lean process improvement in implementing evidence-based practices in behavioral health care. *The Journal of Behavioral Health Services & Research*, *42*(4), pp.504-518.

Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, *7*(1), pp.1-14.

Westermann, O., Förch, W., Thornton, P., Körner, J., Cramer, L. and Campbell, B., 2018. Scaling up agricultural interventions: Case studies of climate-smart agriculture. *Agricultural Systems*, *165*, pp.283-293.

Wooldridge, J.M., 2002. Inverse probability weighted M-estimators for sample selection, attrition, and stratification. *Portuguese economic journal*, *1*(2), pp.117-139.

Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A., Ericksen, P., Said, M. and Jalloh, A., 2016. Toward climate-smart agriculture in West Africa: a review of climate change impacts, adaptation strategies and policy developments for the livestock, fishery and crop production sectors. *Agriculture & Food Security*, *5*(1), pp.1-16.

# CHAPTER FIVE

## THE EFFECT OF CLIMATE SMART AGRICULTURE (CSA) ADOPTION ON SMALLHOLDER FARMERS' HOUSEHOLD FOOD SECURITY.

### 5.1. Introduction

The world is struggling to meet the 2030 deadline of Sustainable Development Goals (SDG) 2, which is to end malnutrition, ensure nutrition and sufficient food for all, and eliminate all forms of hunger(FAO et al., 2021). Between 2016 and 2017, The number of hungry people in 126the world rapidly increased from 804 million to 821 million. In 2019, 690 million people worldwide were suffering from hunger, while 135 million people in 55 countries and territories were suffering from acute food insecurity, with Africa accounting for 73 million of this figure . In 2020, the COVID-19 pandemic and the actions many countries took to contain it added to the already present challenges, further undermining efforts to reduce hunger and malnutrition in the region(FAO et al., 2015). An estimated 720 to 811 million people worldwide were hungry, 161 million more than in 2019 (FAO et al., 2021).. In 2020, nearly 2.37 billion people lacked adequate food, an increase of 320 million in just one year[2]. The number food insecure and hungry people worldwide is high and appears to be worse in part of Sub-Saharan Africa [2]. Between 2014 and 2020, the number of Africans who are malnourished increased by 55% (FAO et al., 2015).

South Africa is nationally food secure, yet there are number of individuals and households that are food insecure in the country(Haymson et al., 2017). . South Africans suffering from moderate to severe food insecurity increased to almost 23, 6% in 2020, while the number of those suffering from severe food insecurity has increased to almost 14, 9% (StatsSA, 2021) . According to research findings from the Food Insecurity Experience Scale (FIES) analysis, 17, 3% (10, 1 million) South Africans were classified as having moderate to severe food insecurity in 2019. In contrast, 7% of people were classified as having severe food insecurity (StatsSA, 2021). However, agriculture continues to be an important source of livelihood for food security and poverty reduction (FAO et al., 2015). Agriculture provides livelihoods for approximately 80% of South Africa's rural population [5]. According to most studies, urban and rural households increasingly rely on local market purchases, which often account for 90% of the smallholder/local produced foods (Baiphethi & Jacobs, 2009). One of the factors that contribute to food insecurity is a higher inflation rate (Baiphethi & Jacobs, 2009). Food costs can account for as much as 60–80% of the total household income (Baiphethi & Jacobs, 2009), necessitating the needs for practicing smallholder agriculture.

Even though smallholder agriculture has all the potential to address food security challenges, the sector continues to face persistent challenges (United Nations Development Programme (UNDP), 2012; Hlatshwayo et al., 2022). Agriculture remains vulnerable to episodic climate shocks (Zougmoré et al., 2016). Extreme variations in temperature and precipitation patterns endanger food production and make people who rely on agriculture for a living more vulnerable (Zougmoré et al., 2016). The changes in production systems brought by climate change may also bring changes in dietary patterns and food utilisation, affecting the stability and resilience of food systems with consequences in terms of long-term food security (El Bilali et al., 2020). Agriculture must address the challenge of ensuring food security while also adapting to climate change (FAO, 2013). Increasing farmers' adaptive capacity, resilience, and resource use efficiency in agricultural production systems can help to mitigate threats (Lipper et al., 2014). Climate-smart agriculture (CSA) is the most recommended as far as increasing the resilience of agricultural production is concerned.

CSA is a strategy for converting and reorienting agricultural systems to support food security in the face of new climate-change realities (Lipper et al., 2014). The study by Radeny et al. (2022) discovered that CSA technologies improve household food security and nutrition situation. Adopting multiple stress-tolerant crops increased dietary diversity in households by 40% and reduced food insecurity by 75%. The study by Branca & Perelli (2020); Ogunyiola (2022) indicated that despite the CSA investment by global development communities, its potential sustainability, economic benefit, and adoption of CSA practices are still slim among smallholder farmers. Most CSA practices are considered to be expensive and unaffordable to smallholder farmers (Mccarthy, 2011; Zougmoré et al., 2016). Heterogenous farming systems, limited finance, high agricultural input costs, and technology are all barriers to CSA adoption (Ogunyiola et al., 2022).

Most studies on CSA adoption found that the determinants of CSA adoption, which are classified as institutional, technical, and socioeconomic factors, have the greatest impact on household food security (Wekesa et al., 2018; Abegunde et al., 2020). These factors have either positive or negative effect and they also determine the intensity of CSA adoption. The studies further explained that farmers that employing a comprehensive diverse package that includes all the category practices have the most significant impact on their state of food security.

However, these studies generally examined the effect of CSA adoption on food security using the Household Food Insecurity Access Scale (HFIAS). This implies that there is a knowledge gap of studies that uses Household hunger Scale (HHS) as a measure of food security, therefore it is against this backdrop that the study seeks to investigate the contribution of CSA adoption on smallholder farmers' food security as determined by HHS.

This introductory section is one of five sections in the study structure. The methodology of the study is discussed in the second section, which includes a description of the study area, data collection methods, and conceptual framework. The third section summarizes the findings of the research, the fourth section discusses the findings of interviews, focus groups, and empirical frameworks. Finally, the conclusion offers a brief summary and critique of the findings, as well as suggestions for future research.

## 5.2. Methodology

### 5.2.1. Description of the Study areas

The study area, sampling, and data collection technique are the same as in chapter three.

### 5.2.2. Data Collection Method

#### 5.2.2.1. Research design

The descriptive research method was used in the study, encompassing qualitative and quantitative research methods to investigate the distributional impact of CSA adoption on food security in KwaZulu Natal. About 49 participants were simple random sampled from Swayimane, and 50 were sampled from Bergville, which makes a total of 99 respondents that were interviewed. The goal was to assess the CSA practices used by various smallholder farmers as well as the household food security status of farmers in the study area. The primary data was collected using semi-structured interview questionnaires to find the farmer's short-term adaptive measures for the 2019/2020 maize production season. The study investigates which climatic hazards endanger farmers' maize yields, how they deal with them, and what potential practices are needed in their farming system to increase production. A questionnaire was also distributed to determine long-term adaptation strategies. Approximately 29 lists of practices were identified with the assumption that each can achieve one or more CSA goals. These practices were classified as knowledge smart, carbon smart, nitrogen smart, water smart, weather smart, and energy smart. Adoption of practices was self-reported in yes/no questions.

#### 5.2.2.2. Household Hunger Scale (HHS)

To assess household food security in the study area, the HHS tool was used. This HHS uses four weeks (30-days) recall period for collecting household food security status data. A 4-week call period is assumed to reduce the risk of biasness due to problems with accurate recalling. A recall period of less than four weeks will not capture the entirety of the experience, and fluctuations in food availability are common within a month ( Ballard, 2011). The HHS focuses on food quantity and does not assess dietary quality. The HHS is a measure at the household level. It does not collect data on food accessibility or consumption; other food security components are typically measured at the national and individual levels (availability) (consumption/utilization).The HHS is intended to be used as a small module within a larger, more comprehensive food security and nutrition questionnaire administered to a representative population-based sample of households

## 5.3. Analytical Framework

### 5.3.1. Computing Household Hunger Scale (HHS)

To assess food security, a categorical HHS indicator was used. The categorical indicator is more accessible to interpret and therefore was mostly preferred for this analysis. First, the HHS score for every respondent was frequency computed. Computing the HHS score was achieved by creating a new variable that recorded the response of each a -of-occurrence question from one of three frequency categories. The coding of the new variable was 1= "rarely," 2-"sometimes," 3-"often," and 0 for a household that answered no to each corresponding occurrence question. The values of the new variables were summed for each household to calculate the HHS score. If the tabulation was done correctly, each household had an HHS score ranging from 0 to 6. The HHS indicator is created using these values. To tabulate the HHS indicator, the HHS score was subjected to two different value cuts (>1 and >3). The 3 Household Hunger Categories are 0-1 HHS score falls under there is little to no hunger in the household. A HHS hunger score of 2-3 indicates moderate hunger in the household, while an HHS score of 4-6 indicates severe hunger in the household ( Ballard, 2011).

### 5.3.2. Ordered probit regression (Effect of CSA adoption on food security)

The ordered probit regression model was used to assess the impact of CSA adoption on the food security of the study area's smallholder farmers' households. The composite score was used to calculate the Household Hunger Scale (HHS), which proxy's food security (the dependent variable). Thus, the ordered probit model is expressed as follows:$Z_i$ = χ'β+$\varepsilon_i$Zμί

(2)

where $Z_i$ is the unobserved discrete random variable, $X_i$ It is the vector of independent variables, β is the vector of parameters of the regression to be estimated, and εi is the vector of the error term (Greene, 2003). Thus, $Z_i$, which is the empirical ordinal variables are presented in the following values:

$Z_i = 0$ if $Z_i \leq 0$

$Z_i = 1$ if $0 < Z_i \leq \mu_i$

$Z_i = J$ if $\mu_{i-1} < Z_i$ (3)

The dependent variable is $Z_i$ = HHS (food security)

Practices (1 = food secure, 0 = food insecure).

The independent variables are:

$N_1$ = CSA Adoption (dummy)

$N_2$ = Drought (D = 1 if yes; 0 = otherwise);

$N_3$ = Household head's marital status (single = 1, married = 2, widowed = 3, divorced/separated = 4);

$N_4$ = on farm income (number);

$N_5$ N5 = Smart phone (1 = yes, 0 = otherwise);

$N_6$ = Access to markets (1 = yes, 0 = otherwise;

### 5.4. Description of variables

The IBM Statistical Package for Social Science (SPSS) version 28 was used to compute the quantitative data analysis for the study. The descriptive statistics provided information on the key socioeconomic characteristics of the sampled smallholder farmers. The study hypothesized that CSA adoption, drought, gender, marital status, once-off-farm income, Smartphone, access to market information, Farmers Association membership, primary source of income, Household size, age, and level of education were factors affecting food security, as well as the impact of CSA on food security. Table 1 lists the descriptive variables influencing household food security and the effect of CSA adoption on the household hunger scale in the study area, as well as their names, variable types, measurements, and expected outcomes.

**Table 6**: Summarizes the descriptive variables' names, variable type and measurement, and an expected outcome (Source: Own analysis)

| **Variable** | **Description** | **Expected results on factors influencing household food security** | **Expected results on the effect of CSA adoption on the household hunger scale** |
|---|---|---|---|
| CSAADOPTION | Dummy(1=yes,0=otherwise) | + | - |
| Drought | Dummy (1=Yes, 0=otherwise) | - | + |
| Gender | Respondent's sex (1=male,0=Female) | +/- | +/- |
| Marital status | | + | - |
| Once-off | Measured in Rands/Kg (Continuous) | + | - |
| Smartphone | Dummy (1=Owns, 0=otherwise) | + | - |
| Access to markets | Whether the household has access to the market or not (1=Yes, 0=otherwise) | + | - |
| Farmer's Association | Whether a household is a member of the farmer's association (1=Yes, 0=otherwise) | + | - |
| The primary source of income | Households' main source of income (Measured in Rands/Kg) | + | - |
| Household size | Number of household members (continuous) | + | - |
| Age | Respondent's age in the year (continuous) | - | |
| level of education | Respondents' level of education (1=No education,2=Primary, 3 =Secondary, 4=Tertiary) | + | - |

## 5.5. Results

### 5.5.1. Descriptive Analysis of Results

#### 5.5.1.1. Demographics characteristics of smallholder farmers in the study area.

The average age of those interviewed in the study area was 59 with the youngest being 26 and the oldest being 88, according to the demographic characteristics of smallholder farmers in the study area. The study sample was dominated by females (79.8%) and males (20.2%). The majority of farmers (41, 4%) had only a primary education, with only 1% having a tertiary education. In the study area, the majority of farmers (72, 2%) are married. About 39.4% of respondents rely on pension grants as their primary source of income, 37.4% on social government grants, and only 8.1% on agricultural produce sales. Regarding the second source of income, most farmers do not have one, and 21, 2% get their second source of income from selling agricultural produce.

#### 5.5.1.2. CSA practices adopted by farmers in the study area

##### 5.5.1.2.1. Short-term CSA Practices adopted by Smallholder maize farmers to cope with natural hazards in the 2019-2020 season.

In order to cope with natural disasters in the 2019–2020 growing season, Figure 2 shows the various short-term CSA practices used by smallholder maize farmers. According to the findings, approximately 71% of farmers did not take any specific action to deal with the drought. In contrast, 6% thought it was impossible to take drought-relief measures. Only 1% used in-field rainwater harvesting methods, in which farmers dig rows (trenches) in the soil to absorb rainwater. To combat diseases, 85.9% of farmers used chemicals, 10% did nothing, and only 2.4% removed affected leaves or crops to prevent disease spread. To combat pests, the results revealed that 80% of farmers used chemicals, 9% took no action, and 1% used grey water harvesting, or water with soap previously used for laundry, to combat pests. Figure 2 depicts the various short-term CSA practices used by smallholder maize farmers to deal with natural disasters during the 2019-2022 season. Approximately 71% of farmers, according to the findings, did not take any specific drought-related action. Only 1% used in-field rainwater harvesting methods, in which farmers dig rows (trenches) in the soil to absorb rainwater.

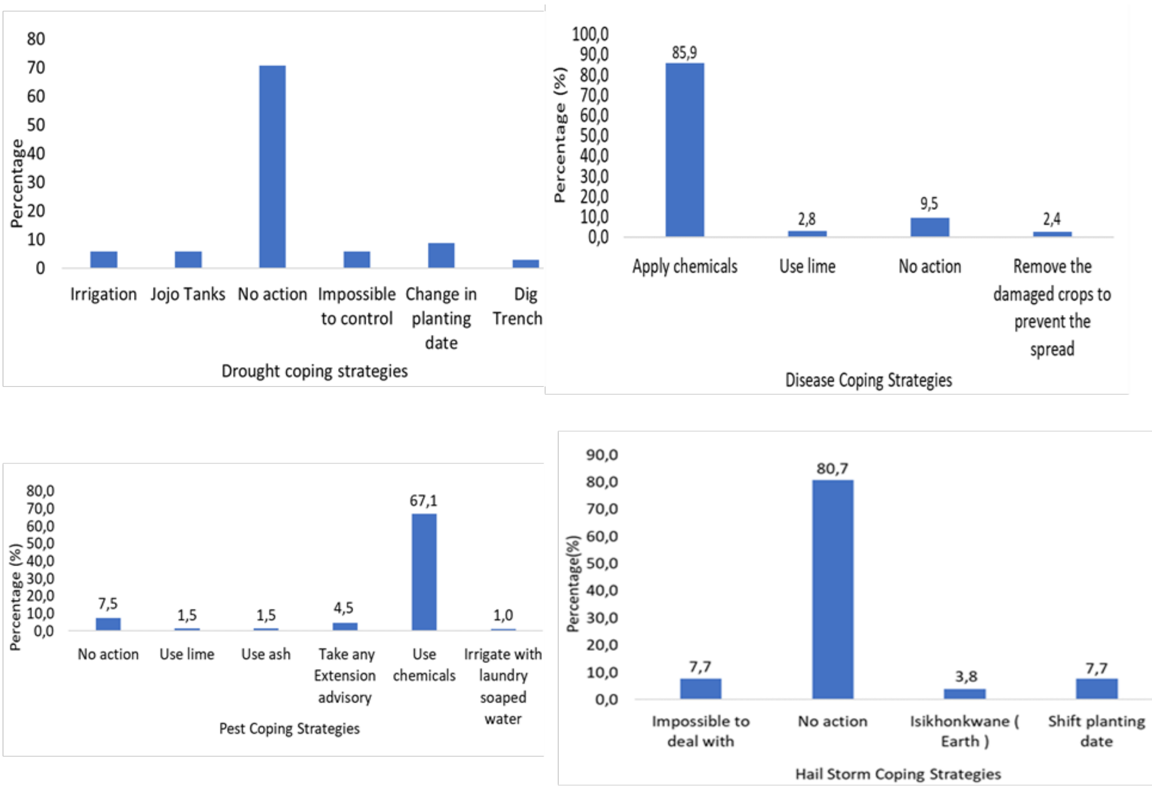



**Figure 7:** The different short-term CSA practices adopted by smallholder maize farmers to cope with natural hazards in the 2019-2020 season (Source: Own analysis)

Around 80.7% of farmers did nothing to prepare for hailstorms, 7.7% believed it was impossible to deal with, and 7.7% shifted planting dates. Concerning flood adaptation, approximately 15% of the affected farmers did nothing to address the problem, 2% dug trenches to channel water away from the plots, and 1% believed that flood adaptation was impossible. The findings also revealed that frost affected 3% of farmers, and they all preferred planting earlier than usual to allow crops to mature sufficiently to withstand frost. Farmers believe that using organic manure, adding lime to neutralize soil pH, mixing different fertilizers and relying on extension advisory services, and using specifically recommended fertilizers will help them withstand natural disasters and increase production.

**5.5.2.2.2. The smallholder maize farmers in KwaZulu Natal employ adaptation strategies over ten years of maize production.**

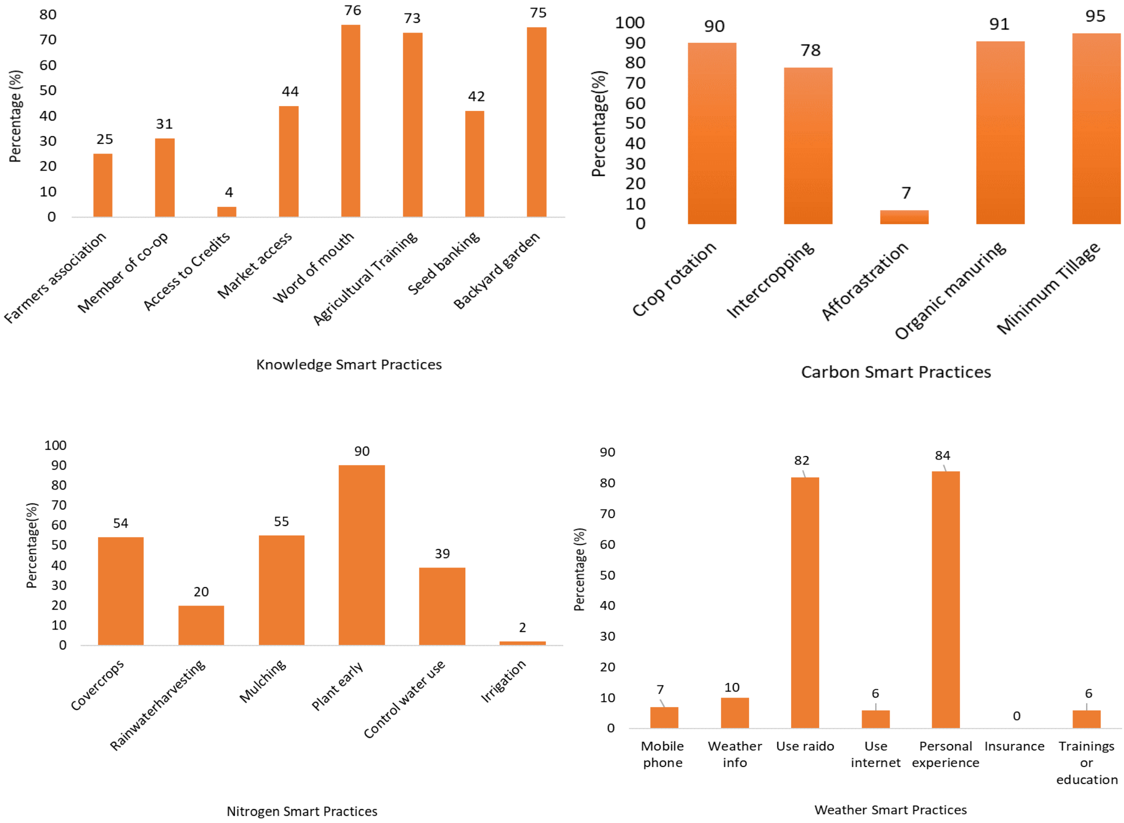



**Figure 8:**Long-term Climate Smart Practices adopted by sampled smallholder maize farmers (Source: Own analysis)

The most common water-smart practice adopted by farmers is planting early in the season (90%) to use rainwater efficiently, followed by 54% who planted cover crops to maintain soil moisture and 55% who used mulch to reduce excessive water use. Only 2% of farmers use irrigation. Among weather-smart practices, approximately 43% of farmers predicted weather events based on personal experience, while 42% relied on radio or television for weather information. The findings show that no farmers buy index-based insurance to protect their crops from weather events. The majority of farmers (74%) used compost as an energy-saving practice.

**5.5.1.3. Household Hunger Scale (HHS) in the study area.**

Figure 4 depicts the three HHS indicators that were created. According to the findings, In the study area, only 8% of the farmers had serious hunger problems in their households. The majority of households (78%) had little or no hunger, and 13.1% of farmers had moderate hunger in their households.

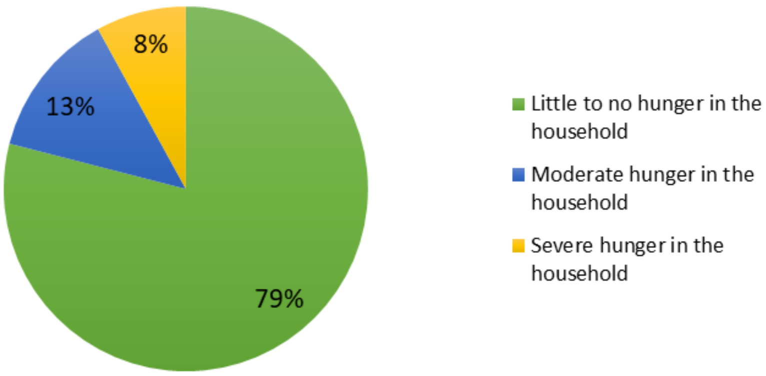



**Figure 9**: HHS Indicator (Source: Own analysis)

**5.2.2.2. Effect of CSA on the adoption of household food security (Ordered Regression model)**

The Ordered probit model's results in Table 4 show the CSA adoption's effect on household food security in KwaZulu Natal. Similar to table 3, it was surprising that only three variables significantly affected the HHS, and are presented in table 4. The p-value of 0.000 indicates that the model as a whole was statistically significant. The estimated cut-off points (μ) showed that the categories were ranked in an ordered way of $\mu_1 > \mu_2$ . The dependent variable, HHS, increases with food insecurity severity, a positive coefficient indicates the possibility of more severe food insecurities, and a negative coefficient indicates the possibility of food security.

**Table 7:** The effect of CSA adoption on household food security (Ordered probit model)

| HHS | Coef. | St.Err. | p-value |
|---|---|---|---|
| CSA ADOPTION | 1.330 | 0.504 | 0.008*** |
| Drought | 1.102 | 0.450 | 0.014** |
| Gender | -0.135 | 0.502 | 0.787 |
| Marital status | -0.350 | 0.324 | 0.279 |
| Smartphone | -0.243 | 0.618 | 0.694 |
| Aaccesstomarketinfo | 0.689 | 0.455 | 0.130 |
| Farmers association | -0.515 | 0.525 | 0.327 |
| Mainsourceofincome | -0.340 | 0.137 | 0.013** |
| Household size | 0.017 | 0.050 | 0.734 |

| | | | |
|---|---|---|---|
| Age | -0.019 | 0.016 | 0.214 |
| level of education | -0.313 | 0.322 | 0.331 |
| TotalAnum | 0.000 | 0.000 | 0.560 |
| cut1 | -1.616 | 1.848 | |
| cut2 | -1.112 | 1.844 | |
| Mean dependent var | 0.343 | | |
| Pseudo r-squared | 0.306 | | |
| Chi-square | 39.818 | | |
| Akaike crit. (AIC) | 118.410 | | |
| Bayesian crit. (BIC) | 154.741 | | |
| Prob > chi2 | 0.000 | | |

**** p<0.01, ** p<0.05, * p<0.1*

The findings show that household adoption of CSA practices was statistically significant at 1% and positively correlated with the household hunger scale, implying that the intensity of CSA practices adopted by smallholder farmers resulted in more hunger. Drought was significant at the 1% level (p=0.000) and correlated positively with HHS. In line with what was expected, the model predicts that farmers experiencing drought conditions are more likely to suffer from severe hunger, resulting in food insecurity. At a 5% level, the primary source of income was found to be significant and it was negatively related to households' HHS. The model predicts that farmers' main source of income will subject them to less or no hunger, thus improving their food security status.

## 5.6. Discussion

The effect of climate changes is still a main issue which cannot be avoided and it worsens hunger, food insecurity and malnutrition. The overall results showed that, 78% of the farmers in the study area experienced little or no hunger, according to the results of HHS indicators measuring household food security status. This means that in the four weeks/30 days before the survey, there were little or no chances of households having; no food to eat of any kind in the house due to a lack of resources to get food, going to bed hungry because there was not enough food, and going a whole day and night without eating anything. The findings of this study are consistent with those of Nkegbe et al. (2017), , who discovered that a higher proportion of respondents in his household food security study experienced little to no hunger.

Drought showed a positive impact on food security as determined by HHS. The findings imply that the frequent occurrence of drought conditions increased experiences of hunger and household food insecurity among smallholder farmers. The findings are in line with Twongyirwe et al. (2019), who stated that drought is widely perceived as a challenge towards attaining food security. Additionally these results also supports the findings of , (Harvey et al., 2018), who indicated that extreme weather events caused 32% of smallholder farmers to experience food insecurity.

The main source of income is crucial because it determines how much the household has to spend on various household needs. Sekhampu (2013) stated that household income determines the amount of food a household can purchase.. In this study, household's main source of income had a negative relationship with HHS. This means that smallholder maize farmers were able to use their main source of income to make a living, and also to meet the food needs for improved food security. These are in line with Onianwa & Wheelock (2006); Bashir et al. (2010) findings which also reported a positive relationship between household income and food security.

It was of interest in this paper to assess whether adopting CSA practices influenced food security status of the smallholder farmers. A positive relationship between CSA adoption and the household hunger scale implies that the level in which CSA practices were adopted increased the likelihood of being food insecure . This outcome could be explained by the fact that smallholder farmers did not use a combination of CSA practices. Most studies emphasize that CSA adoption is more effective for food security when farmers implement a package that includes a variety of CSA practices (Wekesa et al., 2018; Abegunde et al., 2020). These findings contradict those of Brüssow et al. (2017); Hasan et al. (2018) who discovered a positive relationship between CSA adoption and food security. According to the observations, most farmers interviewed were unaware of CSA.

### 5.7. Conclusion and policy recommendation

In this paper, the effect of CSA adoption on food security was examined. The ordered regression model examined the effect of CSA adoption on HHS. Most smallholder farmers experienced little to no hunger. The main source of income influenced the food security status of the smallholder farmers. The experience of drought contributed to food insecurity of smallholder farmers. While adoption of CSA practices did not considerably improve food security status but the contribution of CSA adoption towards food security cannot be ignored. This is because if CSAs are used in tandem and to a greater extent, they have the potential to reduce food insecurity.  To be more resilient to climate change effect, farmers should be encouraged to include a comprehensive diverse CSA package. There is an urgent need to increase efforts towards assisting smallholder farmers in coping with current changes and adapting to future climatic conditions. Public and private organizations should collaborate to facilitate smallholder farmer adaptation to climate change.

## 5.8. References

Abegunde, V.O., Sibanda, M. and Obi, A., 2019. Determinants of adopting climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, *12*(1), p.195.

Baiphethi, M.N., and Jacobs, P.T., 2009. The contribution of subsistence farming to food security in South Africa. Agrekon, 48(4), pp.459-482.

Bashir, M.K., Naeem, M.K. and Niazi, S.A.K., 2010. Rural and peri-urban food security: a case of district Faisalabad of Pakistan. *World Applied Sciences Journal*, *9*(4), pp.403-411.

Branca, G. and Perelli, C., 2020. 'Clearing the air: common drivers of climate-smart smallholder food production in Eastern and Southern Africa. *Journal of Cleaner Production*, *270*, p.121900

Brüssow, K., Faße, A. and Grote, U., 2017. Implications of climate-smart strategy adoption by farm households for food security in Tanzania. *Food security*, *9*(6), pp.1203-1218.

El Bilali, H., Bassole, I.H.N., Dambo, L. and Berjan, S., 2020. Climate change and food security. *Agriculture & Forestry/Poljoprivreda i Sumarstvo*, *66*(3).

FAO, IFAD, PAHO, WFP, and UNICEF. 2021. Latin America and the Caribbean – Regional Overview of Food Security and Nutrition 2021: Statistics and trends. Santiago, FAO. https://doi.org/10.4060/cb7497en

FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition, and affordable healthy diets for all. Rome, FAO. https://doi.org/10.4060/cb4474en

United Nations Development Programme (UNDP). Human Development Report 2012 Africa Human Development Report 2012:Towards a Secure Food Future. 2012. Available online: www.undp.org accessed on 03 September 2022.

Harvey, C.A., Saborio-Rodríguez, M., Martinez-Rodríguez, M.R., Viguera, B., Chain-Guadarrama, A., Vignola, R. and Alpizar, F., 2018. Climate change impacts and adaptation among smallholder farmers in Central America. *Agriculture & Food Security*, *7*(1), pp.1-20.

Hasan, M.K., Desiere, S., D'Haese, M. and Kumar, L., 2018. Impact of climate-smart agriculture adoption on the food security of coastal farmers in Bangladesh. *Food Security*, *10*(4), pp.1073-1088.

Haysom, G., Crush, J. and Caesar, M., 2017. No. 03: The Urban Food System of Cape Town, South Africa.

Hlatshwayo, S.I., Ojo, T.O., Modi, A.T., Mabhaudhi, T., Slotow, R. and Ngidi, M.S.C., 2022. The Determinants of Market Participation and Its Effect on Food Security of the Rural Smallholder Farmers in Limpopo and Mpumalanga Provinces, South Africa. *Agriculture*, *12*(7), p.1072.

Mthethwa, K.N., Ngidi, M.S.C., Ojo, T.O. and Hlatshwayo, S.I., 2022. The determinants of adoption and intensity of climate-smart agricultural practices among smallholder maize farmers. *Sustainability*, *14*(24), p.16926.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R., 2014. Climate-smart agriculture for food security. *Nature climate change*, *4*(12), pp.1068-1072.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2021. Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane KwaZulu-Natal. *Land Use Policy*, *109*, p.105611.

Ogunyiola, A., Gardezi, M. and Vij, S., 2022. Smallholder farmers' engagement with climate-smart agriculture in Africa: role of local knowledge and upscaling. *Climate Policy*, *22*(4), pp.411-426.

Ogunyiola, A., Gardezi, M. and Vij, S., 2022. Smallholder farmers' engagement with climate-smart agriculture in Africa: role of local knowledge and upscaling. *Climate Policy*, *22*(4), pp.411-426.

Titus, B. and Adetokunbo, G., 2007. An analysis of food security situation among Nigerian urban households: Evidence from Lagos State, Nigeria. *Journal of Central European Agriculture*, *8*(3), pp.397-406.

Twongyirwe, R., Mfitumukiza, D., Barasa, B., Naggayi, B.R., Odongo, H., Nyakato, V. and Mutoni, G., 2019. Perceived effects of drought on household food security in Southwestern Uganda: Coping responses and determinants. *Weather and Climate Extremes*, *24*, p.100201.

Onianwa, O.O., and Wheelock, G.D., 2006. An analysis of the determinants of food insecurity with severe hunger in selected southern states. Journal of Rural Social Sciences, 21(1), p.5.

StatsSA. (2020). *Mid-year population estimates* (Issue July).

StatsSA. (2021). *Measuring Food Security in South Africa: Applying the Food Insecurity Experience Scale*.

Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture & Food Security*, *7*(1), pp.1-14.

Wu, F. and Guclu, H., 2013. Global maize trade and food security: Implications from a social network model. *Risk analysis*, *33*(12), pp.2168-2178.

Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A., Ericksen, P., Said, M. and Jalloh, A., 2016. Toward climate-smart agriculture in West Africa: a review of climate change impacts, adaptation strategies and policy developments for the livestock, fishery, and crop production sectors. *Agriculture & Food Security*, *5*(1), pp.1-16.

# CHAPTER SIX

## THE DISTRIBUTIONAL EFFECT OF CLIMATE SMART AGRICULTURE (CSA) ADOPTION ON SMALLHOLDER FARMERS' HOUSEHOLD MAIZE YIELDS.

### 6.1. Introduction

Smallholder or subsistence farmers may be the primary driver of agricultural development and the key to the South African economy's overall growth and development (Wiggins and Keats, 2013). Maize is the most prevalent crop farmed, marketed, and eaten in South Africa. According to studies, South Africa plays a crucial role in exporting maize to other African nations (Wu and Guclu, 2013, Pradhan and Mbohwa, 2014). The sale of maize and products made from maize is a significant source of foreign currency income for the maize sector (Macauley and Ramadjita, 2015). In southern Africa, maize is the primary source of carbohydrates and the largest domestically produced field crop (Agri, 2017). The optimal temperature range for higher maize production is 28°C to 32°C, and the life cycle requires 500 to 800 mm of water (Xie et al., 2017; Bhusal et al., 2021). Hussain et al. (2019) investigated the interaction of heat and drought stress on maize hybrids. Heat and drought stress significantly reduced plant height, shoot fresh weight, shoot dry weight, leaf area, kernels/ear, 100-kernel weight, and grain yield per plant. When stress was applied individually, the effects of drought stress were more severe than those of heat stress (Hussain et al.,2019).

In general, maize is grown in semi-arid regions where it must contend with heat, drought, and variations of these conditions. Reduced precipitation will influence maize production in southern Africa and Europe before 2040, according to research that looked at the annual mean precipitation and particular growth seasons and regions (Serna, 2022). Despite its importance, maize yields are still low (Agbugba et al., 2020). Maize production is under threat due to climate change. Maize is particularly susceptible to climate change while adapting to a wide range of agro-ecologies (Serna, 2022). In the face of climate change, the temperature rises impact maize growth and modifications in rainfall patterns. It is unquestionably understood that temperatures above 35°C have a detrimental effect on maize's vegetative and reproductive growth, from sprouting to grain filling (Serna, 2022). More regions of the world with maize crops will likely be concerned, given that the precipitation variability is a crucial factor because water availability during a specific stage of plant development affects crop cultivation at later phases of the life cycle (Halubok and Yang, 2020).

For example, maize is the most significant crop in the smallholder agricultural regions in the Eastern Cape (EC) region of South Africa (Muzangwa et al., 2017). The non-commercial agricultural sector's maize planting area is estimated to be 297 460 ha, a 0.49% increase over the previous season's 296 000 ha. This sector's expected maize crop is 543-545 tons, which is 1.03% less than the previous season. The Eastern Cape produces approximately 40% of non-commercial maize, followed by KwaZulu-Natal (27%)(SAGL, 2020). Its yields are low, with average yields of under 1 tonne per hectare. Low and erratic rainfall is a significant constraint to the growth of maize.

Climate-smart agricultural (CSA) strategies have been shown to reduce the negative consequences of climate change by boosting crop production and incomes and improving the adaptability and resilience of production systems (Palombi and Sessa, 2013). Some farming methods and technology help to reduce the number of emissions of greenhouse gases and the sequestration of carbon in soils and agricultural biomass (Siminyu et al., 2021). CSA enables a shift to more sustainable agriculture and food systems that are environmentally friendly, productive, and sustainable (Siminyu et al., 2021). Intercropping maize and legumes and using organic manure has been suggested as a potential CSA strategy for addressing the climate change impacts on maize production (Siminyu et al., 2021). Despite the benefits, the adoption of CSA remains low (Chitakira and Ngcobo, 2021). The effects of climate change on agricultural production and farmer adaptation tactics have been the main topics of extensive research on smallholder agriculture in Africa (Chitakira and Ngcobo, 2021). Several studies have been conducted to estimate the impact of CSA adoption on maize yields (Pangapanga-Phiri and Mungatana, 2021; Amadu, 2020). However, there is still a lack of information on expected and counterfactual differences in productivity. This paper aims to investigate the effect of CSA adoption on the conditional quantile(s) of maize yield distribution in smallholder maize farmers in the study areas. The conditional quarantine approach allows the study to not only address the endogeneity of the effect of CSA adoption on maize yields, but also estimate the heterogeneous effect of CSA adoption on maize yields. The latter can be viewed as of testing for the effect in the conditional distribution using a linear specification of the conditional quantile function, which is useful when the affected quantiles are unknown. In this context, the farmers were grouped into pre-determined categories, reflecting different yield distribution levels.

## 6.2. Methodology

### 6.2.1. Description of the Study areas

The study area, sampling, and data collection technique are the same as in chapter three.

### 6.2.2. Data Collection Method

#### 6.2.2.1. Research design

The study used a descriptive research method that included quantitative research methods to assess the distributional effect of CSA adoption on smallholder farmers' maize yields in KwaZulu Natal. Swayimane had 49 participants sampled, and Bergville had 50 simple random samples from 99 respondents interviewed. The goal was to assess the CSA practices used by various smallholder farmers and the household food security status of farmers in the study area. Primary data was collected using semi-structured interview questionnaires to determine the farmer's short-term adaptive measures for the 2019/2020 maize production season. The study investigates which natural hazards endanger farmers' maize yields, how they deal with them, and what potential practices are needed in their farming system to increase production. A questionnaire was also distributed to determine long-term adaptation strategies. Approximately 29 lists of practices were identified with the assumption that each could deliver on one or more CSA goals. Knowledge smart, carbon smart, nitrogen smart, water smart, weather smart, and energy smart were the six (6) categories considered for these practices. The adoption of practices was self-reported in yes/no questions.

#### 6.2.2.1. Yield Estimation from Farmers' Fields- Farmer interview

Actual or realized yield refers to the harvest yield from a farmer's fields. Estimating crop production through farmer interviews entails asking farmers to estimate how much they harvested or expect to harvest for an individual plot, field, or farm. Harvest quantities are farmer estimates and are typically expressed in local harvest units rather than kilograms or tonnes. Conversion factors will be required to convert harvest quantities to standard units (Fermont and Benson, 2011). Most of the time, maize planting in smallholder farms does not follow any rules. Therefore, estimating plant density and harvest yield is difficult. Using mixed cropping systems, continuous planting, and heterogeneous crop performance within a plot can complicate crop yield estimation (Ngoune Tandzi and Mutengwa, 2020).

At the farmer level, various methods can be used to estimate yield. Estimating crop production through farmer interviews requires farmer recall from previous harvests (quantifying previous harvest yield) and farmer prediction (estimating the current yield based on the previous harvest) (Bihter et al., 2016). According to Norman (1995), yield estimation at the farmer level using survey methods should be considered at the maximum crop growth. Compared to any other yield estimation method at the farmer level, farmer estimation methods are very inexpensive and provide quick results. These yield estimation methods are less accurate and sometimes introduce additional biases. As a result, the use of simple mathematical models is advised (Ngoune Tandzi and Mutengwa, 2020). Farmers may estimate their harvest yield production based on the number of bags (25kg, 50kg, or 100 kg) harvested in a given area. This study calculated the fresh or dried maize harvested in a specific plot size.

The GrainsSA yields estimation model was used in the study, and yields were estimated based on the total number of cobs each farmer received in the plot after harvesting. Estimation was conducted by identifying the local harvest unit to measure yield. According to GrainSA (2016), A general guideline is that small cobs have a mass of about 120 grams, medium about 150 grams, and large cobs about 180 grams. Therefore, the average size of the cobs counted in each unit was estimated. As a result, a farmer estimated the total number of units harvested, including those sold, used for household consumption, and donated, and the number of cobs per unit.

If the farmer measures in dozen, a dozen equals 12 cobs of maize per dozen X 1000 total number of dozens obtained in total area, which equals 12000 cobs per hectare. With a medium cob mass of 150 grams, 12000 cobs x 150 divided by 1000 equals kilograms (kg) per ha. The answer is 1800kg/ha. Yields are measured in kg/ha in this scenario. When yields are measured in tons/ha, the kg/ha is divided by 1000 (1 000 kg/ton) to show the expected yield in tons per hectare. The calculation of yield estimates in kg/ha using farmer interview is expressed in formula 1:

Yields in kg/ha= Local harvest unit X (number of cobs per unit) /cob mass(g)/1000

### 6.3. Analytical Framework

#### 6.3.1. Distributional impact of the CSA on yield based on Conditional IV-QTE

Various factors influence farmers' decisions to adopt CSA practices, including on-farm income and access to market information (Foster and Rosenzweig, 2010). We model a farming household's decision to adopt CSA practices, assuming that most farmers are rational and risk-averse and, thus, always act to maximize yields and profit. As a result, adopting improved agricultural innovation can be viewed as a constrained optimization framework in which a farmer will choose to adopt CSA practices when the expected benefits of adoption outweigh the benefits of non-adoption (De Janvry et al., 2010). An estimation technique in a quantile regression framework is required to investigate the effects of CSA adoption on productivity distributions (measured in terms of yield). In particular, we present the following conditional linear quantile model.

$$P^{x}{}_{i} = Q_i R^L + N_i \delta^L + \mu_i, \tag{1}$$

Where $\delta^L$ denotes the quantile treatment effect (QTE) of CSA adoption, $N_i$, on $P_i$ corresponding to the $L^{th}$ quantile of the distributional of productivity(yields).

$Q_i$ It is a vector of observed covariates composed of socioeconomic status, practices, and other farm-specific variables; $R^T$ is a vector parameter of the covariates to be estimated; $\mu_i$ It is an unobserved random variable or error term (Issahaku and Abdulai, 2020). Because the farmer's decision to adopt CSA is assumed to be exogenous, estimating the distributional impacts of CSA adoption using equation (1) may result in biased and inconsistent estimates. This assumption, however, may not be correct because farmers self-select into CSA adoption, and this decision is most likely endogenous (Issahaku and Abdulai, 2020). Other unobservable factors (such as innate farm management skills) influence both farmers' adoption decisions and the outcome variables, resulting in inconsistent and biased $R^T$ and $\delta^T$. The study employs Abadie et al. (2002)'s conditional IV-QTEs approach to account for these estimation issues. This method necessitates using a valid binary instrumental variable that meets exclusion restriction conditions, i.e., it must be uncorrelated with the potential outcome other than the treatment variable. A valid instrument in our study must be correlated with the farmer's adoption decision but uncorrelated with productivity (yield) outcomes. Finding an appropriate instrument is difficult (Olagunju et al., 2020).

In principle, it is reasonable to argue that factors such as on-farm income or farmers' access to market information on maize production can influence farmers' decisions to adopt and use CSA practices. However, they may or may not influence yield outcomes. With the assumption of the existence of a valid instrument, the empirical specification of the Abadie et al. (2002) conditional IV-QTEs model is as follows:

$$(\hat{\beta}^L{}_{XN,}\ \hat{\delta}^L{}_{XN}) = \underset{\beta,\delta}{argumin} \sum_{i}^{P^{BBX}}$$

$$X\ M_i(P_i - Q_i\beta\text{-}N_i\delta), \tag{2}$$

With $P_i^{BBX}$ =1- $\frac{D_{i-(1-Y_i)}}{1-Q_v(Y=1|S_i}$ - $\frac{(1-P_i)Y_i}{1-P_v(Y=1|S_i)}$ (3)

where Y represents the instrumental variable (access to on-farm income or market information). The estimated causal effect is the local QTE among compliers or farmers who have access to varietal information and have adopted CSA practices. By definition, the weights in equation (3) are not always positive, and the minimand is not always convex Abadie et al. (2002). This problem was addressed, and an alternative positive weight $P_i^{BBX+}$ =R($P^{BBX}|P_i, D_i, S_i$) was proposed, which can be estimated using non-parametric local linear regression. The probability $P_v(Y = 1|S_i)$ of having access to varietal information is estimated using a local logit non-parametric estimator, as described in (Frölich and Melly, 2010). The IV-QTE command performed this estimation in SPSS (Frölich and Melly, 2010).

### 6.4. Description of variables

The SPSS software was used to compute the quantitative data analysis for the study. The descriptive statistics provided information on the key socioeconomic characteristics of the sampled smallholder farmers. The study hypothesized that CSA adoption, age, level of education, total household income, gender, marital status, on-farm income, smartphone, access to market information, membership in farmers' associations, and primary source of income were all factors influencing farmer yields. Table 10 lists the names and descriptions of the variables influencing farmers' yields in the study area.

**Table 8:** Summarizes the descriptive variables' names, variable type and measurement, and an expected outcome (Source: Own analysis)

| Name of variable | Description of variable |
|---|---|
| CSAADOPTION | Dummy (1=Yes, 0=otherwise) |
| Household size | Number of household members (continuous) |
| Age | Respondent's age in the year (continuous) |
| Level of Education | Continuous (1=No education,2=Primary, 3 =Secondary , 4=Tertiary) |
| Total household income | Households' total income (Measured in Rands) |
| Gender | Dummy (1=Yes, 0=otherwise) |

| | |
|---|---|
| Marital Status | Continuous(1=Single,2=Married, 3=Divorced, 4=Widowed) |
| On-farm income | On-farm income received by Household (Measured in Rands/Kg) |
| Smartphone | Dummy (1=Owns, 0=otherwise) |
| Access to market info | Whether the Household has access to the market or not (1=Yes, 0=otherwise) |
| Farmers association | Whether the farmer is a member of a farmers' association (1=Yes, 0=otherwise) |
| Main source of income | Households source of income (1 = Fulltime employment,2 = Part-time employment, 3 = Sale of agricultural crops, 4 = Social government grants, 5 =Remittances, 6 = Pension, 7 = Family or neighbour's support, 8 = casual work, 9 = Other |

## 6.5. Results

### 6.5.1. Descriptive Analysis of Results

#### 6.5.1.1. Demographics characteristics of smallholder farmers in the study area.

The average age of those interviewed in the study area was 59.49, with the youngest being 26 and the oldest being 88, according to the demographic characteristics of smallholder farmers in the study area. The study sample was dominated by females (79.8%) and males (20.2%). Most farmers (41, 4%) had only primary education, and only 1% had tertiary education. Most farmers (72, 2%) are married in the study area. About 39.4% of respondents rely on pension grants as their primary source of income, 37.4% on social government grants, and only 8.1% on agricultural produce sales. Regarding the second Source of income, most farmers do not have one, and 21 2% get their second Source of income from selling agricultural produce. The average amount of land owned by farmers was an average of 1,03ha.

#### 6.5.1.2. CSA practices adopted by farmers in the study area

##### 6.5.1.2.1. Short-term CSA Practices adopted by Smallholder maize farmers to cope with natural hazards in the 2019-2020 season.

The various natural hazards troubled farmers during the maize production season of 2019-2020. These natural disasters primarily impacted the quality and quantity of maize yields. Pests were the most common natural hazard that farmers encountered, with 56% of farmers experiencing this hazard, followed by diseases, with 43% of farmers experiencing diseases on their maize crops. Drought affected approximately 34% of farmers. Soil infertility affected only 22% of the population. About 76% of farmers shared one-on-one information with colleagues, also known as word of mouth or farmer-to-farmer knowledge sharing. Only 4% had access to agricultural credits.

Regarding carbon-smart practices, 95% of farmers used minimum tillage, 91% used plant and animal manure, also known as organic manure, and 90% used crop rotation. Approximately 78% of farmers intercropped or grew multiple crops on the same plot of land. Afforestation was the practice that farmers adopted the least. Only 7% of farmers had trees planted around their fields. Regarding nitrogen-smart practices, the findings revealed that most farmers (77%) prefer to plant legumes to improve soil fertility, 59% estimate the amount of fertilizer needed, and only a few farmers (25%) use specific fertilizers.

Planting early in the season (90%) to use rainwater efficiently is the most common water-smart practice adopted by farmers, followed by 54% who planted cover crops to maintain soil moisture and 55% who used mulch to reduce excessive water use. Irrigation is used by only 2% of farmers. Among weather-smart practices, approximately 43% of farmers relied on personal experience to predict weather events, while 42% relied on radio or television for weather information. According to the findings, no farmers purchase index-based insurance to protect their crops from weather events. In terms of energy-saving practices, the majority of farmers (74%) used compost.

#### 6.5.1.2.2. Maize yields obtained by smallholder farmers in the study area.

Figure 10 depicts the local harvest units used by farmers in the study area. According to the findings, most farmers (53%) measure their yields in bags, followed by 33% who measure in dozens, and only 3% who measure in tons, equivalent to one van.

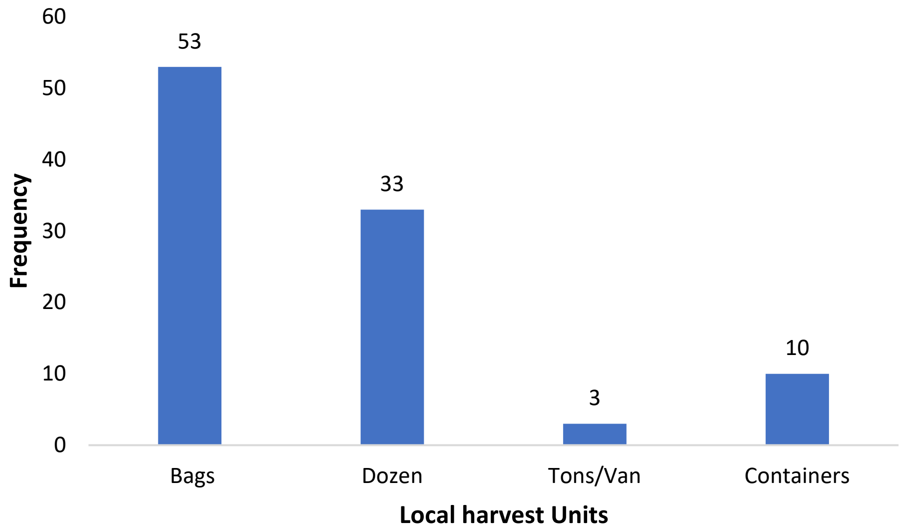



Figure 10:Local harvest units

Only 31 farmers sell maize, and they sell at an average of R7/kg in the study area. The results in table 11 show that farmers sold an average of 226,68kg, the average yields households consumed were 216,18kg/ha, and Households donated only an average of 5,18 kg/ha to neighbours. The total average yield obtained by farmers in the study area was 444,19kg/ha. Farmers assumed they would get an average of 451kg if they had not experienced any climatic hazards, which is 7,2kg/ha more kgs than the actual yields obtained.

**Table 9:** Yields quantities

| Yields quantities | Mean (Kg/ha) |
|---|---|
| Total yields obtained | 444,19 |
| Yields No hazards (kg/ha) | 451,39 |
| Yields good season (kg/ha) | 481.65 |
| Best yields | 515,70 |
| Household consumption | 216,18 |
| Quantity sold | 226,68 |
| Donation | 5,18 |

Most (31%) farmers perceive the 2019/2020 season as where they obtained average yields. Only 10% perceive the yields they received as very low, while 16% perceive the yields to be very high. Figure 11 shows the relationship between farmers' efficiency and yields obtained as perceived by farmers. The graph shows that the lower the farmer's efficiency, the lower the yields they obtain, and the average the farmer's efficiency, the average the yields they obtain. On the other hand, the results show that the yields decline no matter how efficient the farmer is, the yields decline. This may be due to many factors beyond farmers' control, such as harsh weather conditions.


**Figure 11:**Perception of yields obtained and farmers' efficiency

#### 5.2.2. Imperial Result analysis

#### 5.2.2.1. Distributional impact of the CSA on yield based on Conditional IV-QTE

The empirical results of the IV-QTE model on the impact of CSA adoption on farmer maize yields are presented in Table 12. In this paper, the primary variable of interest is CSA adoption, which has been shown to impact farmers' maize yields negatively and significantly at the middle quantiles of 0.25 and 0.50. According to the findings, farmers with average yields benefit less from CSA adoption when compared to other yield quantiles. Household size was significant at p<0,01 and positively correlated with farmer productivity at the middle yield quantile (Q 0.5). This means that an increase in family size resulted in an increase in smallholder farmers' productivity at the middle quantile.

**Table 10:** Distributional impact of the CSA on yield based on Conditional IV-QTE

| | **Q0.15** | | **Q0.25** | | **Q0.50** | | **Q0.75** | | **Q0.85** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Yields kg/ha** | **Coefficient** | **Std. err.** | **Coefficient** | **Std. err.** | **Coefficient** | **Std. err.** | **Coefficient** | **Std. err.** | **Coefficient** | **Std. err.** |
| CSAADOPTION | -228.144 | 145.805 | -215.872 | 111.463* | -194.393 | 84.361** | -152.784 | 328.730 | -226.071 | 281.206 |
| Household size | 7.681 | 14.231 | 9.616 | 8.095 | 14.874 | 6.729** | 3.294 | 20.418 | 13.133 | 41.722 |
| Age | -0.888 | 2.165 | -1.084 | 1.877 | -1.299 | 1.676 | -0.946 | 2.825 | 2.850 | 3.387 |
| Level of education | -24.792 | 60.005 | -55.945 | 60.138 | -5.901 | 51.599 | 75.648 | 98.603 | 185.470 | 116.717 |
| Total Household income/annum | 0.009 | 0.002*** | 0.008 | 0.002*** | 0.006 | 0.004 | 0.009 | 0.013 | 0.010 | 0.006* |
| Gender | -96.755 | 207.230 | -35.356 | 80.818 | -34.850 | 99.256 | 8.587 | 320.441 | -112.493 | 266.889 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Marital status | -19.886 | 62.279 | -48.822 | 43.478 | -93.734 | 30.089*** | -129.971 | 56.767** | -119.681 | 77.088 |
| On-farm income | 0.023 | 0.006*** | 0.024 | 0.006*** | 0.031 | 0.016* | 0.037 | 0.011*** | 0.034 | 0.007*** |
| Smartphone | -216.821 | 157.545 | -285.122 | 120.129** | -9.710 | 110.844 | -143.617 | 427.657 | -125.646 | 231.527 |
| Aaccesstomarketinfo | -23.112 | 173.661 | -48.084 | 189.070 | -187.760 | 249.727 | -606.300 | 932.310 | -588.605 | 536.032 |
| Farmers association | 191.574 | 196.791 | 190.796 | 213.249 | 172.522 | 277.588 | 611.583 | 320.346* | 553.075 | 204.692*** |
| Main Source of income | -64.637 | 28.717*** | -60.532 | 27.082** | 0.442 | 42.210 | 17.684 | 57.220 | -7.429 | 29.373 |
| _cons | 490.854 | 143.736*** | 571.437 | 169.994 | 382.709 | 241.425 | 276.897 | 433.943 | 138.701 | 373.045 |

The total household income per annum showed a positive and significant impact on the lower yield quantiles (0,15 and 0,25) and higher quantiles (0,85), while it did not have any impact on the middle yield quantiles (0.5 and 0.75). The model predicts that an increase in farmers' household income in the lower and higher quantile increases the quantity of yields obtained. Marital status negatively impacted middle yield quantiles (0.50 and 0.75). This implies that having more married couples in a household that produces at the middle quantiles subjected them to a decrease in the yield. Interestingly, on-farm income was positively correlated at the p0,01 significance level across all quantiles (0,15 to 0,85). This implies that increased income from farming led to increased maize productivity at all the yield quantiles. Only at the second yield quantile of 0.25 did smartphones have a negative and statistically significant (p<0,05) effect on farmer yields. Membership in a farmers' association or a farmer's cooperative was positively related to farmer yields at the 75th and 85th quantiles. There was no significant relationship between yields and being a member of the farmers' association at lower quantiles (0,15-0,50). The variable main source of income had a negative and significant impact on yields in the 5th and 25th quantiles. The findings show that farmers with low quantile yields' main source of income contributed to the yields they obtained. In contrast, farmers with higher quantile yields (50th, 75th, and 85th) had no significant relationship with income.

**Table 11**: Distributional impact of the CSA on yield based on Conditional IV-QTE

| | **Q0.15** | **Q0.25** | **Q0.5** | **Q0.75** | **Q0.85** |
|---|---|---|---|---|---|
| Treatment effect of adoption | -228.144 | -215.872 | -194.393 | -152.784 | -226.071 |
| Standard error | 145.805*** | 111.463* | 84.361** | 328.730 | 281.206 |
| % impact of adoption | 91.932 | -0.761 | -0.571 | -0.455 | -0.472 |

*[k] Represents the percentage impact of CSA adoption in each quantile of the farmers' yield. The percentages were estimated as the coefficient on the adoption of CSA divided by the fitted values with the adoption dummy set to zero and other covariates set to means for the treated (Abadie et al., 2002). All estimations include a set of controls included in Table 7.*

Based on IV-QTE, Table 13 depicts the distributional effect of CSA adoption on maize yields, showing the percentage impact of CSA adoption on maize yield quantiles. Adoption only has the most significant percentage impact in the Q0,15 quantile of maize yield distribution. Lower estimates of adoption's percentage impact were discovered in the 0.25-0,85 quantile. According to the findings, CSA adoption significantly affected lower quantile adoption (0,15 to 0,50). There was no correlation between CSA adoption and distribution of upper quantile yields (0,75 and 0,85). The results predict that CSA adoption significantly affected the lower quantile yield distribution (0,15 to 0,50) as opposed to the higher quantile yield distribution (0,75 to 0,85).

### 6.6. Discussion

An important objective of this study is to determine the effect of adopting CSA on yields using the conditional treatment effect of IV-QTE. Despite the fact that the majority of (31) farmers consider 2019-2020 maize production to be average, the results show that total average yields obtained by farmers in the study area were 444,19kg/ha, which is less than the current national standard average yields of 5490kg/ha(SAGL, 2020). Furthermore, there is a 65% difference between farmers' target yields and actual yields obtained by farmers. This indicates that maize productivity is generally low in the study area. The results show that the lower the farmer's efficiency, the lower their yields. The average of the farmer's efficiency is the average yield. On the other hand, the results show that the yields decline no matter how efficient the farmer is. This implies that many factors beyond farmers' control, such as harsh weather conditions, contribute to farmers' yields.

The results revealed that CSA adoption positively affected lower quantile yield distribution (0,15 to 0,50). The distributional impact curve slopes downward. These findings imply that farming households with low yields benefit significantly more from CSA adoption in the study area. These findings are consistent with those of Olagunju et al. (2020) and Issahaku and Abdulai (2020), who discovered a significant positive relationship between low-yielding farmers and CSA adoption. In addition, the middle quantile yield distribution did not adopt a package of CSA practices; therefore, the results of CSA adoption were not recognized. These findings contradict Amadu et al. (2020), who discovered that CSA adoption positively and significantly affects yields.

The positive relationship between household size and farmer yields at the 50th quantile maize yield distribution is not surprising, given how much labor is required in various aspects of maize production, such as land preparation, seedling planting, weeding, and harvesting. The majority of tasks are still completed by hand. These findings suggest that an increase in household size among farmers who produced average yields in the 50th quantile contributed to an increase in yields. Many studies have discovered a significant relationship between yields and household size (Onoja et al., 2012, Yussif, 2019). The findings revealed that, due to its presumed positive correlation with the availability of family labor, the household size would have reduced labor constraints on the farm and resulted in more quality labor available for carrying out farming activities in a timely manner, thereby making the production process more efficient.

The significant positive relationship between total household income at lower yield quantiles of 0.5 and 0.25 and higher yield quantiles of 0.85 indicates that income received by these house households outside of farming contributes to an increase in yields because these households have more resources to invest in improved technologies. In line with the findings of Tamene et al. (2016), Ntabakirabose (2017) discovered that household wealth and off-farm employment increased yield. Furthermore, the higher yields among wealthier households can be explained by the fact that, apart from seed technology, maize productivity is heavily influenced by other inputs such as fertilizer and other observable factors that wealthier households are more likely to have access to than their poor counterparts. This appears to be consistent with the fact that income is a proxy for a broader range of potentially important factors, including access to credit, risk tolerance, access to scarce inputs (water seed fertilizer, insecticides), and access to information (Gebre,2021).

According to the findings, marital status has a negative impact on farmer yields at average quantiles such as the 50th and 75th. As a result of marriage responsibilities, most married farmers did not produce to their full potential. The findings also revealed that smartphones had a negative and statistically significant effect on farmer yields only at the second yield quantile of 0.25. Even though smartphones significantly predicted maize yields, adoption of these practices was low. According to the descriptive findings of the study, only 14% own smartphones, and only 3% use their smartphones to access agricultural information. This means that farmers who own smartphones spend much time on their phones doing things like networking and socializing on social media rather than searching for information to improve their agricultural productivity. These findings are congruent with the findings of Zheng and Ma (2021), which find smartphones have a positive significance on yields.

The positive relationship between being a member of a farmers' association or cooperative and yields obtained at higher quantiles demonstrates that being a member of a farmers' association played a significant role in increasing the yields of farmers who obtained higher yields. This is because membership in a farmers' association or a cooperative gives farmers more accessible access to credit, farm inputs, and markets for their agricultural products, which increases yields. This is consistent with the findings of Musafiri et al. (2022), who discovered that cooperatives are an important platform for supporting and enhancing smallholders' ability to commercialize maize.

### 6.7. Conclusion and policy recommendation

This paper aims to evaluate the distributional effect of CSA adoption on maize smallholder farmers' productivity (yields) in the municipalities of uMshwathi and uKhahlamba, providing a clear picture of the differential effect of CSA adoption. The results show that regardless of how efficient the farmer is, they still encounter a decline in yields. The yields obtained by farmers are low and fall below the national average yields. The IV-QTE was used to estimate the effects of CSA adoption across different quantiles of yield distribution. Only at the very bottom of the maize distribution did CSA adoption have a significant impact. It can be concluded that CSA adoption benefits households with low yields significantly. The results show that several household variables significantly influence farmer yields. CSA adoption, marital status, smartphones, and the main source of income, in particular, have a negative effect on yields.

The findings provide empirical support and recommendation for developing, disseminating, and upscaling climate change adaptation programmes that address smallholder farmers' low productivity.

These findings suggest that smallholder farmers should be provided with ongoing assistance such as irrigation schemes, production credits, farm insurance, reliable weather forecasts, and access to agro-input and output markets in order to reap the long-term benefits of CSA. The policy implication of this study is that framing the yield determinants could facilitate the design and dissemination of strategies to improve farmer resilience and yields at the community level. The significant negative relationship, in particular, may be beneficial to implementing Climate adaptation programs that aim to build the resilience of smallholder farmers to climate change by considering promoting a package of CSA practices that solve most of the problem's farmers face so that the benefits of CSA are recognized. In addition, to the negative relationship between owning smartphones and yields, the study recommends that smartphones are the best tools for smallholder farmers to excess production information even in the absence of extension officers. Most farmers who own smartphones do not use them to access information. Therefore, the study recommends that targeted training, particularly for older and female farmers, can significantly facilitate smartphone-based information acquisition. Programs should be developed to increase rural farmers' access to modern information technologies.

### 6.8. References

Abadie, A., Angrist, J. & Imbens, G., 2002. Instrumental variables estimates of the effect of subsidized training on the quantiles of trainee earnings. *Econometrica,* 70, 91-117.

Adam, D. 2021. How far will global population rise? Researchers can't agree. *Nature,* 597, 462-465.

Agbugba, I., Christian, M. & Obi, A., 2020. Economic analysis of smallholder maize farmers: Implications for public extension services in Eastern Cape. *South African Journal of Agricultural Extension,* 48, 50-63.

Agri, S., 2017. Land Audit: A Transactions Approach. *AGRI SA: Johannesburg, South Africa*.

Amadu, F. O., Miller, D. C. & Mcnamara, P. E. 2020. Agroforestry as a pathway to agricultural yield impacts in climate-smart agriculture investments: Evidence from southern Malawi. *Ecological Economics,* 167, 106443.

Bihter, O., Bakal, H., Gulluoglu, L. & Arioglu, H., 2016. The effects of row spacing and plant density on yield and yield components of peanut grown as a double crop in mediterranean environment in Turkey. *Turkish Journal of Field Crops,* 22, 71-80.

Bhusal, B., Poudel, M.R., Rishav, P., Regmi, R., Neupane, P., Bhattarai, K., Maharjan, B., Bigyan, K.C. and Acharya, S., 2021. A review on abiotic stress resistance in maize (Zea mays L.): effects, resistance mechanisms and management. *Journal of Biology and Today's World*, *10*(2), pp.1-3.

Chitakira, M. & Ngcobo, N. Z., 2021. Uptake of Climate Smart Agriculture in Peri-Urban Areas of South Africa's Economic Hub Requires Up-Scaling. *Frontiers in Sustainable Food Systems*, 512.

De Janvry, A., Dustan, A. & Sadoulet, E., 2010. Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: options for the CGIAR. *Unpublished working paper, University of California-Berkeley*.

Fermont, A. & Benson, T., 2011. Estimating yield of food crops grown by smallholder farmers. *International Food Policy Research Institute, Washington DC,* 1, 68.

Foster, A. D. & Rosenzweig, M. R., 2010. Microeconomics of technology adoption. *Annual review of Economics,* 2.

Frölich, M. & Melly, B., 2010. Quantile treatment effects in the regression discontinuity design: process results and gini coefficient.

Gebre, G.G., Mawia, H., Makumbi, D. and Rahut, D.B., 2021. The impact of adopting stress-tolerant maize on maize yield, maize income, and food security in Tanzania. *Food and Energy Security*, *10*(4), p.e313.

Government, S. A., 2015. Agriculture.

Grainsa 2016. The how's and why's of yield estimation.

Halubok, M. & Yang, Z.-L., 2020. Estimating Crop and Grass Productivity over the United States Using Satellite Solar-Induced Chlorophyll Fluorescence, Precipitation and Soil Moisture Data. *Remote Sensing,* 12, 3434.

Hussain, H.A., Men, S., Hussain, S., Chen, Y., Ali, S., Zhang, S., Zhang, K., Li, Y., Xu, Q., Liao, C. and Wang, L., 2019. Interactive effects of drought and heat stresses on morpho-physiological attributes, yield, nutrient uptake and oxidative status in maize hybrids. *Scientific reports*, *9*(1), pp.1-12.

Issahaku, G. & Abdulai, A., 2020. Can Farm Households Improve Food and Nutrition Security through Adoption of Climate-smart Practices? Empirical Evidence from Northern Ghana. *Applied Economic Perspectives and Policy,* 42, 559-579.

Macauley, H. & Ramadjita, T., 2015. Cereal crops: Rice, maize, millet, sorghum, wheat.

Musafiri, C. M., Kiboi, M., Macharia, J., Ng'etich, O. K., Kosgei, D. K., Mulianga, B., Okoti, M. & Ngetich, F. K., 2022. Adoption of climate-smart agricultural practices among smallholder farmers in Western Kenya: do socioeconomic, institutional, and biophysical factors matter? *Heliyon,* 8, E08677.

Muzangwa, L., Mnkeni, P. N. S. & Chiduza, C., 2017. Assessment of conservation agriculture practices by smallholder farmers in the Eastern Cape Province of South Africa. *Agronomy,* 7, 46.

Ngoune Tandzi, L. & Mutengwa, C. S., 2020. Estimation of Maize (Zea mays L.) Yield Per Harvest Area: Appropriate Methods. *Agronomy,* 10, 29.

Norman, D. W., 1995. The farming systems approach to development and appropriate technology generation, Food & Agriculture Org.

Ntabakirabose, G., 2017. An economic analysis of the factors influencing maize productivity and efficiency in Rwanda: a case study of Gatsibo District. *Agricuture-Jkuat*.

Olagunju, K. O., Ogunniyi, A. I., Awotide, B. A., Adenuga, A. H. & Ashagidigbi, W. M., 2020. Evaluating the distributional impacts of drought-tolerant maize varieties on productivity and welfare outcomes: an instrumental variable quantile treatment effects approach. *Climate and development,* 12, 865-875.

Onoja, A. O., Deedam, N. J. & Achike, A. I., 2012. Profitability and yield determinants in Nigerian cocoa farms: Evidence from Ondo State. *Journal of Sustainable Development in Africa,* 14, 172-183.

Palombi, L. & Sessa, R., 2013. Climate-smart agriculture: sourcebook. *Climate-smart agriculture: sourcebook.*

Pangapanga-Phiri, I. and Mungatana, E.D., 2021. Adoption of climate-smart agricultural practices and their influence on the technical efficiency of maize production under extreme weather events. *International Journal of Disaster Risk Reduction*, *61*, p.102322.

Sagl, T. S. A. G. L., 2020. Maize Crop Quality Report 2019-2020.pdf. SAGL.

Serna, L., 2022. Maize stomatal responses against the climate change. *Frontiers in Plant Science,* 13.

Siminyu, P., Oluoch-Kosura, W., De Groote, H. & Mbau, J. S. 2021. Assessing the contribution of climate-smart agricultural practices to the resilience of maize farmers in Bungoma County, Kenya.

Tamene, L., Mponela, P., Ndengu, G. & Kihara, J., 2016. Assessment of maize yield gap and major determinant factors between smallholder farmers in the Dedza district of Malawi. *Nutrient cycling in agroecosystems,* 105, 291-308.

Wiggins, S. & Keats, S., 2013. Leaping and Learning: Linking smallholders to markets in Africa.

Xie, T., Gu, W., Meng, Y., Li, J., Li, L., Wang, Y., Qu, D. and Wei, S., 2017. Exogenous DCPTA ameliorates simulated drought conditions by improving the growth and photosynthetic capacity of maize seedlings. *Scientific Reports*, *7*(1), pp.1-13.

Yussif, M. M. 2019. *Social networks and integrated soil fertility management adoption: effects on maize yields and food security of farmers in Northern Region.*

Zheng, H. & Ma, W., 2021. Smartphone-based information acquisition and wheat farm performance: insights from a doubly robust IPWRA estimator. *Electronic Commerce Research*, 1-26.

# CHAPTER SEVEN

# CONCLUSION AND RECOMMENDATIONS

## 7.1. Summary

Smallholder farmers' ability to produce maize is highly vulnerable to climate change. Increased temperatures eventually cause yields to decline and promote the spread of illnesses, pests, and weeds. Global food security could be threatened by the detrimental effects of climate change on agriculture. A method for guiding efforts that will change agri-food systems into more ecologically friendly and climate-resilient practices is called climate-smart agriculture (CSA). The main objective of a CSA is to raise agricultural income and productivity sustainably. The study's main objective is to evaluate how CSA adoption affects small-holder farmers' welfare in the KwaZulu Natal local municipalities of uMshwathi and uKhahlamba.

The study has three specific objectives: To assess the determinants of adoption and intensity of Climate-Smart Agricultural Practices among small-holder maize farmers; to evaluate the distributional effect of CSA adoption on small-holder farmers' household food security; and to evaluate the distributional effect of CSA adoption on small-holder farmers' productivity (yields) in the study areas. The study was conducted using a qualitative and quantitative approach. The study relied on the primary data from 99 respondents (49 from Swayimane and 50 from Bergville) selected using simple random sampling.

Excel and Statistical Software for Social Science (SPSS) version 24 were used to analyze the quantitative data. In order to meet the objectives, the study used a variety of econometric analytical tools. The Probit regression model was used to determine factors influencing the adoption of CSA practices. The Poisson regression model was used to assess the intensity of CSA adoption on smallholder farmers. The Household Hunger Scale (HHS) was used to assess the food security status of households in the study area. A Logistic Regression model was used in the study to determine the factors influencing food security among smallholder farmers. The study used Conditional IV-QTE to correct for endogeneity and sample selection on the impact of CSA adoption on the yields of smallholder farmers.

The study reported that socioeconomic factors such as age, education, farm size, and farm ownership affect whether smallholder farmers can effectively implement CSA and CSA adoption affect household food security and productivity. These socioeconomic characteristics were also expected to impact the probability of CSA adoption and the number of CSA used by the farmers, thus affecting the food security status and productivity of smallholder farmers in this study. It is concluded that socioeconomic characteristics considerably influenced the likelihood of CSA adoption and the intensity of adoption by smallholder maize farmers. Thus, they have a significant effect on household food security and productivity. This implies a need to improve these factors, which will spontaneously enhance farmers' CSA adoption likelihood, building resilience and improving farmers' welfare.

### 7.2. Conclusion

The adoption of CSA practices helps smallholder farmers increase their agricultural productivity but also helps to improve smallholder farmer resilience to the impact of climate change. This study assessed the factors affecting the adoption and intensity of CSA adoption among smallholder maize farmers. The findings showed that drought, on-farm income, and household size positively significantly influenced the adoption of CSA practices. In contrast, the main source of income and educational level had a significant negative influence. Drought also had a significant positive impact on the intensity of CSA adoption, whereas marital status had a significant negative effect. It is concluded that socioeconomic characteristics considerably influenced the likelihood of CSA adoption and the intensity of adoption by smallholder maize farmers. Improved education among smallholder farmers can improve CSA adoption. Word of mouth, by which farmers share information with their family and friends, significantly improved the knowledge about climate change and adaptation.

According to the findings, 78% of the farmers in the study area experienced little or no hunger. As a result, household food production should be encouraged to ensure consistent increased food access. The findings show that CSA adoption increased hunger and food insecurity. Farmers must be encouraged to include a more significant number of CSA packages that include a variety of CSA practices. Farmers must incorporate as many CSAs as possible to reap the most significant benefit from CSAs. If CSAs are used in tandem and to a greater extent, they have the potential to alleviate food insecurity. Furthermore, farmer empowerment is required to transition to more capital-intensive practices gradually. The drought had a significant negative impact on food security and increased hunger.

The results show that regardless of how efficient the farmer is, they still encounter a decline in yields. The yields obtained by farmers are low and fall below the national average yields. The IV-QTE was used to estimate the effects of CSA adoption across different quantiles of yield distribution. Only at the very bottom of the maize distribution did CSA adoption have a significant impact. This implies that CSA adoption benefits households with low yields significantly. The results show that several household variables significantly influence farmer yields. CSA adoption, marital status, smartphones, and the main source of income, in particular, have a negative effect on yields.

The findings provide empirical support and recommendation for developing, disseminating, and upscaling climate change adaptation programmes that address smallholder farmers' low productivity.

### 7.3. Recommendations and policy implications

The study recommends that numerous local organizations with a strong comparative advantage in agriculture, climate change, and adaptation collaborate to invest in increasing rural public awareness of climate change and adaptation. An investment in outcome-based accredited training that caters to all farmers' primary education levels will ensure that training activities significantly impact the outcome of competent farmers with skills and knowledge about climate change and adaptation. The study suggests that climate change awareness and adaptation information be disseminated through the media and in locally understood languages.

These findings mainly suggest an urgent need to increase efforts to assist smallholder farmers in coping with current changes and adapting to future climatic conditions. Public and private organizations should collaborate to facilitate smallholder farmer adaptation to climate change. Policies, technical, research solutions, and extension services should be combined and strengthened to provide technical support to farmers in increasing their resilience to climate change. The findings also emphasized the significance of household income in improving food security and poverty reduction. Income-earning opportunities must be expanded through job creation and income-generating activities. The household's age had a positive impact on food security. It is recommended that there is a need to identify and raise awareness of youths' roles in the agricultural value chain and increase opportunities for youth to participate in agriculture.

These findings suggest that smallholder farmers should be provided with ongoing assistance such as irrigation schemes, production credits, farm insurance, reliable weather forecasts, and access to agro-input and output markets in order to reap the long-term benefits of CSA. The policy implication of this study is that framing the yield determinants could facilitate the design and dissemination of strategies to improve farmer resilience and yields at the community level.

The significant negative relationship, in particular, may be beneficial to implementing Climate adaptation programs that aim to build the resilience of smallholder farmers to climate change by considering promoting a package of CSA practices that solve most of the problems farmers face so that the benefits of CSA are recognized. In addition, to the negative relationship between owning smartphones and yields, the study recommends that smartphones are the best tools for smallholder farmers to excess production information even in the absence of extension officers. Most farmers who own smartphones do not use them to access information. Therefore, the study recommends that targeted training, particularly for older and female farmers, can significantly facilitate smartphone-based information acquisition. Programs should be developed to increase rural farmers' access to modern information technologies.

## 7.4. Limitations of the study and suggestions for further research

The study only looked at the factors influencing CSA adoption and intensity among smallholder maize farmers in one province of KwaZulu-Natal. Further research should be carried out in all nine provinces of South Africa. This study's findings will help develop a comprehensive report that will be submitted to policymakers, government, and other stakeholders for CSA implementation.

# APPENDIX A: CONSENT LETTER

**UKZN HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE (HSSREC)**

APPLICATION FOR ETHICS APPROVAL
For research with human participants

Information Sheet and Consent to Participate in Research

Date:

Greetings dear Participant.

My name is Khethiwe Mthethwa from the School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal. Mobile Number: 0833133768; Email: naledi340@gmail.com

You are being invited to consider participating in a study that involves research on the effect of Climate Smart Agricultural (CSA) adoption on farmer's welfare. The aim and purpose of this research is to understand the factors that influence adopting CSA practices and how adopting CSA effect food security and yields among smallholder farmers. The study is expected to enroll a total of 100 participants, drawn from two sites, that is 50 from Bergville under UKhahlamba local municipality and 50 from Swayimane under UMshwathi local municipality. It will involve the following procedures focus group discussions, semi-structured interviews and questionnaires. The duration of your participation if you choose to enroll and remain in the study is expected to be 45 minutes. The study is funded by the University of KwaZulu Natal.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number:HSS/0945/018M).

In the event of any problems or concerns/questions you may contact the researcher at (Mobile Number: 0813187033; Email: naledi340@gmail.com or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Participation in this research is voluntary and the participant is free to withdraw at any time, without giving any reason and without there being any negative consequences. In addition, should the participant not wish to answer any particular question or questions, she or he is free to decline.

Participants' responses will be kept strictly confidential. The name of the participant will not be linked with the research materials, and will not be identified or identifiable in the report or academic publication that result from the research.

Participants' anonymised data will be kept for future research purposes such as publications related to this

BREC UKZN Oct 2008 1

study after the completion of the study.

---

CONSENT

I (Name…………………………………………………….) have been informed about the study that involves research on the effect of Climate Smart Agricultural (CSA) adoption on farmer's welfare. The aim and purpose of this research is to understand the factors that influence adopting CSA practices and how adopting CSA effect food security and yields among smallholder farmers.

I confirm that I have read and understood the provided information sheet and have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.

I understand that my responses will be kept strictly confidential. I understand that my name will not be linked with the research materials, and will not be identified or identifiable in the report or academic publication that result from the research.

I agree that my anonymised data will be kept for future research purposes such as publications related to this study after the completion of the study.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at 0833133768.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion YES / NO
Video-record my interview / focus group discussion YES / NO
Use of my photographs for research purposes YES / NO

| | |
|---|---|
| ____________________ | ____________________ |
| Signature of Participant | Date |
| ____________________ | ____________________ |
| Signature of Witness<br>(Where applicable) | Date |
| ____________________ | ____________________ |
| Signature of Translator<br>(Where applicable) | Date |

## APPENDIX B: QUESTIONNAIRE

### CLIMATE ADAPTATION QUESTIONAIRE

Name of Respondent: ……………………………………………….. Phone number: ……………………………..

Area………………………………………………………………………………………………………………………….

**SECTION A: DEMOGRAPHIC FACTORS**

1. Gender of head of household

| Male | | Female | |
|---|---|---|---|

2. What is your household size ………………………………………………………?
3. What is your age (Years)…………………………………………………………….?
4. What is your marital status?

| Single | | Divorced | |
|---|---|---|---|
| Married | | Widowed | |

5. What is your normal main source of income? In addition, what is your other main source of income?

| Source of income | Main source of income (Choose one only) | Other sources of income (Choose one only) |
|---|---|---|
| 1 = Fulltime employment<br>2 = Part-time employment<br>3 = Sale of agricultural crops<br>4 = Social government grants<br>5 =Remittances<br>6 = Pension<br>7 = Family or neighbour's support<br>8 = casual work<br>9 = Other, (Please specify) ___________ | | |

6. Do you have a smart cell phone? Yes/No
   If yes, did you use it for accessing agricultural information? Yes/No

## SECTION B: CLIMATE SMART AGRICULTURAL PRACTICES

| | PRACTICES | Yes | No |
|---|---|---|---|
| A | **KNOWLEDGE SMART** | | |
| 1 | Belong to farmer associations | | |
| 2 | Get access to information of market prices of produce & inputs | | |
| 3 | Share one-on-one information with colleagues (Farmer-to-farmer knowledge sharing) | | |
| 4 | Store seeds for next season/emergency (Seed banking) | | |
| 5 | Have a backyard garden in addition to my farm | | |
| B | **CARBON SMART** | | |
| 1 | Change the type of crop planted on this land in some seasons (Crop rotation) | | |
| 2 | Plant different type of crops together (Mix cropping) | | |
| 3 | Plant trees in and around my farm (afforestation) | | |
| 4 | Use plants and animal manure on my farm (Organic manuring) | | |
| 5 | Use less heavy equipment on my farm (minimum tillage) | | |
| C | **NITROGEN SMART** | | |
| 1 | Use specific fertilizer/manure based on the type of soil (Site specific nutrients application) | | |
| 2 | Plant legumes among crops | | |
| 3 | Estimate the amount of fertilizer/manure needed at a time (Precision fertilization) | | |
| D | **WATER SMART** | | |
| 1 | Plant cover crops to maintain soil moisture | | |
| 2 | Harvest and store rainwater to be used on my farm | | |
| 3 | Engage in mulching to reduce excessive use of water | | |
| 4 | Plant at early season to make use of rain water | | |
| 5 | Regulate/control the water used in watering crops | | |
| E | **WEATHER SMART** | | |
| 1 | Use mobile phone to access weather information | | |
| 2 | Received weather information through community information centre | | |
| 3 | Usage of radio/tv for weather information | | |
| 4 | Access to weather information on the internet | | |
| 5 | Use personal experience to predict weather events | | |
| 6 | Take Index-Based Insurance (IBI) to protect my farm | | |
| 7 | Received education/training on how to access weather information by an organisation | | |

| F | Energy smart | | |
|---|---|---|---|
| 1 | Compost my residue after harvesting | | |
| 2 | Convert my residue into bioenergy | | |
| 3 | Use solar equipment in farming | | |
| 4 | Use of less fuel consuming vehicles | | |

## Section C: Maize yields

1. How do you normally measure your maize yields? (a) In bags (b) Dozens (c) In containers (d) Other…………………………
2. How much is one unit of the measurement listed above? ………………………
3. How much yields did you obtain this season? (Specify units) ……………………
4. How much are you selling each unit for?
5. How much did you sell and how much was consumed by your household (ratio)
6. Was your maize affected by the following natural hazards?

| Natural hazard | Yes | No |
|---|---|---|
| Drought | | |
| Pests | | |
| Diseases | | |
| Hailstorm | | |
| Heavy rains/floods | | |
| Livestock trampling | | |
| Soil infertility | | |
| Other…………………………………. | | |

7. If this season's yield was affected by natural hazards, what yields do you normally get? (Specify units)…………………………………………
8. You told me your yield normal yield is ……How you rate the yield you obtained this season in the following scale.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very Low | | | | Very High |

9. How much is "5" on the scale or what is the best yield one could get on your farm when using all the best maize production practices in a normal rainfall year? (Specify units)
10. How many much is "1" on the scale or what is the yield the worst farmer (not using any recommended practices) would get on your farm? (Specify units)
11. On a five-point scale below, how do you rate your efficiency as a maize farmer compared to other farmers in this area?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very Low | | | | Very High |

12. If your yield this year was….what, are you striving for the next season? (Specify units)
13. How can you improve your farming to reach that you want to achieve.
14. How do you intend to cope with the natural hazards you stated in (4)

| Natural hazard | Coping strategies |
|---|---|
| Drought | |
| Pests | |
| Diseases | |
| Hailstorm | |
| Heavy rains/floods | |
| Livestock trampling | |
| Other…………………………………. | |

**Section D: Food Security**

**SECTION E: FOOD SECURITY AND COPING STRATEGIES DURING COVID 19**

7. In the past seven days, have there been times when the household did not have enough food or money to buy food? Yes/No

8. Please answer the following food security related questions below

| **Behaviour:** | Yes/No | **Frequency of occurrence:**<br><br>1=Rarely (1 – 2 times a month)<br>2=Sometimes (3 – 10 times a month)<br>3=Often (more than 10 times a month) |
|---|---|---|
| In the 30 days, was there ever no food to eat of any kind in your household because of lack of resources to get food? | | |
| In the past 30 days, did any household member go to sleep at night hungry because there was not enough food? | | |
| In the past 30 days, did any household member go all day and night without eating anything because there was not enough food? | | |

9. What coping strategies have you had to use (use the list below) in the past 7 days?

   For each coping strategy how many days has your household had to use in the last seven days?

| **Consumption coping strategies during lockdown** | Yes/No | Number of days out of the past seven |
|---|---|---|
| a. Rely on less preferred and less expensive foods? | | |
| b. Borrow food, or rely on help from a friend or relative? | | |
| c. Purchase food on credit? | | |
| d. Gather wild food, hunt, or harvest immature crops? | | |
| e. Consume seed stock held for next season? | | |

| | | |
|---|---|---|
| f. Send household members to eat elsewhere? | | |
| g. Send household members to beg? | | |
| h. Limit portion size at meal times? | | |
| i. Restrict consumption by adults in order for small children to eat? | | |
| j. Feed working members of household at the expense of non-working members? | | |
| k. Reduce number of meals eaten in a day? | | |
| l. Skip entire days without eating? | | |

# APPENDIX C: ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

10 September 2018

Ms Khethiwa Naledi Mthethwa 214511796
School of Agricultural; Earth & Environmental Science
Pietermaritzburg Campus

Dear Ms Mthethwa

**Protocol reference number: HSS/0945/018M**
**Project title: The contribution of Climate Smart Agriculture (CSA) practices in adapting to climate change: The case of smallholder farmers in KwaZulu-Natal**

**Full Approval – Expedited Application**

In response to your application received 16 July 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.**

**PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.**

**The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.**

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

[redacted]

.............................................................................................

**Professor Shenuka Singh (Chair)**
**Humanities & Social Sciences Research Ethics Committe**

**/pm**

cc Supervisor:Dr M Ngidi & Dr K Caster
cc. Academic Leader Research: Professor Onisimo Mutanga
cc. School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
**Postal Address:** Private Bag X54001, Durban 4000
**Telephone:** +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
**Website:** www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood · Howard College · Medical School · Pietermaritzburg · Westville