Article

Factors Determining the Adoption of Strategies Used by Smallholder Farmers to Cope with Climate Variability in the Eastern Free State, South Africa

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Abstract: This study was undertaken to understand the smallholder farmer's perception of the effects of climate variability, their adaptation strategies to cope with climate variability and factors determining the adoption of their adaptation strategies in the eastern Free State Province of South Africa. Adaptation strategies were grouped into two categories, i.e., traditional adaptation strategies and scientific adaptation strategies. Traditional adaptation strategies consisted of practices that require minimal technical expertise and less external inputs such as changing from crops to livestock, crop diversification, increasing land under production, changing crop type and water harvesting. Scientific adaptation strategies consisted of practices that require additional external inputs, labour, and some level of technical expertise such as changing crop variety, improving soil fertility and soil conservation. Data were collected from 391 smallholder farmers using a structured household questionnaire and were verified through focus group discussion meetings with key informants. Data were analysed using the descriptive statistics, frequency analysis and a binary logistic model. Results indicated that the majority of smallholder farmers perceived that climate change had triggered food-related impacts in the study area and had adopted at least one adaptation strategy. This study showed that awareness and knowledge were the key factors that determined the adoption of traditional adaptation strategies in the study area. The adoption of scientific adaptation strategies was additionally determined by the availability of external financial investments. It is recommended that the promotion of traditional practices should focus on raising awareness of climate change and adaptation strategies while the promotion of scientific practices additionally requires the provision and accessibility of financial institutional support and incentives.

Keywords: awareness of climate change; climate information; scientific adaptation strategies; traditional adaptation strategies

1. Introduction

Agriculture is widely recognized as the vehicle through which rural development, food and nutrient security can be attained in Africa [1–3]. However, agricultural production is highly sensitive to climate change/variability as the result of its high reliance on climate variables such as rainfall, temperature, wind speed and relative humidity [4–6]. Furthermore, the majority of the African smallholder farmers farm in soils of low fertility, have inadequate farm equipment and limited income, have restricted access to climate information and often lack basic agronomic knowledge, thus making them highly vulnerable to the negative effects of climate variability [7,8].

In Africa, an increase in air temperatures, the high variability of rainfall onsets and amounts, prolonged dry spells, and the frequent occurrence of intensified extreme weather hazards such as floods and droughts are expected as a result of predicted climate change [9–11]. Such changes are already affecting agricultural production with evidence of crop failure, food insecurity, death of livestock as well as outbreaks of pests and diseases being reported in recent years in this region [9,10,12]. Consequently, climate change and variability are already affecting and will continue to threaten the livelihood and food security of the majority of the smallholder farmers in Africa due to their vast reliance on rainfed agricultural production and often having restricted adaptation capacity as a result of financial, resources and knowledge constraints [6,9,13–15].

The need to limit the adverse effects of climate-related risks on agriculture production through effective adaptation and mitigation strategies is becoming more urgent to support sustainable agricultural productivity and to improve food security for African smallholder farmers [9,10,15–17]. Several adaptation strategies have been developed, validated, and recommended to cope with the effects of climate variability on rainfed crop production [8,18,19]. These can be broadly grouped into two categories, i.e., traditional adaptation strategies and scientific adaptation strategies. Traditional adaptation strategies consist of simple practices that do not require additional inputs such as labour, hybrid seeds, fertilizers and technical farm implements or intensive-technical skills such as changing planting dates, changing crop types, crop diversification, rainwater harvesting, increasing land under crop production, or changing from crops to livestock [18,20,21]. Scientific adaptation strategies consist of more complex practices that are knowledge-intensive and require additional external inputs and labour such as changing crop variety, improving soil fertility and soil conservation [18,20–22]. Despite the well-documented effectiveness and feasibility of the traditional strategies to cope with climate change in resource-constrained rural communities, adoption remains low in Africa mainly due to the lack of awareness of climate change and effective adaptation strategies [18,20,21]. On the other hand, the low adoption of scientific strategies to cope with climate change is often attributed to low levels of education, age, low income, lack of awareness of climate change and adaptation strategies, lack of labour, poor access to credit and extension services [8,18,19,23]. Previous studies on farmers' perceptions of climate change across the African continent indicated that the majority of smallholder farmers often perceive the variability of onsets, rainfall amount and duration of the rainy season as well as the frequent occurrence of droughts and incidences of pests and diseases to be the major weather-induced risks attributed to climate change that affect their agricultural production [24–26]. Furthermore, these studies indicated that availability of labour, gender, farming experience, income, level of education, land ownership, access to extension services, credit and markets were often the main determinants of the choices of adaptation strategies used by smallholder farmers across the African continent [5,18,19,27–29]. This previous research showed that farmers' perceptions of climate change and their relative adaptation strategies are local-specific as a result of differences in local policies, availability of infrastructure, resources, political and cultural ideologies as well as access to climate information [5,6,30–32].

Given the wide range of cultural ideologies and agro-climatic conditions in South Africa, knowledge of the farmers' perceptions and their adaptation strategies across the country is crucial for the development and implementation of effective and informed policies to enhance sustainable agricultural productivity [33]. Although a few early studies were undertaken to understand farmers' perceptions and their relative adaptation strategies to cope with climate variability in South Africa [8,28,33,34], these did not investigate the determinants of the choices of adaptation strategies used by smallholder farmers in the country. The understanding of those determinants is a prerequisite for the development of informed and effective interventions to build climate-resilient rural communities, not only in the case of the study area but also in other communities facing similar socio-economic challenges [19]. Furthermore, amongst the studies on determinants of the choice of adaptation strategies that have been conducted across the African continent, very few have considered the differences between traditional and scientific adaptation strategies [18–21]. Therefore, the determinants and the challenges limiting

smallholder farmers in Africa from adopting traditional adaptation strategies have not been well investigated [18]. However, traditional adaptation strategies have the potential to be adopted easily by resource-constrained smallholder farmers despite their serious socio-economic and institutional challenges that still need to be solved at a national level. Consequently, the improved understanding of the challenges preventing smallholder farmers from adopting traditional adaptation strategies is imperative for the development of informed and effective interventions to enhance climate-resilience of these farmers with little effort and external resources. Therefore, this study was undertaken to understand the smallholder farmer's perception of the effects of climate change on their crop production, their adaptation strategies and factors determining the adoption of their adaptation strategies in the eastern Free State Province of South Africa. Firstly, we determine their perception of the effects of climate change on agricultural production. Secondly, we identify the adaptation strategies they used and the extent of their adoption. Thirdly, we identify the factors determining the adoption of those adaptation strategies. Finally, we recommend relevant approaches to increase the climate-resilience of smallholder farmers in the study area.

2. Materials and Methods

2.1. Study Site Description

The study was carried out in the different villages of the Harrismith and Phuthaditjhaba towns that are located in the Maluti-a-Phofung municipality within the Thabo Mofutsanyana district in the eastern part of the Free State Province of South Africa (Figure 1). Free State is located between latitudes 26.6° S and 30.7° S and between longitudes 24.3° E and 29.8° E and is the third of the largest provinces in the country [35,36]. According to Moswetsi et al. [37], it alone produces more than 30% of the total maize production in the country and most of its agricultural production (approximately 90%) is under rainfed cropping systems [35,36,38].

Figure 1. Location of the study area [39].

The Maluti-a-Phofung municipality has a subtropical highland climate with a mean annual air temperature of 17 °C and a mean annual rainfall ranging between 500 and 900 mm [38]. This area receives most of its rainfall in the summer months (December to February) and often in the form of thunderstorms [39]. The region has a high spatial rainfall variability that is attributed to orographic patterns [35–37]. The summers are characterized by humid and hot days with air temperatures exceeding 30 °C, while the winters are cold and dry with air temperatures below 11 °C which may decrease to below 0 °C in June and July months [36].

Droughts and frost occurrence are the major climatic risks that affect agricultural production in this area [35,36,38,40]. The high reliance of this region on rainfed agricultural production makes it more sensitive to the adverse effects of climate variability such as decreasing rainfall amounts, altered rainfall distribution and elevated air temperatures that have been already witnessed and are expected to advance [34,38,40]. Therefore, the need for adoption of adaptation strategies is critical to build climate-resilient farming communities, improve crop yields, food security and alleviate poverty as the potential effects of climate change continue to threaten the sustainability of agricultural production in this region.

2.2. Data Collection

Data for this study were collected from the smallholder farmers in different villages around the Harrismith and Phuthaditjhaba towns as part of the baseline datasets of the InnovAfrica project. InnovAfrica is a multi-disciplinary project that is funded by the European Union's H2020 research and innovation programme and is carried out across six African countries, including South Africa. This on-going project aims to improve the food and nutritional security of smallholders in Africa by integrating sustainable agricultural practices, innovative institutional approaches with novel extension and advisory services. The objective of the project is to strengthen the climate adaptive capacity of smallholders in Africa, improve their productivity, profitability, and nutritional benefits while at the same time reducing adverse environmental impacts.

Primary data were collected by the Agricultural Research Council (ARC) of South Africa in the year 2018 using the pre-tested, structured household questionnaire developed by the Kenya Agricultural & Livestock Research Organization (KALRO). The demographic and socio-economic characteristics of the household head such as age, gender, occupation, level of education, monthly income, farm size, ownership of farm equipment and livestock, access to media, hired labour, extension services, credit and farmer associations, as well as their perception of the effects of climate change and their adaptation strategies were investigated. The KIPUS software of Knowledge Intelligence Applications GmbH (KIAG) was used for data capturing and online storage.

Data were collected using a systematic random sampling technique, purposely pursuing smallholder farmers in the villages around the Harrismith and Phuthaditjhaba towns [39]. The selection of a representative sample of farmers was based on the list provided by local extension officers from the Free State Department of Agriculture and Rural Development for each ward, as well as all smallholder farmers from each village who had active backyard gardens and were keen to participate in the household survey voluntary [39]. Before data collection commenced, ten graduates from the study area who had at least a National Diploma in Agriculture or related fields were appointed and trained as enumerators to collect data used for this study. A total of 600 smallholder farmers were interviewed across the different villages. Data collected from the household survey were compiled in a Microsoft Excel spreadsheet and underwent a cleaning process to identify and remove incomplete and suspicious data. As part of data validation, focus group discussion meetings were held with key informants, representing different stakeholders such as the local extension officers, traditional leadership, farmer's association, and smallholder farmers who were beneficiaries of the InnovAfrica project. After the data cleaning process, a total of 391 questionnaires of good quality data were retained for further data analysis.

2.3. Data Analysis

Primary data collected from the household survey were coded by allocating an arithmetical value for easier statistical analysis. The Statistical Package for the Social Sciences (SPSS) version 23.0 was used for data processing and statistical analysis. The demographic and socio-economic characteristics of the smallholder farmers were analysed using descriptive statistics. The perceived impacts of climate change and the adaptation strategies used by smallholder farmers in the study were analysed using the frequency analysis. The frequency analysis has been used in previous similar studies to investigate the farmers' perception of the effects of climate change [5,27].

A binary logistic regression model, with the dependent variable (adoption of either traditional or scientific adaptation strategies) against demographic and socio-economic characteristics of the household as the explanatory variables was used to investigate the factors determining the adoption of the adaptation strategies (Table 1). Explanatory variables were selected based on the literature [5,18,19,41,42]. A detailed description of the explanatory variables was provided by Myeni et al. [39].

Table 1. Description of the explanatory variables used in a binary logistic regression model and expected outcomes.

Independent Variables	Description and Measurement Type	Variable Type	Expected Outcome (+/−)	
			Traditional	Scientific
Gender	Male (1/0)	dummy	+	+
Age	Age of the farmer (years)	continuous	+	−
Level of education	Level of education (years)	continuous	0	+
Occupation	Own or family farming (1/0)	dummy	+	+
Off-farm income	Household off-farm income (Rands)	continuous	0	+
On-farm income	Household on-farm income (Rands)	continuous	0	+
Access to climate information	Access to climate information (1/0)	dummy	+	+
Ownership of farm equipment	Ownership of farm equipment (1/0)	dummy	+	+
Farm size	Land size of arable land (ha)	continuous	−	−
Access to hired labour	Access to hired labour (1/0)	dummy	+	+
Ownership of livestock	Ownership of livestock (1/0)	dummy	+	+
Awareness of adaptation strategies	Awareness of adaptation strategies (1/0)	dummy	+	+
Access to extension services	Access to extension services (1/0)	dummy	+	+
Access to credit	Access to credit (1/0)	dummy	0	+
Access to farmer associations	Access to farmer associations (1/0)	dummy	+	+

(+/-) indicates a positive or negative correlation with the dependent variable. Zero indicates no correlation with the dependent variable.

Responses on the dependent variable were characterized into two categories, i.e., traditional adaptation strategies and scientific adaptation strategies. The traditional adaptation strategies involved practices such as changing from crops to livestock, crop diversification, increasing land under production, changing crop type and water harvesting, while the scientific adaptation strategies involved practices such as changing crop variety, improving soil fertility and soil conservation, which were not common in the study area. The response on the dependent variable traditional adaptation strategies was whether or not the farmer had adopted at least two relevant practices to cope with climate variability, whilst for the dependent variable scientific adaptation strategies, the response was whether or not the farmer had adopted at least two of those practices to cope with climate variability. The binary logit model is more suitable in this case because the response on the dependent variable was either that a farmer had adopted or not adopted either traditional or scientific strategies. The binary logit model has been used in previous similar studies to investigate the relationship between a binary dependent variable and numerical explanatory variables [43–46].

3. Results and Discussion

3.1. Summary of Demographic and Socio-Economic Characterization of Smallholder Farmers

Data obtained from the household survey on the demographic and socio-economic characteristics of smallholder farmers are presented in Table 2. The results indicate that 52% of the farms were headed by men and that 41% of farmers were between 52–66 years while only 6% of farmers were youth (<35 years). The majority of smallholder farmers had limited education with 36% having accomplished secondary education, 30% had no formal education while only 3% had attained tertiary education. Furthermore, the study indicated that the main occupation of the majority of the household heads (73%) was their own or family farming while only 7% were either self-employed or employed for farming. The study also showed that the majority of smallholder farmers (82%) were not making any income from their farms, 10% were earning between ZAR 10.00–500.00 (USD 0.65–32.57) per month, while only 2% were earning above ZAR 2000.00 (USD 130.28). These findings suggested that the majority of the smallholder farmers were only producing for subsistence purposes in the study area. Furthermore, the results revealed that the majority (62%) of the smallholder farmers had limited off-farm income and were earning between ZAR 1010.00–2000.00 (USD 65.79–130.28) per month, while only 1% were earning above ZAR 10,000.00 (USD 651.41). These findings suggest that off-farm income from either old age or child-support social grants was the major source of income for the majority of the households, as also reported by [41]. Furthermore, the study revealed that most of the farmers had access to media, with the main sources owned by farmers being television (84%) and radio (73%), while only 4% owned computers. The study also suggested that the majority of the farmers had limited access to farm equipment with the most equipment they owned being irrigation equipment (18%), water tanks (9%) and tractors (2%), while only 1% owned a spray pump. The majority (66%) of smallholder farmers owned between 0.5–1 ha of land while only 5% owned more than 2 ha. The majority of farmers (86%) also had no access to hired labour, probably due to financial constraints. The results suggested that crop production was the core agricultural activity for smallholder farmers in the study area while only 18% of the farmers also owned livestock, as also reported by [39]. Furthermore, the results suggested that most of the smallholder farmers (99%) do not have access to extension services, credit, and farmer associations in the study area. These findings are in agreement with previous studies that had revealed that the majority of South African smallholder farmers have poor access to extension services [47–49], credit [50,51], and farmer associations [7,49,52].

Table 2. Demographic and socio-economic characteristics of smallholder farmers ($n = 391$).

Variables	Description	Frequency (%)	Mean	Std. Dev	Min	Max
Household head characteristics						
Gender	Male (1/0)	51.9	0.52	0.500	0	1
Age	20–35 (years)	6.4	29.56	4.312	20	35
	36–51 (years)	24.8	43.52	4.555	36	51
	52–66 (years)	40.4	60.49	4.259	52	66
	>67 (years)	28.4	74.06	6.283	67	95
Education	No formal education (years)	29.9	0.01	0.092	0	0
	Adult education (years)	3.1	6.75	4.731	1	12
	Primary education (years)	27.9	4.48	1.859	1	11
	Secondary education (years)	36.3	10.37	2.556	8	16
	Tertiary education (years)	2.6	13.90	4.012	15	20
Occupation	Own or family farming (1/0)	73.1	0.73	0.444	0	1
	Employed for farming (1/0)	6.9	0.07	0.254	0	1
	Self-employed (1/0)	7.4	0.07	0.262	0	1
	Employed in other sectors (1/0)	12.6	0.13	0.337	0	1

Table 2. Cont.

Variables	Description	Frequency (%)	Mean	Std. Dev	Min	Max
Monthly on-farm income	0 (ZAR)	81.6	0.00	0.000	0	0
	10–500 (ZAR)	10.0	300.26	130.495	100	500
	5010–2000 (ZAR)	6.9	1403.70	426.508	600	2000
	>2000 (ZAR)	1.5	2740.00	428.019	2400	3500
Monthly off-farm income	<500 (ZAR)	6.6	117.69	181.490	0	460
	500–1000 (ZAR)	12.8	730.60	178.239	500	1000
	1010–2000 (ZAR)	61.9	1639.95	145.547	1140	2000
	2010–5000 (ZAR)	15.1	3335.93	707.612	2080	5000
	5010–10,000 (ZAR)	2.8	6818.18	1270.290	5500	9000
	>10,000 (ZAR)	0.8	14,000.00	2645.751	11,000	16,000
Media	Television (1/0)	83.6	0.84	0.416	0	1
	Radio (1/0)	73.1	0.73	0.455	0	1
	Computer (1/0)	4.1	0.04	0.211	0	1
Farm equipment owned	Irrigation equipment (1/0)	18.4	0.18	0.395	0	1
	Tractor (1/0)	2.3	0.02	0.150	0	1
	Spray pump (1/0)	0.8	0.01	0.087	0	1
	Water tanks (1/0)	9.4	0.09	0.293	0	1
Total area owned	<0.5 (ha)	21.0	0.38	0.06	0.25	0.49
	0.5–1 (ha)	66.0	0.81	0.23	0.5	1
	1.1–2.0 (ha)	8.4	1.62	0.32	1.2	2
	>2 (ha)	4.6	3.49	0.85	2.2	6.1
Hired labour	Hired labour (1/0)	13.8	0.14	0.345	0	1
Ownership of livestock	Ownership of livestock (1/0)	18.4	0.18	0.388	0	1
Extension services	Access to extension services (1/0)	0.8	0.01	0.087	0	1
Credit	Access to credit (1/0)	1.0	0.01	0.101	0	1
Farmer associations	Access to farmer associations (1/0)	0.8	0.01	0.087	0	1

3.2. Farmers' Perception and Adaptation to Climate Change

3.2.1. Farmers' Perception of Climate Change

Farmers' Perception of the Effects of Climate Change

Awareness of the effects of climate change is the main prerequisite for smallholder farmers to adopt adaptation strategies to offset the negative impacts of climate change/variability on agricultural productivity [53]. Data obtained from the household survey on farmers' perceptions of the effects of climate change are presented in Table 3. Results indicate that smallholder farmers perceived that climate change had caused the decline in crop yield (49%), food price increase (36%), food shortage/insecurity (29%) and loss of the entire crop (24%), while less than 6% of the farmers perceived the death of livestock and loss of assets as the major impacts of climate change in the study area. These findings suggest that the majority of the smallholder farmers who were aware of the effects of climate change perceived that climate change had caused food-related impacts in the study area. The low perceived effects of climate change on the loss of assets and the death of livestock could be attributed to low ownership of assets and livestock in the study area [39].

Table 3. Farmers' perception of the effects of climate change ($n = 391$).

Weather Impacts	Frequency	Percentage (%)
Loss of assets	22	5.6
Loss of entire crop	93	23.8
Food price increase	141	36.1
Loss of income	43	11.0
Death of livestock	16	4.1
Food shortage/insecurity	112	28.6
The decline in crop yield	191	48.8

Farmers' Perception of the Problems Attributed to Climate Change

Data obtained from the household survey on farmers' perceptions of the problems attributed to climate change are presented in Table 4. The results indicate that most smallholder farmers (72%) perceived that climate change had triggered droughts while only 2% of the farmers perceived that climate change had increased disease incidence in the study area. The perceived frequent occurrence of droughts by smallholder farmers is in agreement with the scientific evidence that drought is the major agro-climatological hazard that threatens the sustainability of agricultural production in the eastern Free State [34,40,54]. Furthermore, the results of this study suggest low awareness of the other problems caused by climate change in the study area except only the frequent occurrence of droughts.

Table 4. Farmers' perception of problems attributed to climate change ($n = 391$).

Weather Problems	Frequency	Percentage (%)
Flooding	46	11.8
Drought	280	71.6
Erratic rainfall pattern	82	21.0
Hailstorms	40	10.2
Increased insects and pests	27	6.9
Increased disease incidence	8	2.0

3.2.2. Adaptation Strategies Used by Smallholder Farmers to Cope with Climate Variability

About 77% of the smallholder farmers perceived that weather has changed in the study area over the past 10 years, suggesting a high level of awareness of climate change. Furthermore, the results indicate that most smallholder farmers (76%) had adopted at least one adaptation strategy in the study area, with only 24% having undertaken no adaptation strategy. These findings agreed with the previous studies that reported that the majority of smallholder farmers (>70%) had adopted at least one strategy to cope with climate change/variability in Africa [46,55]. The results further revealed that water harvesting (51%), change of crop variety (47%), soil conservation (46%) and improved soil fertility (28%) were the most common practices used by smallholder farmers to cope with climate variability in the study area, while increased land under production (18%), diversified crops (15%), change of crop type (11%) and change from crop to livestock production (5%) were the least adopted practices (Table 5). The discussions during the focus group meetings revealed that high preference for water harvesting and change of crop variety strategies were attributed to the effectiveness of these strategies to cope with the effects of droughts that were frequently occurring in the study area. The findings of this study agreed with the findings of Gandure et al. [34], who reported that rainwater harvesting was the most popular adaptation strategy used by smallholder farmers at Thaba Nchu in the eastern Free State. The relatively low adoption of improved soil fertility (28%) could be attributed to the high cost of liming or fertilizers, such that the majority of the smallholder farmers cannot afford it as a result of financial constraints and poor access to capital [39]. This study also suggested a low

adoption of crop diversification and changing crop type, despite the effectiveness and feasibility of these traditional strategies in offsetting the negative effects of climate variability on crop production without any additional technical, labour and financial inputs in resource-constrained communities. Furthermore, the discussions during the focus group meetings revealed that low preference for these traditional adaptation strategies could be attributed to the persisting lack of awareness of the effective and feasible adaptation strategies in the study area. The findings of this study agreed with previous studies that reported the low adoption of traditional strategies across African countries [18,20,21].

Table 5. Strategies used by smallholder farmers to cope with climate variability ($n = 391$).

Adaptation Strategies	Frequency	Percentage (%)
No adaptation strategy used	92	23.5
Change of crop variety	184	47.1
Change from crop to livestock production	19	4.9
Diversified crops	58	14.8
Improve soil fertility	109	27.9
Increased land under production	70	17.9
Soil conservation	179	45.8
Water harvesting	198	50.6
Change of crop type	46	11.8

3.3. Factors Determining the Adoption of Adaptation Strategies Used by Smallholder Farmers

3.3.1. Factors Determining the Adoption of Traditional Adaptation Strategies by Smallholder Farmers

Results obtained from a binary logistic regression model indicated that on-farm income ($p < 0.05$), access to climate information ($p < 0.1$), and awareness of traditional adaptation strategies ($p < 0.01$) were the main variables that had a significant influence on the adoption of traditional adaptation strategies by smallholder farmers in the study area (Table 6).

Table 6. Estimated results on the factors determining the adoption of traditional adaptation strategies.

Explanatory Variables	Coefficients	Odds Ratios	Std. Err.	z	$p > z$
Gender	0.024	1.024	0.269	0.008	0.929
Age	0.001	1.001	0.012	0.014	0.905
Level of education	0.027	1.027	0.036	0.573	0.449
Occupation	−0.021	0.979	0.331	0.004	0.948
Off-farm income	0.000	1.000	0.000	0.558	0.455
On-farm income	0.001 **	1.001	0.000	4.203	0.040
Access to climate information	−0.445 *	0.641	0.267	2.774	0.096
Ownership of farm equipment	−1.366	0.255	0.858	2.534	0.111
Farm size	−0.010	0.990	0.215	0.002	0.961
Access to hired labour	−0.282	0.754	0.413	0.467	0.494
Ownership of livestock	0.063	1.065	0.362	0.030	0.861
Awareness of adaptation strategies	2.887 ***	17.948	0.418	47.816	0.000
Access to extension services	2.292	9.894	1.631	1.976	0.160
Access to credit	−1.955	0.142	1.500	1.698	0.193
Access to farmer associations	−1.251	0.286	1.563	0.641	0.423
Number of observations = 391					

Std. Err. is the Standard Error in parentheses (* $p < 0.1$, ** $p < 0.05$ *** $p < 0.01$).

3.3.2. Factors Determining Adoption of Scientific Adaptation Strategies by Smallholder Farmers

Results obtained from a binary logistic regression model indicated that farm size ($p < 0.05$), ownership of livestock ($p < 0.1$), awareness of scientific adaptation strategies ($p < 0.01$), and access to credit ($p < 0.1$) were the main variables that had a significant influence on the adoption of scientific adaptation strategies by smallholder farmers in the study area (Table 7).

Table 7. Estimated results on the factors influencing the adoption of scientific adaptation strategies.

Explanatory Variables	Coefficients	Odds Ratios	Std. Err.	z	p > z
Gender	0.075	1.077	0.306	0.060	0.807
Age	−0.006	0.994	0.014	0.191	0.662
Level of education	−0.010	0.990	0.041	0.058	0.810
Occupation	0.237	1.268	0.384	0.381	0.537
Off-farm income	0.000	1.000	0.000	0.028	0.868
On-farm income	0.000	1.000	0.000	1.328	0.249
Access to climate information	0.130	1.139	0.306	0.180	0.671
Ownership of farm equipment	0.189	1.209	0.731	0.067	0.796
Farm size	−0.610 **	0.543	0.303	4.045	0.044
Access to hired labour	0.455	1.576	0.431	1.114	0.291
Ownership of livestock	0.737 *	2.089	0.389	3.580	0.058
Awareness of adaptation strategies	4.231 ***	68.761	1.018	17.260	0.000
Access to extension services	−1.604	0.201	1.841	0.759	0.384
Access to credit	2.793 *	16.335	1.474	3.592	0.058
Access to farmer associations	2.075	7.967	1.510	1.888	0.169

Number of observations = 391

Std. Err. is the Standard Error in parentheses (* $p < 0.1$, ** $p < 0.05$ *** $p < 0.01$).

3.3.3. Overall Discussion

In this section, brief discussions of the explanatory variables that had a significant effect on the adoption of either traditional or scientific adaptation strategies used by smallholder farmers to cope with climate variability in the study area are provided.

On-Farm Income

The effect of the variable on-farm income had a positive and significant influence (0.001) only on the adoption of traditional practices used by smallholder farmers in the study area. For a unit increase in on-farm income, the odds of a farmer adopting traditional adaptation strategies are 1.001. The results suggest that farmers who sell their produce were more likely to adopt traditional adaptation strategies than their counterparts. The possible explanation for this is that farmers who are selling their produce are making their living from crop production, hence sustaining their production was their top priority. Consequently, farmers who were selling their produce were more enthusiastic to optimize their indigenous knowledge and the resources they had for optimal crop production under the threat of climate change.

Access to Climate Information

The variable access to climate information had a negative and significant effect (−0.445) only on the adoption of traditional adaptation practices used by smallholder farmers in the study area. For a unit increase in access to climate information, the odds of a farmer adopting traditional adaptation strategies are 0.641. Unexpectedly, the results suggest that smallholder farmers with access to climate information were less likely to adopt traditional adaptation strategies. During the focus group discussions, it was discovered that the majority of farmers had access only to the daily weather forecast from either radio or television and very few had access to medium-term or seasonal forecasts. This climate information is unreliable and does not provide farmers with any recommendations on management practices.

Furthermore, the focus group discussions also revealed that the majority of smallholder farmers had no access to early warning systems and information on rainfall distribution throughout the season which could help them to plan better and make informed decisions on crop management to minimize the impacts of weather-related risks [42,56,57]. The poor access to relevant, timely, and reliable climate information hindered the farmers' adoption of the traditional practices as a result of uncertainties and lack of confidence in their indigenous knowledge, which has become more unreliable as climate variability intensifies. Therefore, the need for the provision of meaningful, reliable and local-specific climate information so that farmers can have confidence in making their decisions regarding crop choices, planting dates and adaptation strategies cannot be overemphasized [27,29,42,58,59].

Awareness of Adaptation Strategies

Awareness of adaptation strategies was the main factor that had a positive and significant effect on the adoption of both traditional adaptation strategies (2.887) and scientific adaptation strategies (4.231) used by smallholder farmers in the study area. For a unit increase in the variable awareness of adaptation strategies, the odds of a farmer adopting them are 17.948 for traditional adaptation strategies and 68.761 for scientific adaptation strategies. The results suggest that knowledge and awareness were the main prerequisites for smallholder farmers to be able to adopt adaptation strategies in the study area. The findings of this study are in agreement with previous studies that showed that knowledge and awareness were the main variables determining the adoption of adaptation strategies by smallholder farmers in Africa [6,29,60,61]. Focus group discussions revealed the low awareness of the feasible adaptation strategies in the study area, although some smallholder farmers were already practising these strategies without knowing their effectiveness in building a climate-resilience farming community. The lack of awareness could be attributed to the low level of education and poor access to extension services in the study area which hindered the smallholder farmers from reading and understanding the climate information as well as the relative, feasible and effective adaptation strategies [39]. Consequently, the lack of awareness of adaptation strategies, if not addressed at a high priority level, is more likely to hinder smallholder farmers in the study area from adopting strategies to cope with climate variability. These findings suggest that targeting policies and interventions that aim to raise awareness of climate change and relative adaptation strategies alone can significantly improve the climate resilience of the smallholder farmer in the study area.

Farm Size

Variable farm size had a negative and significant effect (-0.610) only on the adoption of scientific practices used by smallholder farmers in the study area. For a unit increase in farm size, the odds of a farmer adopting scientific adaptation strategies are 0.543, suggesting that those with larger farm sizes were less likely to adopt scientific adaptation strategies, probably due to the labour-intensiveness and resource-intensiveness of the strategies. Thus, large farms require significant financial investments on labour and inputs, which is currently financially unattainable in the study area. These findings agreed with previous studies that reported that farm size had a negative influence on the adoption of the adaptation strategies by smallholder farmers [18,19,28,59,62].

Ownership of Livestock

The results showed that ownership of livestock had a positive and significant influence (0.737) only on the adoption of scientific practices used by smallholder farmers in the study area. For a unit increase in the variable ownership of livestock, the odds of a farmer adopting scientific adaptation strategies are 2.089, suggesting that those who own livestock were more likely to adopt scientific adaptation strategies. The possible explanation for this is that farmers owning livestock can generate extra income from their sales to hire labour and also purchase inputs such as fertilizers and hybrid seeds that are required for scientific adaptation strategies. Furthermore, farmers possessing livestock were more likely to adopt practices that have the potential to increase their crop production to improve

feed security for their livestock [39]. The findings of this study agreed with previous studies that reported a positive influence of livestock ownership on the adoption of the adaptation strategies by smallholder farmers [59,62].

Access to Credit

The results showed that access to credit significantly and positively (0.737) affected only the adoption of scientific adaptation strategies used by smallholder farmers in the study area. For a unit increase in the variable access to credit, the odds of a farmer adopting scientific adaptation strategies are 16.335, suggesting that those who had access to credit were more likely to adopt scientific adaptation strategies. The possible explanation for this is that access to credit offsets financial constraints and thus enables the farmer to hire labour and purchase inputs such as improved crop variety and fertilizers required for scientific adaptation strategies. These findings are in agreement with previous studies that reported that access to credit significantly and positively influences the adoption of scientific adaptation strategies by smallholder farmers [6,18,27,29].

4. Conclusions and Recommendations

Climate change/variability is already and is likely to continue affecting agricultural productivity negatively in Africa where the majority of the smallholder farmers are reliant mainly on rainfed crop production for their livelihoods and household food security. This study was undertaken to understand the smallholder farmer's perception of the effects of climate change, their adaptation strategies, and factors determining the adoption of their adaptation strategies in the eastern Free State Province of South Africa. The results showed that most of the smallholder farmers who were aware of the impacts of climate change perceived that climate change had caused food-related impacts such as a decline in crop yield, food price increase, food shortage/insecurity, and loss of the entire crop. The study further showed that the majority of the smallholder farmers had adopted at least one practice to cope with climate variability in the study area. Water harvesting, changing crop variety, soil conservation, and improving soil fertility were the most popular adaptation strategies used by smallholder farmers in the study area while increasing land under crop production, crop diversification, changing crop type, and changing from crop to livestock production were the least used practices.

Results indicated that on-farm income and awareness of traditional adaptation strategies were the main factors that significantly and positively influence the adoption of traditional adaptation strategies, while access to climate information had a significant and negative effect on their adoption. Furthermore, the study indicates that ownership of livestock, awareness of scientific adaptation strategies and access to credit were the key factors that significantly and positively influence the adoption of scientific adaptation strategies, while farm size had a significant and negative effect on their adoption. The study showed that awareness and knowledge were the key factors influencing the adoption of traditional adaptation strategies in the study area while scientific adaptation strategies were additionally influenced by the availability of additional financial investments. The findings suggest that interventions that aim to raise climate change awareness alone can significantly improve the adoption of traditional adaptation strategies. Therefore, awareness-raising of climate change and relative adaptation strategies through training, education and field days is recommended for wider adoption of the adaptation strategies. Furthermore, interventions and policies that enhance the access of smallholder farmers to financial institutional support and incentives are recommended for wider adoption of scientific adaptation strategies.

The findings of this study suggest that, in order to enhance climate-resilience with minimal external inputs, the promotion of traditional adaptation strategies that are feasible to these resource-constrained smallholder farmers is critical. Therefore, it is recommended that interventions and policies aiming to strengthen the climate adaptive capacity of smallholders should concentrate on promoting the adoption of traditional adaptation strategies such as changing from crops to livestock, crop

diversification, increasing land under production, changing crop type, water harvesting, and planting dates through awareness-raising.

Availability and accessibility of relevant, timely and reliable climate information enable the farmers to plan effectively and make informed decisions on adaptation strategies to be used, and hence build climate-resilient farming communities. However, the lack of awareness of climate change and adaptation strategies, as well as poor access to climate information, are the key knowledge-related barriers hindering smallholder farmers from coping effectively with climate variability in the study area. This lack of knowledge could be attributed to poor access to extension services, which are assigned to provide smallholder farmers with technical advisories on climate information, adaptation strategies and sustainable agricultural practices as well as information on credit and market facilities. Therefore, it is recommended that the quality and outreach of extension services in the study area is improved through capacity building and provision of resources as well as relevant, timely and reliable climate information.

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