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Determinants of smallholder crop farmers' access to climate services in Elundini local municipality, Eastern Cape province, South Africa

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Climate variability presents significant implications for agricultural production and overall food security, leading to seeking better access to climate services that can improve farmers' decision-making in combating climate change impacts. The study examined the factors influencing smallholder crop farmers' access to climate services in Elundini local municipality, Eastern Cape province. The study adopted a quantitative method using a cross-sectional survey approach. A multistage sampling procedure was employed to select 217 smallholder crop farmers. The study used primary data collected through structured questionnaires and face-to-face interviews. To analyze the data the paper employed a binary Probit model. The study results indicated that access to both short-term weather and seasonal forecasts is positively influenced by ownership of mobile phones and access to extension services. Similarly, access to short-term weather forecasts is positively influenced by age, monthly income, ownership of radio, timely climate information, and perceiving that climate change has negative effects on crop production. The study further revealed that land size, knowledge of climate change, and climate services accuracy are positive and significant factors in access to seasonal forecasts. On the other hand, being educated negatively influenced access to seasonal forecasts while land size had a negative and significant effect on short-term weather forecasts. The study concludes that age, land size, ownership of mobile phones, and access to extension services were significant factors that determine both farmers' access to short-term weather and seasonal forecasts. Therefore, the study recommends that if the access and uptake of climate services are to be improved, government stakeholders, researchers, and forecast producers should collaborate and offer training sessions and workshops on climate services relevance and how to acquire and interpret them, particularly for elderly farmers.

KEYWORDS

access, binary probit model, climate services, determinants, smallholder crop farmers

1 Introduction

According to scientific climate research, the climate is changing rapidly (Meinshausen et al., 2022). Sylla et al. (2018) suggest that extreme weather phenomena including droughts, floods, and windstorms are becoming more frequent and intense due to changes in climate. These occurrences can lead to significant decreases in crop production quantity and quality, as well as failures (Toreti et al., 2020). Calzadilla et al. (2014) noted that these crop losses and failures are already evident, particularly in smallholder agricultural systems. This is owing to smallholder farmers' reliance on rainfed farming, especially in semi-arid regions such as Africa (Rowhani et al., 2011). International Fund for Agricultural Development (IFAD) (2013) defines smallholder crop farmers as individuals who are marginalized and have a tough time gaining access to resources, finance, knowledge, and technology. Additionally, smallholder farmers in Africa are distinctive in such a way that they usually use land for free or at a low cost because it is owned by the community (Mgbenka et al., 2015). Furthermore, smallholder crop farmers are highly dependent on family labour, have low adaptive capacity, income, access to resources, and are vulnerable to climate change (Ubisi et al., 2017; Harvey et al., 2018). According to Harvey et al. (2014), there are not less than 450 million smallholder farmers throughout the world. In Africa, Hlophe-Ginindza and Mpandeli (2020) mentioned that four out of five farms comprise of smallholder farmers. Similarly, in South Africa, the agricultural sector is dominated by smallholder farmers (Kom et al., 2022), and the Eastern Cape province is not omitted (Mdoda et al., 2020). Moreover, most African smallholder farmers rely on their Indigenous knowledge for weather and climate forecasting (Antwi-Agyei et al., 2021). According to Mashizha (2019), climate change has caused a 5% drop in agricultural productivity over the last three decades. Dinesh et al. (2015) observed that maize, sorghum, millet, and groundnut outputs have been declining in some parts of Africa due to changes in climate. Furthermore, the evidence of yield declines due to changes in climatic conditions is more visible among staple crops like maize in Africa. For instance, research by Owusu et al. (2019) indicates that about 9,656 tons of maize losses were recorded among smallholder farmers in Ghana due to the 2015 El Nino drought. Jiri et al. (2016) conducted a study in Zimbabwe and reported that about 76% of the interviewed farmers agreed that their maize output has been dropping in the last two decades. Oduniyi et al. (2019) argue that over the past years, reduced maize production has been associated with changes in climate conditions in South Africa. Coleman (2022) adds that about 60% of planted maize has been destroyed by the recent 2022 floods in South Africa Moreover, it is expected that by 2050 because of changes in climatic conditions, maize yields will decrease by up to 10% throughout the world (FAO, 2016). In Africa, the decrease in maize outputs due to climate change by 2050 will be higher than the 10% global reduction (Fosu-Mensah et al., 2019). On the other hand, by 2050 in Africa, millet and sorghum outputs are anticipated to fall by 15 and 17%, respectively (Knox et al., 2012). Similarly, Schlenker and Lobell (2010) by the 21st century, projected that cassava, sorghum, millet, groundnut, and maize yields are expected to decrease by values ranging from 8 to 22% in Sub-Saharan Africa. In South Africa by 2,100, farmers are expected to experience a reduction in maize output from up to 38% (Kogo et al., 2019). Therefore, as opined by Buckland and Campbell (2021), smallholder farmers' ability to innovate and adapt to unexpected climate circumstances will significantly impact their future welfare. Among other adaptation strategies that smallholder farmers might employ to address the climate change effects, climate services are increasingly considered a vital tool for adaptation (Hansen et al., 2019) and for improving their food security [World Meteorological Organization (WMO), 2016]. In agriculture, climate services aim to ensure that farmers are making the right decisions that will improve their production and livelihoods and can build resilience towards climate change (Singh et al., 2016). The services cover information on temperature, rainfall, wind speed, humidity, drought, and floods, and are usually made available to users on a daily up to seasonal basis from various institutions using both media and human means (Kadi et al., 2011). Moreover, the services may also include other useful information on farming practices such as those on pest and disease outbreaks and crop varieties (Nkiaka et al., 2019). In other words, these services predict what a day, week, month, or season may look like in terms of weather parameters which will help farmers know which type of activity to be involved in concerning the type and timing of climate services (Vincent et al., 2013). Literature shows that for smallholder farmers to be able to access and utilize climate information, the climate services must be available, timely, accurate, reliable, and understandable, and must have the capacity to meet the farmers' needs (Carr and Onzere, 2018), and be useable (Singh et al., 2018). This indicates that smallholder farmers may only benefit from climate services if they match the criteria, which is still a problem (Oyekale, 2015). Studies indicate that climate services, especially seasonal rainfall forecasts, have been available to smallholder farmers in Africa since the 1990s (World Meteorological Organization & African Centre of Meteorological Applications for Development, 1990). In some African countries, smallholder farmers have been accessing and making farming decisions based on them (Diouf et al., 2020; McKune et al., 2018; Nkiaka et al., 2019; Vaughan et al., 2019). However, smallholder crop farmers in most African countries have low climate services accessibility (World Bank, 2016; Krell et al., 2020) and usage (Eguru, 2012; Maponya and Mpandeli, 2013; Nhemachena et al., 2014; Moeletsi et al., 2013; Ochieng et al., 2017). Nonetheless, the above findings could not be generalized across Africa because smallholder farmers are not homogeneous. They differ in resource endowments, consequently, heterogeneity is expected in terms of the levels of accessing and using climate information across regions (Buckland and Campbell, 2021). Hence, it is essential first to understand smallholder crop farmers' climate services access to establish a baseline for climate information at the municipality level. Access to climate services refers to a situation whereby a farmer can obtain the information they heard of from various dissemination channels such as extension officers and farmer groups (Chiputwa et al., 2019). Sarku et al. (2022), revealed that accessing climate services can mean how easy it is for climate information to get to farmers through user-friendly and suitable communication channels. Several factors could affect how much smallholder farmers know about, have access to, and use climate services (Buckland and Campbell, 2021). These factors range from the farmer's socio-economic status, the specific type of climate information available, the format, and the channel of receiving the climate information (Buckland and Campbell, 2021). Ochieng et al. (2017) and Maponya and Mpandeli (2013) add that significant dependence on native knowledge, inadequate skills, and access to information, being illiterate, and a strong cultural identity are other issues undermining the utilization of climate services in Southern African countries. There is a growing literature that focuses on factors that are influencing access to climate services (Diouf et al., 2019; Oyekale, 2015; Bessah et al., 2021; Baffour-Ata et al., 2022). Some studies looked at factors influencing access together with the usage of climate services (Mubangizi et al., 2018; Muema et al., 2018; Masesi, 2019; Josephert et al., 2019). Nevertheless, there is slight evidence showing the factors that are influencing each type of climate service or climate information accessed. Except for Oyekale (2015) who studied "factors influencing access to forecasts on the incidence of pests or diseases and the start of rainfall." Each type of climatic service has its level of access and is ideal for a certain farming choice. Therefore, if there is a need to understand how farmers make decisions and use climate information, knowing factors that influence access to specific climate services is vital.

1.1 Determinants of farmers' access to climate services

For a farmer to access and utilize specific climate information, certain factors including farmers' Age (Gitonga et al., 2020; Masesi et al., 2018; Muema et al., 2018), gender (Oyekale, 2015; Coulibaly et al., 2017; Alliagbor et al., 2021), marital status (Sanga and Elia, 2020; Owusu et al., 2020; Diouf et al., 2020), education (Oyekale, 2015; Sanga and Elia, 2020; Diouf et al., 2019; Onwuemele, 2018), farm size (Muema et al., 2018; Buckland and Campbell, 2021; Bessah et al., 2021), household size (Muema et al., 2018; Oyekale, 2015; Gitonga et al., 2020), farming experience (Alliagbor et al., 2021; Ofuoku and Obiazi, 2021; Antwi-Agyei et al., 2020), and monthly income (Muema et al., 2018; Alidu et al., 2022; Oyekale, 2015) are assumed to determine their chances. These socio-economic and farm characteristics can hinder or enable a farmer to access climate services. For instance, being a male (Oyekale, 2015; Coulibaly et al., 2017; Alliagbor et al., 2021), married (Sanga and Elia, 2020), educated farmer (Oyekale, 2015; Sanga and Elia, 2020; Diouf et al., 2019; Onwuemele, 2018) with high monthly income (Muema et al., 2018; Alidu et al., 2022; Oyekale, 2015) living in larger household improves farmers chances of accessing climate services (Muema et al., 2018; Oyekale, 2015; Gitonga et al., 2020). On the contrary, a study by Alliagbor et al. (2021), noted that the farming experience can be classified as a moderating variable that negatively and significantly influences access to scientific weather forecasts. Alliagbor et al. (2021) emphasize that this is because smallholder farmers in areas like Nigeria put too much faith in their ability to predict weather conditions using local indications and their prior experience and expertise. Farm characteristics such as farm size improve farmers' access to climate services (Losloso et al., 2020). Similarly, Masesi et al. (2018) stated that farmers in Kenya believe that it is unacceptable to speculate on climatic uncertainties because big land sizes demand significant quantities of resources for sustainable agricultural objectives. Hence, they usually consult climate projections on the possibility of a given season before investing in big plots of land (Masesi et al., 2018). According to Bessah et al. (2021), climate change awareness may open farmers' eyes to see the potential of climate information in preparing them to lessen the adverse effects of climate risk. Hence, farmers who perceive changes in climate as a risk are in a better position to access climate services (Oyekale, 2015; Bessah et al., 2021; Buckland and Campbell, 2021).

Institutional factors including the availability of resources, access to extension officers, access to credits, and markets are also influencing access to climate services (Muita et al., 2021; Muema et al., 2018). Literature is skewed on farmers' probability of having access to climate services improved by better access to extension services (Alidu et al., 2022; Onwuemele, 2018; Buckland and Campbell, 2021; Baffour-Ata et al., 2022). Buckland and Campbell (2021) associated the positive influence of extension services with their potential to be a source of climate services used by smallholder farmers. In addition, extension agents in South Africa have the role of teaching rural farmers about climate change and helping them adapt to it (Popoola et al., 2020) using various strategies, including climate services (Ncoyini et al., 2022). The reviewed literature shows evidence that the adoption of climate services improves with access to extension services in Africa. Nevertheless, it is not clear if that is the case across African regions given that in South Africa extension agents lack the ability or skills to help farmers understand climate information (Wilk et al., 2017). Being part of a farmer group increases farmers' chances of accessing climate services (Diouf et al., 2019; Muema et al., 2018; Buckland and Campbell, 2021). According to Tarhule and Lamb (2003) being in a group gives farmers a chance to discuss how climate change affects agriculture and possible climate adaptation strategies. Also, According to Muema et al. (2018), this is because farmer groups are one of the channels that are used for accessing seasonal forecasts. Among other factors, the unreliability and uncertainty are climate forecast attributes that have been associated with low access (Sanga and Elia, 2020) and utilization of climate services (Barasa et al., 2017; Antwi-Agyei et al., 2021; Grey, 2019). Similarly, based on an econometric model, a smallholder farmer who perceives climate services as reliable is in a better position to make farming choices informed by the accessed information (Losloso et al., 2020; Mubangizi et al., 2018). The above implications agree with the work of Maponya and Mpandeli (2013), Ncoyini et al. (2022), and Chisadza et al. (2020) who reported that South African farmers tend to utilize climate information that they perceive to be reliable and accurate. In other words, the literature suggests that low access or utilization of climate services is associated with smallholder farmers perceiving the information as inaccurate or unreliable and vice versa. In other parts of Africa, how climate information is disseminated, and its modes of dissemination hinder smallholder farmers' usage of climate services (Naab et al., 2019; Murgor, 2015). For instance, in West Africa, Nkiaka et al. (2020) argue that climate information disseminated through media sources is usually information on weather events only. The dissemination time is usually when farmers are busy with farm activities, household chores, or other activities. This results in most farmers only listening to the radio or television in the morning and missing other shows during the day, which lowers their chances of receiving and using climate information (Nkiaka et al., 2020). Nevertheless, authors like Muema et al. (2018) applied a two-step Heckman Probit model and reported a positive association between media sources and climate services accessibility and utilization in Kenya. The authors suggested that owning a radio is associated with improved utilization, while access to television is associated with higher chances of receiving seasonal forecasts (Muema et al., 2018). Similarly, having access to radio and television has increased farmers' likelihood of accessing climate services (Oyekale, 2015). The above is in line with Onwuemele (2018) who attests that the more information and communication technology resources the farmers have access to, the greater their chances are of both accessing and using climate services.

2 Materials and methods

2.1 Description of the study area

Elundini was the area under investigation which is a category B municipality of Joe Gqabi District in the north-eastern part of the Eastern Cape, South Africa as displayed in Figure 1. The municipality covers an area of 5,065 km^2 and has 17 Wards, making it the smallest municipality within the district (Elundini Local Municipality, 2015). The municipality has Maclear, Mount Fletcher, and Ugie as its main towns. The area is home to the Xhosa population, and it is regarded to be among the vulnerable areas in terms of socio-economic status within the district [Joe Gqabi District Municipality (JGDM), 2016]. The Elundini municipality is home to 144,929 individuals, equivalent to 38.9% of the total Joe Gqabi district population (Statistics South Africa, 2016). The survey also showed that about 15,209 households in the municipality are involved in agricultural activities, with only 4,730 of these households involved in crop production. Furthermore, Elundini local municipality is recognized for its temperature variations ranging from 13 to 33°C, with higher temperatures expected during summer and lower temperatures during winter (Maroyi, 2017). In a year, the area has 150 days of frost likely from March to November with Maclear and Mount Fletcher recording many winter snowfall incidents. The municipality is a high-rainfall region that receives most of it during the summer months, with an average rainfall of 800 mm-1200 mm per annum (Maroyi, 2017). These favorable climate conditions allow the residents in the area to be involved in both livestock and crop farming. Joe Gqabi District Municipality (2016) reported that Elundini local municipality is the only area with high agricultural potential in the Joe Gqabi district. Furthermore, it is the only municipality that has suitable soil for farming within the district (Joe Gqabi District Municipality, 2016). According to Ngcaba and Maroyi (2021), crop farmers in the municipality primarily grow maize, potatoes, spinach, carrots, cabbage, and beetroot. Nonetheless, just like in many areas within the Eastern Cape province, climate change is affecting Elundini negatively, especially in the eastern parts of the municipality through extreme events such as heavy rains, floods, storms, soil erosions, and land degradation (Elundini Local Municipality, 2015). This has affected crop production in terms of crop losses and increased pest incidences (Elundini Local Municipality, 2015).

2.2 Research design and data collection

The current study adopted a quantitative data method using a cross-sectional research design approach. A cross-sectional study methodology permitted the gathering of data on many variables at once and the collection of information on variables that include the degree to which smallholder crop farmers accessed certain climate services. It also allowed for gathering data on the socioeconomic and institutional circumstances of these farmers. Jovancic (2019) notes that data collection is a systematic approach of collecting and measuring information on key factors in a predefined, logical manner that allows the investigator to react to inquiries, submit research questions, test hypotheses, and evaluate outcomes. The field survey was carried out using semi-structured questionnaires written in English but disseminated to farmers in Xhosa during the face-to-face interviews. Face-to-face interviews were conducted with smallholder crop farmers by eleven trained enumerators. The enumerators were from the University of Fort Hare and spoke Xhosa. They were trained two days before the data collection took place and the data collection process took seven days.

2.3 Sampling procedure and size

To select respondents, a multistage sampling method was employed. The first step included purposive sampling, whereby Elundini municipality was purposively chosen as a study area. Elundini Municipality was chosen because compared to other municipalities in the Joe Gqabi district it is the only area with high agricultural potential [Joe Gqabi District Municipality (JGDM),

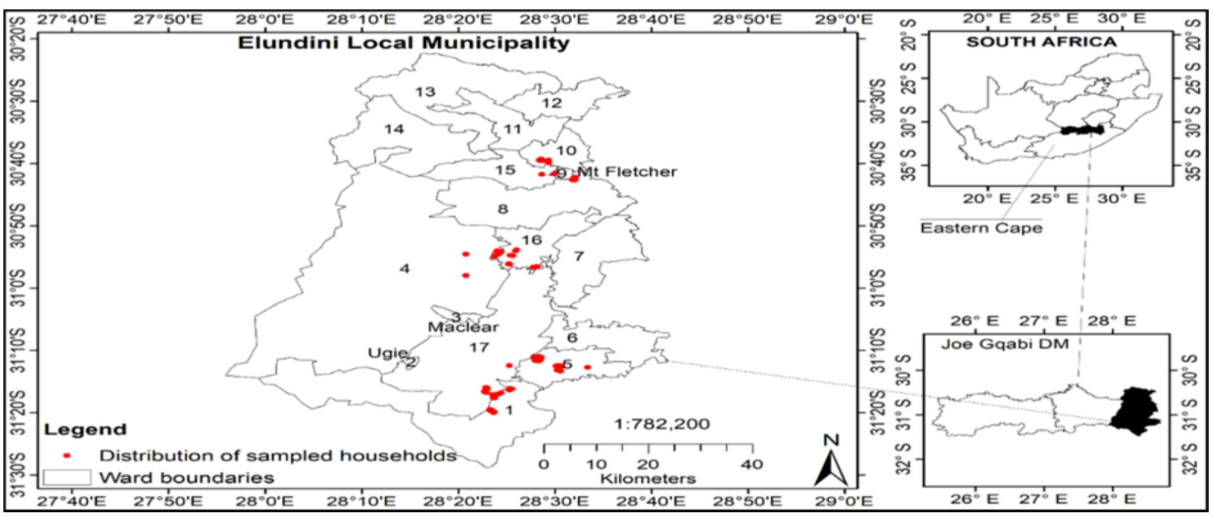

FIGURE 1
Map of Elundini local municipality. Source: Department of GIS, University of Fort Hare.

2016]. Furthermore, there is high climate variability in terms of heavy rains and floods (Elundini Local Municipality, 2015), and is one of the under-researched areas. In the second stage, six wards were purposively selected from the three towns within Elundini local municipality. The purposive selection of wards was based on their agricultural relevance, exposure to climate variability, and accessibility to climate services. The third step also included a purposive selection of two villages per ward, which summed up to a total of 12 villages that represented the whole municipality. In the final step, 217 smallholder crop farmers were randomly selected from the 12 villages. In determining the appropriate size of the sample Yamane's (1967) equation was adopted. The equation may be written as.

$$n = \frac{N}{\left[1+N(e)2\right]} = n = \frac{4730}{\left[1+4730(0.05)^2\right]} = 368.81 \text{ therefore } n = 370.$$

Where n represents the sample size, N represents the total number of crop farming households (sampling frame), and e is the error of margin (which is 0.05 with a confidence level of 95%). According to a Statistics South Africa (2016), the total number of crop farming households in Elundini local municipality was 4,730 which was used as a sampling frame. Therefore, based on Yamane's equation the targeted sample size was 370 small-holder crop farmers. Nonetheless, only 217 smallholder crop farmers were successfully interviewed because of farmers' accessibility and availability, the timing of the data collection, weather (thunderstorms, lightning, and hailstorms), and COVID-19 restrictions.

2.4 Model specification

The current study employed two separate probit models. The choice of two separate binary probit models over models such as the Bivariate probit model was because access to weather forecasts and seasonal forecasts were not correlated to each other in the bivariate probit model (see Appendix A). Furthermore, probit models were chosen because, unlike the logit model which assumes a linearity between climate services access and the explanatory variables, incorporates non-linear effects of independent variables as well. The Probit model can be specified as in Equation 1 below.

$$\begin{aligned} \text{Pri1}\left(\text{Access to CS}\right) = a + \sum_{j=1}^{j} \Upsilon_j \text{ Socioeconomic and farm characteristics}_{ij} + \\ \sum_{j=1}^{j} \lambda_j \text{ Institutional factorsi}_{ij} + \\ \sum_{j=1}^{j} \lambda_j \text{ Climate services attribute }_{ij} + \\ \sum_{j=1}^{j} \lambda_j \text{ Enabling factors }_{ij} + \\ \vartheta_j \text{ Climate change awareness i} + \varepsilon i \end{aligned} \quad (1)$$

Pri1 in Equation 1 denotes the dependent variables (access to specific climate services), with a value of 1 indicating that the farmer accessed short-term weather or seasonal forecasts, with a value of 0 indicating that they did not. Socioeconomicij signifies farmers' characteristics, including gender, education, marital status, and land size as displayed in Table 1. Institutionalij signifies factors such as access to extension services. Climate services attributesi$j$ are a set of factors such as accurate, localized, and timely climate service. Climate change awarenessi signifies farmers' knowledge of the change in climatic conditions. Furthermore, enabling factors ij represent ownership of communication channels such as radio and mobile phones. α, ϒj, λ j, ωj, ϑ j are the parameters determined using the highest likelihood estimation method. ε ik is the error term. Equation 2 below presents the marginal effect, which is the change in

TABLE 1 Variables used to assess the determinants of access to specific climate services.

Groups of variables	Explanatory variables	Access to CS	Cited literature
Socio-economic factors	Age (years)	–	Gitonga et al. (2020)
	Gender (0 = Female; 1 = Male)	+	Alliagbor et al. (2021)
	Education (0 = not educated; 1 = educated)	+	Feleke (2015)
	Monthly income (Rands)	+	Muema et al. (2018)
Farm characteristics	Land size (Hectares)	+	Muema et al. (2018)
	Mixed farming (0 if not; 1 if practicing mixed farming)	+/–	
Institutional factors	Farmers group membership (1 if yes and 0 if no)	+	Buckland and Campbell (2021) and Muema et al. (2018)
	Access to extension services (1 if has access and 0 if no)	+	Buckland and Campbell (2021)
Enabling factors	Ownership of radio (1 if own radio and 0 if no)	+	Ouedraogo et al. (2021) and Bond et al. (2021)
	Ownership of mobile phones (1 if own mobile phone and 0 if no)	+	Ouedraogo et al. (2021)
Climate change awareness	Knowledge of climate change (1 if yes and 0 if no) CC negatively affected crop production (1 if yes and 0 if no)	+	Bessah et al. (2021)
Climate services attributes	Localized climate information (1 if yes and 0 if no)	+	Oladele et al. (2019)
	Timely climate information (1 if yes and 0 if no)	+	Mubangizi et al. (2018) and Nantongo et al. (2021)
	Climate services accuracy (1 if yes and 0 if no)	+	Mpandeli and Maponya (2013)

Source: authors' computation.

access to weather or seasonal forecasts because of a change in an explanatory variable.

$$\frac{\partial \Pr(CIS_i = 1)}{\partial X_{ij}} = \frac{\partial E(CIS_i | X_{ij})}{\partial X_{ij}} = \Omega(\chi_j^{i'} \Upsilon)\Upsilon \quad (2)$$

where Υ represents a set of parameters related to the independent variables and Xij represents a set of jth independent variables.

3 Results and discussion

3.1 Descriptive analysis

This section presents descriptive results of the socio-economic profile, farming characteristics, and access to climate services status of smallholder crop producers in the municipality of Elundini. The results in Table 2 indicate that most (167) of the smallholder crop farmers mentioned to have access to climate services and only 50 could not access climate services in Elundini municipality. The results imply that in Elundini local municipality there is high accessibility of climate services among smallholder crop farmers. This might be viewed as a positive outcome that can assist farmers in making wise choices about their crops as well as farming activities in response to climate variability and change. Naab et al. (2019) and Tarchiani et al. (2021) agree that high climate services access can allow farmers to make knowledgeable crop selection choices and employ agricultural techniques that may lessen the negative consequences of climatic conditions. The current study findings are in line with Ncoyini et al. (2022) who recently reported high accessibility of climate services from KwaZulu-Natal smallholder sugarcane farmers. The results further revealed that more than half (51%) of the respondents were married, and 52% were men. Moreover, an average smallholder crop farmer in the study area was 61 years old, had about 15 years of farming experience, and stayed in a household with about 5 members. This indicates that smallholder farmers in the study area are old, experienced in farming, and with moderate household size. It was also observed that an average farmer without access to climate services had an average of 16 years of farming experience, which is higher than the experience for individuals with access, and there was no difference in the average household size of farmers with access and those without access to climate services. The lack of a significant difference in family size between the two groups suggests that access to climate services may not be strongly associated with household demographics. Most (94%) of the surveyed farmers were knowledgeable about the changes in climate and its impacts on crop production with almost (99%) all the farmers who had access to climate services knew about the changing climate. This could potentially make farmers seek coping strategies (Mandleni and Anim, 2011) such as weather and seasonal forecasts, which can assist them in making better cropping decisions given the changes in climate conditions. Nonetheless, few crop smallholder farmers participated in farmer's organizations (29%) at the same time they had limited access to government extension services (35%). The results further reveal that most respondents had at least primary education (45%) with slight differences between farmers with access and those without access to climate services. Having farmers dominated by primary education might result in difficulty in obtaining, understanding, and interpreting climate information. Regarding unemployment status, there is no significant difference between farmers who had access to climate services and those who did not. However, The unemployment rate of the pooled sample in the study area is high, with about 80% of the respondents being unemployed. These farmers mostly (69.56%) depended on government social grants for living. The results revealed that in most of the farming households in the study area (94%), maize was the main crop grown by farmers.

Table 3 presents the type of climate services that are accessible to smallholder crop farmers. The results indicate that smallholder crop farmers that had access to climate services mainly accessed

TABLE 2 Descriptive statistics of characteristics of the smallholder farmers.

Variables	Pooled (n = 217)		Had access (n = 167)		No access (n = 50)		Chi2
	Freq	%	Freq	%	Freq	%	
Gender (male)	112	52%	83	50%	29	58%	1.0613
Marital status (married)	111	51%	87	52%	24	48%	0.2583
Employment status (employed)	44	20%	34	20%	10	20%	0.0031
Part of farm organization (yes)	63	29%	58	35%	5	10%	11.4223
Access to extension services (yes)	76	35%	71	43%	5	10%	17.8764
Knowledge of climate change (yes)	205	94%	166	99%	39	78%	33.7355
Main crop grown (maize)	205	94%	157	94%	48	96%	0.2911
Main source of income (social grant)	151	70%	119	71%	32	64%	0.9576
Education (primary education)	98	45%	76	45.5%	22	44%	0.0354

Continuous variables	Mean (st. err.)	Mean (st. err.)	Mean (st. err.)	Difference (T-test)
Age of a farmer	61 (0.96)	62 (1.10)	61 (1.94)	−0.82 (−0.37)
Farming experience	15 (0.82)	14.5 (0.92)	16 (1.81)	1.63 (0.80)
Household size	5 (0.18)	5 (0.21)	5 (0.42)	0.10 (0.22)

Source: author's compilation; field survey (2022).

TABLE 3 Types of climate services accessed by smallholder crop farmers.

Types of climate services	Frequency of accessing climate services	Access		No access	
		Freq	(%)	Freq	(%)
Weather forecast	Daily	132	79%	35	21%
	Weekly	75	45%	92	55%
Seasonal forecast	Monthly	36	22%	131	78%
	3–4 months period	22	13%	145	87%

A crop farmer may access more than one type of climate service and product, hence the percentage does not add up to 100 or the frequency does not add to 167. Source: authors computation; field survey (2022).

daily (79%), and weekly (45%) weather forecasts, respectively, and very few had accessed monthly (22%) and 3–4 months climate forecasts (13%). The results imply that most of the smallholder crop farmers have access to the weather forecast, and very few have access to the seasonal forecast. In this study weather forecasts consisted of daily and weekly climate information. On the other hand, seasonal forecasts consisted of climate information accessed monthly and in 3–4 months periods. The results suggest that farmers in Elundini might be able to make short-term decisions informed by the weather forecast. However, they are limited in making long-term seasonal cropping decisions due to the lack of information on what to expect in the next season. The current results relate to findings by Masesi (2019) which observed that smallholder farmers were accessing climate services daily, weekly, monthly, and seasonally in Kenya. Additionally, the findings align with studies by Ofuoku and Obiazi (2021) and Ncoyini et al. (2022) which stated that over two-quarters of farmers accessed the daily weather forecasts and less on the seasonal forecasts in Nigeria and KwaZulu-Natal South African province.

3.2 Factors influencing access to specific climate services among smallholder farmers

Table 4 presents the probit model results on the factors influencing farmers' access to climate services, particularly those influencing weather and seasonal forecasts. The model fits are explained by looking at the likelihood ratio, chi-square test, and McFadden Pseudo R^2. The Pseudo R^2 (0.5205) of the short-term weather forecast and (Pseudo $R^2 = 0.2199$) of seasonal forecasts show an excellent fit of the model for the analysis. The likelihood ratio Chi-squares are significant at 1% for both models, indicating that the models with the estimated parameters are significant compared to the unfitted or constant-only models. Both the coefficient and the marginal effects are presented. However, only the marginal effects will be discussed in this study to show how access to seasonal and short-term weather forecasts responds to a change of one of the explanatory variables when other explanatory variables are held constant. The variance inflation factor (VIF) was performed to test for multicollinearity and the values were between 1.06 and 2.15 for all the explanatory variables as shown in Appendix B which shows there was no multicollinearity detected. The findings show that the age of the farmer was positively associated with access to weather forecasts but negatively associated with seasonal forecasts, both significant at a 10% significant level. The findings suggest that a unit change in the age of the farmer the higher the likelihood of accessing short-term weather forecasts by 0.3%. This means that older farm household heads are more likely to access short-term weather forecasts by 0.3% more than younger farmers in Elundini. One possible explanation for these results can be because of the use of radio to access weather information, which is one of the trusted sources of climate information among elderly farmers (Diouf et al., 2019), compared to younger farmers. On the other hand, a unit increase in the age of the household head result in a 0.3% decrease in access to seasonal forecasts. These results imply that older farmers are less likely to access seasonal forecasts compared to younger farmers. This might be because accessing seasonal forecasts requires a sophisticated understanding of technology such as computers and smartphones which might be advantageous for younger farmers because they are technology easy (Okello et al., 2012). Moreover, access to seasonal forecasts might require the use of the internet which based on a recent study by McCampbell et al. (2023) older farmers have limited access to it. Hence, older farmers may be less likely to access seasonal climate information compared to young farmers who are eager to learn new things. The results were also observed in Namibia by Gitonga et al. (2020) who revealed that an increase in farmers' age lowers access to climate services.

The results further indicate that the farmers' education was negative and significantly influenced access to seasonal forecasts, at a 10% significance level. These results mean that a unit change from being uneducated to being educated reduces the farmers' chances to access seasonal forecasts by 6.6%. These results were not expected, given that education was expected to increase access to seasonal forecasts (Feleke, 2015; Oyekale, 2015; Anang et al., 2021). Nonetheless, the current findings may be explained by the complexity of the concepts of seasonal forecasts (Muyiramye, 2020) that require formal education which the interviewed sample is dominated by illiterate people. Furthermore, this may be because Indigenous wisdom is valued more highly in illiterate communities than scientific knowledge (Ochieng et al., 2017). Household monthly income was positively and significantly associated with weather forecasts at the 5% significance level. Specifically, an additional Rand to the household's monthly income increases the probability of access to weather forecasts by 0.0013%. While this suggests that higher-income households are more likely to access weather forecasts, the magnitude of this effect is quite small. The positive association could be explained by the fact that farmers with higher incomes may have better access to the tools (such as radios, smartphones, or other communication devices) necessary for receiving weather information. Studies by Muema et al. (2018),

TABLE 4 Determinants of smallholder farmers' access to specific climate services.

Independent variables	Weather forecasts			Seasonal forecasts		
	Coef.	*dy/dx*	*P>z*	*Coef.*	*dy/dx*	*P>z*
Age of a farmer	**0.018**	**0.003**	**0.051****	**−0.013**	**−0.003**	**0.094***
Gender	0.001	0.000	0.997	−0.015	−0.004	0.944
Education status	−0.051	−0.009	0.774	**−0.282**	**−0.066**	**0.063***
Monthly income	**0.000**	**0.000013**	**0.034****	−4.85e-06	−1.16e-06	0.801
Land size	**−0.109**	**−0.019**	**0.038****	**0.085**	**0.020**	**0.037****
Mixed farming	−0.205	−0.035	0.620	−0.189	−0.045	0.572
Ownership of radio	**1.944**	**0.328**	**0.000*****	0.311	0.074	0.189
Ownership of mobile phone	**1.757**	**0.297**	**0.000*****	**0.512**	**0.123**	**0.041****
Part of the farmer group	−0.109	−0.018	0.737	0.334	0.080	0.214
Access to extension services	**0.571**	**0.096**	**0.065***	**0.896**	**0.215**	**0.001*****
Knowledge of climate change	−0.470	−0.079	0.132	**0.449**	**0.108**	**0.092***
Climate change has negative effects on crop production	**1.636**	**0.276**	**0.093***	0.080	0.019	0.897
Climate services accuracy	0.175	0.030	0.591	**0.509**	**0.122**	**0.040****
Timely climate information	**0.901**	**0.152**	**0.037****	0.038	0.009	0.892
Localized climate information	0.438	0.074	0.230	0.045	0.011	0.864
_cons	−2.007		0.007	−0.972		0.110
Number of observations	217			217		
LR chi^2(15)	140.47			52.55		
Prob > chi^2	**0.0000*****			**0.0000*****		
Pseudo R^2	0.5205			0.2199		

***Significant at 1% level; **Significant at 5% level; *Significant at 10% level. The bold values imply the significant results regardless of their level. Source: field survey (2022) generated on Stata software 15.

Oyekale (2015), and Onwuemele (2018) support the idea that income facilitates access to climate information, allowing farmers to proactively plan for adaptation strategies.

The land size available and used for crop production had a negative association with weather forecast, but a positive one with seasonal forecast, both at a 5% significance level. The results imply that a unit increase in land size reduces the farmers' chances to access weather forecasts but increases his/her chances to access seasonal forecasts by 1.9 and 2%, respectively. The negative association between land and access to short-term weather forecasts might be because short-term weather forecasts are mainly useful for day-to-day farming choices which might require a farmer to make immediate decisions (FAO, 2019). Meanwhile, in rural areas, farmers with big lands are not always present on their farms because of the distance that separates them from their homes. Thus, weather forecasts might be less valuable in larger farms. Furthermore, this can be associated with the fact that in most cases bigger farms in rural areas are in areas where there is poor or no signal/ internet connection for farmers to access regular weather updates. On the other hand, the positive association between land size and access to seasonal forecasts could be explained by the farmers' need to improve productivity and avoid large crop failure and losses, through the access, and eventually use of seasonal forecasts. Muema et al. (2018) suggest that families farming on bigger farms can diversify crop possibilities, resulting in a strong demand for climate services as these farmers would be interested in knowing which crops to grow in the upcoming season. Similarly, Losloso et al. (2020) argued that increased farm size increases risk and susceptibility to adverse weather and climatic occurrences, which means better climate information is needed to deal with it. Additionally, Bessah et al. (2021) argue that the main goal of farmers who are increasing their fields is to become more commercial. Hence, they are anticipated to access seasonal climate information better. Muema et al. (2018) found comparable results in Kenya that an increase in land area is associated with improved access to seasonal forecasts.

The results indicate that ownership of radio was positive and significantly associated with access to weather forecasts at 1% significance levels. The findings suggest that owning a radio improves farmers' ability to access weather forecasts by a magnitude of 32.8%. This was expected because radio is the main channel used by smallholder crop farmers to access weather forecasts in the study area. Also, this can be associated with the ability of radio to communicate climate information using farmers' local language (Radeny et al., 2019). Several scholars from Africa reported comparable results that farmers who own radios are more able to access climate services than non-owners (Ouedraogo et al., 2021; Bond et al., 2021; Gitonga et al., 2020; Oyekale, 2015). Ownership of mobile phones had a positive association with access to both weather and seasonal forecasts at 1 and 5% significance levels, respectively. The findings imply that owning a mobile phone raises farmers' probability of receiving weather forecasts by a magnitude of 29.7%.

Similarly, smallholder farmers who are owning mobile phones are more likely to access seasonal forecasts by a magnitude of 12.3%. This was expected because in the study area, mobile phones are among the channels used to obtain climate services by smallholder crop farmers. Ouedraogo et al. (2021) argue that with mobile phones, farmers may get climate information anytime from any location without having to travel long distances to access the information they need. Furthermore, just like other ICT devices like radio, mobile phone is also becoming increasingly affordable which makes it possible for farmers to access climate services without having to spend a lot of money on expensive equipment (Wyche and Olson, 2018).

Yegbemey and Egah (2021) add that mobile phones have been identified as crucial in the spread of climate services in rural communities. Hence, farmers who own mobile phones have better access to climate services than non-owners. The results further revealed that access of a farmer to government extension services had a positive and significant association with access to both weather and seasonal forecasts at a 10 and 1% significance level, respectively. The findings imply that farmers' ability to access extension services the better the chances of accessing both short-term weather and seasonal forecasts by a magnitude of 9.6 and 21.5%, respectively. The current results can be associated with the ability of extension agents to be among the channels used to access climate information in the study area, KwaZulu-Natal province of South Africa, and Nigeria (Ncoyini et al., 2022; Ofuoku and Obiazi, 2021). In addition, this was anticipated because the extension staff's role is to educate farmers regarding climatic conditions and various adaptation measures such as certain types of climate services during agricultural meetings and workshops (Nhundu, 2010). That explains why farmers who are accessing extension services are more able to access climate services as opposed to those with no access. Comparable findings were reported in Nigeria that improved smallholder farmers' access to seasonal rainfall (Ofuoku and Obiazi, 2021) and weather forecasts (Alliagbor et al., 2021) are associated with better access to extension services.

The results indicated that knowing that the climate has been changing was positively associated with access to seasonal forecasts at a 10% significance level. The findings suggest that knowing about changes in climatic conditions or being exposed to climate events increases farmers' probability of receiving seasonal forecasts by a magnitude of 10.8%. This is not surprising because if farmers are susceptible to climate change events, they would be forced to search for the latest information such as seasonal forecasts that will assist them in surviving under such conditions (Ogara, 2016 cited in Muema et al., 2018). Furthermore, Masesi (2019) argues that as farmers continue to view climate change as a threat to their production and livelihoods, more seasonal climate information is considered as a means of warning them about extreme events. Thus, there is better access to seasonal forecasts among smallholder crop farmers who knew about changes in climate as opposed to those who did not. Bessah et al. (2021), Bond et al. (2021), and Oyekale (2015) discovered comparable results that the ability of farmers to access climate services rises with an increase in the farmers' knowledge of climate change. Perceiving that extreme climate change events have negatively affected farmers' crop production in the past ten years has a positive and significant relationship with access to weather forecasts at a 10% significance level. The results imply that perceiving that climate change events harm farmers' crop production raises their chances of accessing weather forecasts by 27.6%. This may be because farmers who have seen how climate change has negatively impacted their crop productivity may see the importance of accessing weather forecasts. Accessing weather forecasts will assist them in putting effective measures that will ensure that the crops grown survive until harvesting time. Bessah et al. (2021) agree that farmers exposed to climatic shocks would also be interested in receiving information that will serve as an early warning about climate-related events or risk management tools. Hence, farmers who notice that changes in climate have negative effects on crop production are likely to access weather forecasts compared to those who perceive otherwise.

The results show that climate services accuracy was found to positively influence smallholder crop farmers' access to seasonal forecasts at a 5% significance level. The positive influence indicates that smallholder farmers who perceive seasonal forecasts to be accurate are 12.2% more likely to access them compared to those who perceive them as inaccurate. The positive influence was expected because Josephert et al. (2019) argue that it is vital for seasonal forecast producers to disseminate seasonal information that is correct since inaccurate information might mislead farmers and harm crop output. Furthermore, numerous authors suggest that there are higher chances of accessing and making informed farming choices when farmers see climate information as accurate, timely, and readily comprehensible (Mpandeli and Maponya, 2013; Lemos et al., 2014; Nkiaka et al., 2019; Roudier et al., 2014). Hence, farmers who perceive seasonal forecasts as accurate are more likely to access them compared to farmers who do not. The results further indicated a positive relationship between perceiving climate information as timely and access to weather forecasts at a 5% significance level. The result suggests that farmers who perceive weather forecasts as timely are 15.2% more likely to access them than those who perceive them as untimely. This was expected because timely climate information will allow farmers to have enough time to investigate how to get such information and from which source, unlike when the information is accessible when they no longer need it. Furthermore, this might be because one of the most important attributes that help farmers decide whether a climate information service can be implemented successfully is the time it is made available to farmers (Mubangizi et al., 2018). Additionally, according to Nantongo et al. (2021), climate information is only useful to farmers when it is accessed on time. Hence, those who perceive the climate services as timely are in a better position to access them compared to farmers who perceive the information as untimely.

4 Conclusion and recommendations

The objective of the study was to examine the factors that influence smallholder crop farmers' access to specific climate services in Elundini local municipality. The study concluded that smallholder crop farmers' access to short-term weather forecasts is positively influenced by age, monthly income, ownership of radio, timely climate information, and perceiving that climate change has negative effects on crop production and is negatively influenced by land size. On the other hand, better access to seasonal forecasts is associated with land size, knowledge of climate change, and climate services accuracy. Smallholder crop farmers' age and education are negative and significant factors in seasonal climate forecast accessibility. Furthermore, the study concludes that ownership of mobile phones and accessing extension services are the driving factors in the accessibility of both short-term weather and seasonal forecasts. The study recommends that the various factors including socio-economic, farm characteristics, institutional, enabling factors, climate risk factors, information availability, or climate services attributes should be considered in the process of improving climate services access, and uptake, and ensuring that farmers benefit from the forecasts. For instance, young farmers have better access to seasonal forecasts compared to older farmers. Therefore, it is recommended that government stakeholders, researchers, and forecast producers should collaborate and offer training sessions and workshops on seasonal climate forecasts' relevance and how to acquire and interpret them too particularly for elderly farmers. These workshops may consist of practical demonstrations and hands-on activities to enhance their understanding and confidence in accessing and utilizing seasonal climate information effectively. Also, encourage the sharing of climate information among farmers by creating mentorship programs where younger farmers may share their experiences and skills in obtaining and the application of seasonal forecasts. Moreover, given that mobile phone ownership is associated with better access to both weather and seasonal forecasts and ownership of radio only influences access to weather forecasts. Therefore, there is a need to ensure that mobile phones and radio are accessible and affordable to farmers to allow more farmers to access climate services. This can be done by the implementation of programs that will provide affordable and user-friendly mobile phones and radios to farmers especially those with lower incomes. Such programs may involve a collaboration of local radio stations, telecommunication companies, non-government organizations, and government initiatives. For future research purposes, similar studies may be conducted in other South African provinces and municipalities. Also, the primary focus of this study was smallholder crop farmers. This means the findings might not be applicable to other agricultural systems, such as livestock farming, because they are only limited to smallholder crop farmers. Despite that, a similar study with a focus on livestock farming can be done. Furthermore, Given the relatively high agricultural potential of Elundini Local Municipality and its exposure to significant climate variability, there may be an upward bias in the results. Farmers in this area could exhibit a stronger interest in accessing climate services than those in municipalities with less agricultural potential. Therefore, the findings may not fully reflect the situation in other areas where agriculture plays a lesser role or climate variability is less pronounced. In addition, since wards were selected intentionally, the results could not be generalized to other wards within the municipality, as the non-random selection favored those with greater access to climate services.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Fort Hare's Research Ethics Committee (UREC) with an ethical reference number MAN011SNOC01. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because the study also involved elderly individuals who were not able to read or write or stay alone so instead of written informed consent. However, we got verbal consent from farmers before we started with the interviews.

Author contributions

Y-IN: Investigation, Methodology, Writing – original draft, Data curation. JM: Supervision, Writing – review & editing, Data curation. LZ: Supervision, Writing – review & editing, Funding acquisition. SN: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted without any commercial or financial relationships that could potentially create a conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2024.1447510/full#supplementary-material

APPENDIX A
Bivariate Probit regression results.

APPENDIX B
Multicollinearity test for the independent variables.

References

Alidu, A. F., Man, N., Ramli, N. N., Haris, N. B. M., and Alhassan, A. (2022). Smallholder farmers access to climate information and climate-smart adaptation practices in the northern region of Ghana. *Heliyon* 8:e09513. doi: 10.1016/j.heliyon.2022.e09513

Alliagbor, R., Awolala, D. O., and Ajibefun, I. A. (2021). "Smallholders' use of weather information as a smart adaptation strategy in the savannah area of Ondo state, Nigeria" in African handbook of climate change adaptation. eds. W. Leal Filho, L. Oguge, D. Ayal, H. Adeleke and I. da Silva (Cham, Switzerland: Springer Nature), 1601–1611.

Anang, B. T., Amesimeku, J., and Fearon, J. (2021). Drivers of adoption of crop protection and soil fertility management practices among smallholder soybean farmers in Tolon district of Ghana. *Heliyon* 7:e06900. doi: 10.1016/j.heliyon.2021.e06900

Antwi-Agyei, P., Amanor, K., Hogarh, J. N., and Dougill, A. J. (2020). Predictors of access to and willingness to pay for climate information services in North-Eastern Ghana: a gendered perspective. *Environ. Dev.* 37:100580. doi: 10.1016/j.envdev.2020.100580

Antwi-Agyei, P., Dougill, A. J., and Abaidoo, R. C. (2021). Opportunities and barriers for using climate information for building resilient agricultural systems in Sudan savannah agro-ecological zone of North-Eastern Ghana. *Clim. Serv.* 22:100226. doi: 10.1016/j.cliser.2021.100226

Baffour-Ata, F., Antwi-Agyei, P., Nkiaka, E., Dougill, A. J., Anning, A. K., and Kwakye, S. O. (2022). Climate information services available to farming households in northern region, Ghana. *Weather Clim. Soc.* 14, 467–480. doi: 10.1175/WCAS-D-21-0075.1

Barasa, C. A., Shisanya, C., and Makokha, G. L. (2017). Constraints to forecast application for agricultural production in Bungoma Central Sub-County, Bungoma County Kenya. *Int. J. Innovat. Res. Adv. Stud* 4, 243–252.

Bessah, E., Donkor, E., Raji, A. O., Taiwo, O. J., Agodzo, S. K., Ololade, O. O., et al. (2021). "Determinants of maize farmers' access to climate information services in Ghana" in Handbook of climate change management: research, leadership, transformation and action. eds. W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar and T. Wall. (Cham, Switzerland: Springer Nature).1–20.

Bond, J., Dung, N. T., Hung, H. G., Mai, N. T. H., and Phuong, H. T. A. (2021). Farmers' barriers to the access and use of climate information in the mountainous regions of Thua Thien hue province, Vietnam. *Clim. Serv.* 24:100267. doi: 10.1016/j.cliser.2021.100267

Buckland, S. F., and Campbell, D. (2021). An assessment of factors influencing awareness, access, and use of agro-climate services among farmers in Clarendon, Jamaica. *Geoforum* 126, 171–191. doi: 10.1016/j.geoforum.2021.07.032

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J., and Ringler, C. (2014). Climate change and agriculture: impacts and adaptation options in South Africa. *Water Resour. Econ.* 5, 24–48. doi: 10.1016/j.wre.2014.03.001

Carr, E. R., and Onzere, S. N. (2018). Effective (for 15% of the men): lessons in understanding and addressing user needs in climate services from Mali. *Clim. Risk Manag.* 22, 82–95. doi: 10.1016/j.crm.2017.03.002

Chiputwa, B., Wainaina, P., Makui, P., Nakelse, T., Zougmoré, R., and Ndiaye, O. (2019). Evaluating the impact of the multidisciplinary working group model on farmers' use of climate information Services in Senegal. (may). https://www.climatelinks.org/sites/default/files/asset/document/2019{_}USAID{_}mercycorps{_}evaluatingtheimpactofthemultidisciplinaryworkinggroupmodelonfarmers{\%}27useofcisinsenegal.pdf

Chisadza, B., Mushunje, A., Nhundu, K., and Phiri, E. E. (2020). Opportunities and challenges for seasonal climate forecasts to more effectively assist smallholder farming decisions. *S. Afr. J. Sci.* 116, 1–5. doi: 10.17159/sajs.2020/4649

Coleman, A., (2022). High rainfall causes extensive damage to summer grain crop farmers weekly. Available at: https://www.farmersweekly.co.za/agri-news/south-africa/high-rainfall-causes-extensive-damage-to-summer-grain-crop

Coulibaly, J. Y., Birachi, E. A., Kagabo, D. M., and Mutua, M., (2017). Climate services for agriculture in Rwanda: baseline survey report. CCAFS working paper no. 202. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: http://hdl.handle.net/10568/80820

Dinesh, D., Bett, B., Boone, R., Grace, D., Kinyangi, J., and Lindahl, J. (2015). *Impact of climate change on Africa agriculture: focus on pests and diseases*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available at: www.ccafs.cgiar.org

Diouf, N. S., Ouedraogo, M., Ouedraogo, I., Ablouka, G., and Zougmor'e, R. (2020). Using seasonal forecast as an adaptation strategy: gender differential impact on yield and income in Senegal. *Atmos.* 11:1127. doi: 10.3390/atmos11101127

Diouf, N. S., Ouedraogo, I., Zougmore, R. B., Ouedraogo, M., Partey, S. T., and Gumucio, T. (2019). Factors influencing gendered access to climate information services for farming in Senegal. *Gend. Technol. Dev.* 23, 93–110. doi: 10.1080/09718524.2019.1649790

Eguru, A. (2012). *Water Productivity in Agriculture: Challenges and Opportunities for Smallholder Farmers in the Drylands of Eastern and Southern Africa*. Report,. Kenya: University of Nairobi.

Elundini Local Municipality (2015). Final integrated developmental plan, Maclear. Available at: http://www.elundini.org.za/images/IDP/IDP%202012_13.pdf (Accessed 16/05/2016).

FAO (2016). *Save and grow in practice: maize · rice · wheat. A guide to sustainable cereal production*. Rome, Italy: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/3/a- i5318e.pdf.

FAO, (2019). Handbook on climate information for farming communities – What farmers need and what is available. Rome. 184. Licence: CC BY-NC-SA 3.0 IGO.

Feleke, H. G. (2015). Assessing weather forecasting needs of smallholder farmers for climate change adaptation in the central Rift Valley of Ethiopia. *Earth Sci. Clim. Change* 6. doi: 10.4172/2157-7617.1000312

Fosu-Mensah, B. Y., Manchadi, A., and Vlek, P. G. (2019). Impacts of climate change and climate variability on maize yield under rainfed conditions in the sub-humid zone of Ghana: a scenario analysis using APSIM. *West African J. Appl. Ecol.* 27, 108–126.

Gitonga, Z. M., Visser, M., and Mulwa, C. (2020). Can climate information salvage livelihoods in arid and semiarid lands? An evaluation of access, use, and impact in Namibia. *World Dev. Perspect.* 20:100239. doi: 10.1016/j.wdp.2020.100239

Grey, M. S. (2019). Accessing seasonal weather forecasts and drought prediction information for rural households in Chirumhanzu district Zimbabwe. *Jamba* 11:a777. doi: 10.4102/Jamba.v11i1.777

Hansen, J. W., Furlow, J., Goddard, L., Nissan, H., Vaughan, C., Rose, A., et al. (2019). Scaling climate services to enable effective adaptation action (report). Rotterdam and Washington, DC: Global Commission on Adaptation Available at: https://hdl.handle.net/10568/105763.

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., and Rabarijohn, R. H. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences* 369:20130089.

Harvey, C. A., Saborio-Rodríguez, M., Martinez-Rodríguez, M. R., Viguera, B., ChainGuadarrama, A., Vignola, R., et al. (2018). Climate change impacts and adaptation among smallholder farmers in Central America. *Agric. Food Secur.* 7, 1–20. doi: 10.1186/s40066-018-0209-x

Hlophe-Ginindza, S. N., and Mpandeli, N. S. (2020). *The Role of Small-Scale Farmers in Ensuring Food Security in Africa*. IntechOpen: In Food Security in Africa Available at: https://www.intechopen.com/chapters/72086

International Fund for Agricultural Development (IFAD) (2013). COSOP mid term review http://operations.ifad.org/web/ifad/operations/country/home/tags/nigeria02/02/2015; 5:11.

Jiri, O., Mafongoya, P. L., Mubaya, P. C., and Mafongoya, O. (2016). Seasonal climate prediction and adaptation using indigenous knowledge systems in agricultural systems in southern Africa: a review. *J. Agric. Sci.* 8, 156–172. doi: 10.5539/jas.v8n5p156

Joe Gqabi District Municipality Joe Gqabi District Municipality (2016). Integrated development plan review 2016/2021. South Africa: Alwal North.

Josephert, A. A., Wilberforce, C., Caroline, M., and Ong'anyi, P. O. (2019). Access and use of seasonal climate forecasts information on maize crop production in Vihiga County, Kenya. *Int. J. Res. Innov. Soc. Sci.* 3, 328–338.

Jovancic, N., (2019). Data collection methods for obtaining quantitative and qualitative data. Available at: https://blog.leadquizzes.com/data-collectionmethods/ (Accessed 21 June 2020).

Kadi, M., Njau, L. N., Mwikya, J., and Kamga, A. (2011). The state of climate information Services for Agriculture and Food Security in east African countries CCAFS working paper no. 5. Denmark: Copenhagen. Available at: www.ccafs.cgiar.orgb.

Knox, J., Hess, T., Daccache, A., and Wheeler, T. (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environ. Res. Lett.* 7:034032. doi: 10.1088/1748-9326/7/3/034032

Kogo, B. K., Kumar, L., Koech, R., and Langat, P. (2019). Modelling impacts of climate change on maize (*Zea mays* L.) growth and productivity: a review of models, outputs, and limitations. *J. Geosci. Environ. Prot* 7, 76–95. doi: 10.4236/gep.2019.78006

Kom, Z., Nethengwe, N. S., Mpandeli, N. S., and Chikoore, H. (2022). Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. *GeoJournal* 87, 677–700. doi: 10.1007/s10708-020-10272-7

Krell, N. T., Giroux, S. A., Guido, Z., Hannah, C., Lopus, S. E., Caylor, K. K., et al. (2020). Smallholder farmers' use of mobile phone services in Central Kenya. *Clim. Dev.* 1–13. doi: 10.1080/17565529.2020.1748847

Lemos, M. C., Lo, Y. J., Kirchhoff, C., and Haigh, T. (2014). Crop advisors as climate information brokers: building the capacity of US farmers to adapt to climate change. *Clim. Risk Manag.* 4-5, 32–42. doi: 10.1016/j.crm.2014.08.001

Losloso, J. A. L., Predo, C. D., Sajise, A. J. U., Pulhin, J. M., and Espaldon, M. V. O. (2020). Determinants of the use of weather and seasonal climate information among smallholder maize farmers in Bulalacao, Oriental Mindoro, Philippines. Philippine agricultural. *Scientist* 103, 136–149.

Mandleni, B., and Anim, F. D. K. (2011). Climate change awareness and decision on adaptation measures by livestock farmers (no. 353-2016-18073). African Journal of Agricultural Research, 6, 4076–4081.

Maponya, P., and Mpandeli, S. (2013). The role of extension services in climate change adaptation in Limpopo province, South Africa. *J. Agric. Ext. Rural Dev.* 5, 137–142. doi: 10.5897/JAERD12.117

Maroyi, A. (2017). Assessment of useful plants in the catchment area of the proposed Ntabelanga dam in the eastern Cape Province. *South Africa. Sci World J* 2017:3763607. doi: 10.1155/2017/3763607

Masesi, G.K., Wambugu, S.K., and Recha, C.W. (2018). Socio-economic factors influencing utilization of seasonal climate forecast among smallholder farmers in SemiArid Lower Eastern Kenya: A Case of Masinga Sub-County. *Journal of Environment and Earth Scienc.* 8. Available at: www.iiste.org

Masesi, G. K. (2019). Access and utilization of seasonal climate forecast among smallholder farmers in Masinga Sub-County, Machakos County, Kenya Doctoral dissertation, Chuka University, Tharaka-Nithi County, Kenya).

Mashizha, T. M. (2019). Building adaptive capacity: reducing the climate vulnerability of smallholder farmers in Zimbabwe. *Business Strate. Dev.* 2, 166–172. doi: 10.1002/bsd2.50

McKune, S., Poulsen, L., Russo, S., Devereux, T., Faas, S., McOmber, C., et al. (2018). Reaching the end goal: do interventions to improve climate information services lead to greater food security? *Clim. Risk Manag.* 22, 22–41. doi: 10.1016/j.crm.2018.08.002

McCampbell, M., Adewopo, J., Klerkx, L., and Leeuwis, C. (2023). Are farmers ready to use phone-based digital tools for agronomic advice? Ex-ante user readiness assessment using the case of Rwandan banana farmers. *The Journal of Agricultural Education and Extension* 29, 29–51.

Mdoda, L., Mushunje, A., Olajide, A. K., and Lesala, M. E. (2020). Climate change effects on agricultural productivity in the smallholder farming systems of the Eastern Cape Province, South Africa. *J Hum Ecol* 71, 236–244.

Meinshausen, M., Lewis, J., McGlade, C., Gütschow, J., Nicholls, Z., Burdon, R., et al. (2022). Realization of Paris agreement pledges may limit warming just below 2° C. *Nature* 604, 304–309. doi: 10.1038/s41586-022-04553-z

Mgbenka, R. N., Mbah, E. N., and Ezeano, C. I. (2015). A review of smallholder farming in Nigeria: need for transformation. *Agric. Eng. Res. J.* 5, 19–26.

Moeletsi, M. E., Mellaart, E. A. R., Mpandeli, N. S., and Hamandawana, H. (2013). The use of rainfall forecasts as a decision guide for small-scale farming in Limpopo Province, South Africa. *J. Agric. Educ. Ext.* 19, 133–145. doi: 10.1080/1389224X.2012.734253

Mpandeli, S., and Maponya, P. (2013). The use of climate forecast information by farmers in Limpopo Province, South Africa. *J. Agric. Sci.* 5:47. doi: 10.5539/jas.v5n2p47

Mubangizi, N., Kyazze, F. B., and Mukwaya, P. I. (2018). Smallholder farmers' access and use of scientific climatic forecast information in Mt. Elgon region, eastern Uganda. *Int. J. Agric. Sci. Res. Technol. Extens. Educ. Syst.* 8, 29–42.

Muema, E., Mburu, J., Coulibaly, J., and Mutune, J. (2018). Determinants of access and utilization of seasonal climate information services among smallholder farmers in Makueni County, Kenya. *Heliyon* 4:e00889. doi: 10.1016/j.heliyon.2018.e00889

Muita, R., Dougill, A., Mutemi, J., Aura, S., Graham, R., Awolala, D., et al. (2021). Understanding the role of user needs and perceptions related to sub-seasonal and seasonal forecasts on farmers' decisions in Kenya: a systematic review. *Front. Clim.* 3:580556. doi: 10.3389/fclim.2021.580556

Murgor, D. K. (2015). Farmers access to climate and weather information and its impact on maize and wheat production in Uasin Gishu County, Kenya: University of Eldoret Available at: http://41.89.164.27:8080/xmlui/handle/123456789/927.

Muyiramye, D, (2020). Agricultural vulnerability to changing rainfall patterns: assessing the role of smallholder farmers' perceptions and access to weather forecast information in adaptation-decision making: a case study of the North-Western provinces, Rwanda. Second cycle, A2E. Uppsala: SLU, Dept. of urban and rural development. Available at: http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-s-500079.

Naab, F. Z., Abubakari, Z., and Ahmed, A. (2019). The role of climate services in agricultural productivity in Ghana: the perspectives of farmers and institutions. *Clim. Serv.* 13, 24–32. doi: 10.1016/j.cliser.2019.01.007

Nantongo, B., Ssekandi, J., Ngom, A., Dieng, B., Diouf, N., Diouf, J., et al. (2021). Evaluating the impact of weather and climate information utilization on adoption of climate-smart technologies among smallholder farmers in Tambacounda and Kolda regions, (Senegal). *J. Environ. Earth Sci.* 11, 32–41.

Ncoyini, Z., Savage, M. J., and Strydom, S. (2022). Limited access and use of climate information by small-scale sugarcane farmers in South Africa: a case study. *Clim. Serv.* 26:100285. doi: 10.1016/j.cliser.2022.100285

Ngcaba, P., and Maroyi, A. (2021). Home gardens in the eastern Cape Province, South Africa: a promising approach to enhance household food security and well-being. *Biodiversitas J. Bio. Diversity* 22:953. doi: 10.13057/biodiv/d220953

Nhemachena, C., Mano, R., Mudombi, S., and Muwanigwa, V. (2014). Perceptions on climate change and its impact on livelihoods in Hwange District, Zimbabwe. Jàmbá. *Journal of Disaster Risk Studies*, 6, 1–6. doi: 10.4102/jamba.v6i1.123

Nhundu, K. (2010). Determinants of farmer participation in irrigation development posts fast track land reform: A case of Mashonaland East Province of Zimbabwe: University of Fort Hare. doi: 10.22004/ag.econ.97065

Nkiaka, E., Taylor, A., Dougill, A. J., Antwi-Agyei, P., Fournier, N., Bosire, E. N., et al. (2019). Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa. *Environ. Res. Lett.* 14:123003. doi: 10.1088/1748-9326/ab4dfe

Nkiaka, E., Taylor, A., Dougill, A. J., Antwi-Agyei, P., Adefisan, E. A., Ahiataku, M. A., et al. (2020). Exploring the need for developing impact-based forecasting in West Africa. *Frontiers in Climate.* 2:565500.

Ochieng, R., Recha, C., and Bebe, B. O. (2017). Enabling conditions for improved use of seasonal climate forecast in arid and semi-arid Baringo county, Kenya. *Open Access Libr.* 4:e3826, 1–15. doi: 10.4236/oalib.1103826

Oduniyi, O. O., Antwi, M. A., and Tekana, S. S. (2019). Prioritization on cultivation and climate change adaptation techniques: a potential option in strengthening climate resilience in South Africa. *Agron Colomb* 37, 62–72. doi: 10.15446/agron.colomb.v37n1.76093

Ofuoku, A., and Obiazi, C. (2021). Constraints to access and utilization of meteorological services in Delta state, Nigeria. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi* 31, 150–161. doi: 10.29133/yyutbd.738294

Okello, J. J., Kirui, O. K., Njiraini, G. W., and Gitonga, Z. M. (2012). (2012). Drivers of use of information and communication technologies by farm households: the case of smallholder farmers in Kenya. *J. Agric. Sci.* 4, 111–124. doi: 10.5539/jas.v4n2p111

Oladele, O. I., Gitika, M. P., Ngari, F., Shimeles, A., Mamo, G., Aregawi, F., et al. (2019). Adoption of agro-weather information sources for climate smart agriculture among farmers in Embu and Ada'a districts of Kenya and Ethiopia. *Inf. Dev.* 35, 639–654. doi: 10.1177/0266666918779639

Onwuemele, A. (2018). Determinants of access and utilization of climate services among vulnerable communities: a case study of Isoko communities in Delta state, Nigeria. *Clim. Change* 4, 734–742. doi: 10.4018/978-1-5225-5787-6.ch011

Ouedraogo, I., Diouf, N. S., Ablouka, G., Zougmore, R. B., and Whitbread, A. (2021). Utility and triggers in the uptake of agricultural weather and climate information services in Senegal, West Africa. *Atmosphere* 2021:1515. doi: 10.3390/atmos12111515

Owusu, K., Emmanuel, A. K., Musah-Surugu, I. J., and Yankson, P. W. K. (2019). The effects of 2015 El Nino on smallholder maize production in the transitional ecological zone of Ghana. *Int. J. Clim. Change Strat. Manag.* 11, 609–621. doi: 10.1108/IJCCSM-02-2018-0014

Owusu, V., Ma, W., Renwick, A., and Emuah, D. (2020). Does the use of climate information contribute to climate change adaptation? Evidence from Ghana. *Clim. Dev* 13, 616–629. doi: 10.1080/17565529.2020.1844612

Oyekale, A. S. (2015). Access to risk mitigating weather forecasts and changes in farming operations in east and West Africa: evidence from a baseline survey. *Sustain. For.* 7, 14599–14617. doi: 10.3390/su71114599

Popoola, O. O., Yusuf, S. F. G., and Monde, N. (2020). Information sources and constraints to climate change adaptation amongst smallholder farmers in Amathole district municipality, eastern cape province, South Africa. *Sustain. For.* 12, 5846–5868. doi: 10.3390/su12145846

Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., et al. (2019). Indigenous knowledge for seasonal weather and climate forecasting across East Africa. *Clim. Chang.* 156, 509–526. doi: 10.1007/s10584-019-02476-9

Roudier, P., Muller, B., D'aquino, P., Roncoli, C., Soumare, M. A., Batte, L., et al. (2014). The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal. *Clim. Risk Manag.* 2, 42–55. doi: 10.1016/j.crm.2014.02.001

Rowhani, P., Lo, D. B., Linderman, M., and Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agric. For. Meteorol.* 151, 449–460. doi: 10.1016/j.agrformet.2010.12.002

Sanga, E. E., and Elia, E. F. (2020). Socio-demographic determinants of access to climate change information among tomato growing farmers in Mvomero district, Tanzania. *Univ. Dar es Salaam Library Journal* 15, 121–136. doi: 10.4038/udslj.v15i2.210784

Sarku, R., Van Slobbe, E., Termeer, K., Kranjac-Berisavljevic, G., and Dewulf, A. (2022). Usability of weather information services for decision-making in farming: evidence from the Ada East District, Ghana. *Clim. Serv.* 25:100275. doi: 10.1016/j.cliser.2021.100275

Schlenker, W., and Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environ. Res. Lett.* 5:014010. doi: 10.1088/1748-9326/5/1/014010

Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., et al. (2018). The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. *Clim. Dev.* 10, 389–405. doi: 10.1080/17565529.2017.1318744

Singh, C., Urquhart, P., and Kituyi, E., (2016). From pilots to systems: barriers and enablers to scaling up the use of climate information services in smallholder farming communities. CARIAA working paper no 3. International Development Research Centre/UK Aid, Ottawa/London. Available at: http://www.idrc.ca/cariaa

Statistics South Africa (2016) South African community survey 2016. Indicators derived from the full population Community Survey. Available at: https://wazimap.co.za/profiles/municipality-EC141-elundini/

Sylla, M. B., Pal, J. S., Faye, A., Dimobe, K., and Kunstmann, H. (2018). Climate change to severely impact west African Basin scale irrigation in 2°C and 1.5°C global warming scenarios. *Sci. Rep.* 8:14395. doi: 10.1038/s41598-018-32736-0

Tarchiani, V., Coulibaly, H., Baki, G., Sia, C., Burrone, S., Nikiema, P. M., et al. (2021). Access, uptake, use and impacts of agrometeorological services in Sahelian rural areas: the case of Burkina Faso. *Agronomy* 11:2431. doi: 10.3390/agronomy11122431

Tarhule, A., and Lamb, P. J. (2003). Climate research and seasonal forecasting for west Africans: perceptions, dissemination, and use? Perceptions, dissemination, and use? *Bull. Am. Meteorol. Soc.* 84, 1741–1760. doi: 10.1175/BAMS-84-12-1741

Toreti, A., Deryng, D., Tubiello, F. N., Müller, C., Kimball, B. A., Moser, G., et al. (2020). Narrowing uncertainties in the effects of elevated CO2 on crops. *Nat. Food* 1, 775–782. doi: 10.1038/s43016-020-00195-4

Ubisi, N. R., Mafongoya, P. L., Kolanisi, U., and Jiri, O. (2017). Smallholder farmer's perceived effects of climate change on crop production and household livelihoods in rural Limpopo province, South Africa. *Change Adapt. Soc. Ecol. Syst.* 3, 27–38. doi: 10.1515/cass-2017-0003

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P., and Carr, E. (2019, 2019). Evaluating agricultural weather and climate services in Africa: evidence, methods, and a learning agenda. *WIREsClim Change* 10:e586. doi: 10.1002/wcc.586

Vincent, K., Cull, T., Chanika, D., Hamazakaza, P., Joubert, A., Macome, E., et al. (2013). Farmers' responses to climate variability and change in southern Africa–is it coping or adaptation? *Clim. Dev.* 5, 194–205. doi: 10.1080/17565529.2013.821052

Wilk, J., Andersson, L., Graham, L. P., Wikner, J., Mokwatlo, S., and Petja, B. (2017). From forecasts to action—what is needed to make seasonal forecasts useful for south African smallholder farmers? *Int. J. Disaster Risk Reduct.* 25, 202–211. doi: 10.1016/j.ijdrr.2017.07.002

World Meteorological Organization & African Centre of Meteorological Applications for Development (1990). *Guidelines for the Preparation of National Meteorological and Climatological Services (WMO-No. 684)*. Geneva, Switzerland: World Meteorological Organization.

World Bank., (2016). A year in the lives of smallholder farmers. Available at: https://www.worldbank.org/en/news/feature/2016/02/25/a-year-in-the-lives-of-smallolder-farming-families (Accessed: 09 September 2021).

World Meteorological Organization (WMO) (2016). Climate services for supporting climate change adaptation. Geneva: WMO, WMO-No. 1170.

Wyche, S., and Olson, J. (2018). Gender, Mobile, and Mobile internet| Kenyan Women's rural realities, Mobile internet access, and "Africa rising. *Inform. Technol. Int. Dev.* 14:15. doi: 10.1007/s40701-018-0091-0

Yamane, T. (1967). Statistics, an introductory analysis. *2nd* Edn. New York, NY, USA: Harper and Row.

Yegbemey, R. N., and Egah, J. (2021). Reaching out to smallholder farmers in developing countries with climate services: a literature review of current information delivery channels. *Climate Serv.* 23:100253. doi: 10.1016/j.cliser.2021.100253