frontiers | Frontiers in Climate

TYPE Original Research
PUBLISHED 05 February 2026
DOI 10.3389/fclim.2026.1746574

OPEN ACCESS

EDITED BY
Prince Dacosta Aboagye,
Nagoya University, Japan

REVIEWED BY
Romitha Wickramasinghe,
Nagoya University, Japan
Mussa Deme,
Hiroshima University, Japan

*CORRESPONDENCE
Zoleka Ncoyini-Manciya
✉ ncoyiniz@ukzn.ac.za

RECEIVED 14 November 2025
REVISED 22 January 2026
ACCEPTED 23 January 2026
PUBLISHED 05 February 2026

CITATION
Ncoyini-Manciya Z and Manciya S (2026) Bridging smallholder farmers to climate information: the role of agricultural advisors in KwaZulu-Natal, South Africa.
Front. Clim. 8:1746574.
doi: 10.3389/fclim.2026.1746574

Bridging smallholder farmers to climate information: the role of agricultural advisors in KwaZulu-Natal, South Africa

Zoleka Ncoyini-Manciya[1]* and Sixolise Manciya[2]

[1]Discipline of Agrometeorology, School of Agriculture, Earth and Environmental Sciences, University of Kwa-Zulu-Natal, Scottsville, Pietermaritzburg, South Africa, [2]Department of Agriculture, Faculty of Natural Sciences, Mangosuthu University of Technology, Jacobs, South Africa

Food insecurity remains a persistent challenge in many African countries, where smallholder farmers depend heavily on climate-sensitive agricultural systems. Agricultural Advisors (AAs) are positioned to support farmers' adaptation efforts, yet their capacity to access, interpret, and disseminate climate information remains insufficiently understood. This study examined AAs access to climate information, whether they disseminate it to farmers, and whether the information aligns with farmers' practical decision-making needs. A mixed-methods approach was employed, combining semi-structured questionnaires administered to 77 AAs in the Ugu and Harry Gwala districts of KwaZulu-Natal, South Africa, with six focus group discussions involving smallholder farmers. Quantitative data were analysed using SPSS v28 and Excel, while qualitative data employed thematic analysis through Nvivo14. Results indicate that most of the AAs access seasonal climate forecasts, early warning data, and long-term climate projections. However, only 7.8% received the information from the South African Weather Service (SAWS). While 78.5% reported creating awareness on climate change and 72.5% on adaptation measures, only 32.4% felt confident advising farmers on coping strategies. Only 27.2% reported receiving sufficient information, 40.6% reported limited understanding of available adaptation strategies, and 45.3% had not initiated adaptation measures in their areas. Farmers similarly reported minimal engagement with AAs on climate guidance. These findings reveal a disconnect between climate information access and the delivery of practical, actionable advice. By examining both the AAs and farmers' sides, the study provides locally grounded insights into extension service effectiveness. Targeted capacity-building for AAs and strengthened advisor–farmer interactions are essential to improve confidence, access to reliable, site-specific information, and provision of actionable guidance, supporting practical adaptation, enhancing smallholder resilience, thereby contributing to SDGs 1, 2, and 13.

KEYWORDS

adaptive capacity, agricultural advisors, climate change adaptation, climate information, knowledge transfer, smallholder farmers

1 Introduction

In Sub-Saharan Africa, persistent poverty and food insecurity remain pressing challenges, with over 430 million people living in extreme poverty and more than 570 million experiencing multidimensional deprivation (World Bank, 2019; Mogess et al., 2023). Approximately 21% of the population is affected by chronic hunger, contributing to high rates of morbidity and mortality, particularly among children under five (Owolade et al., 2022; Bahar et al., 2020;

Drammeh et al., 2019). Smallholder and subsistence farmers play a critical role in local food production, yet their productivity is constrained by limited access to resources, knowledge, and support services (Ngumbela et al., 2020; Mbatha, 2024). These constraints are compounded by climate variability and change, which threaten the sustainability of rural livelihoods (Tantoh and Mckay, 2023).

In South Africa, agricultural extension services aim to bridge the gap between research and practice by supporting farmers with knowledge, skills, and advisory services (Kgakatsi and Rautenbach, 2014; Qwabe et al., 2022). Extension officers are expected to promote food security, improve resource management, and enhance rural livelihoods (van Niekerk et al., 2011). However, the increasing frequency and severity of climate-related hazards pose additional challenges. These include the need to access, interpret, and disseminate complex climate information, support farmers in adjusting to unpredictable weather patterns, manage limited resources, and address the vulnerability of smallholder farmers to extreme events such as droughts, floods, and heatwaves. Furthermore, Agricultural Advisors (AAs) often face limited training on climate science, insufficient access to timely and localized climate data, and the challenge of communicating risk in a way that is actionable and contextually relevant for farmers' decision-making (Ncoyini-Manciya and Manciya, 2024). These challenges for AAs have direct implications for smallholder farmers, who may therefore have limited access to relevant climate information. Existing evidence suggests that weather forecasts, seasonal forecasts, and long-term climate projections are often underutilized at the farm level, while agricultural advisors may struggle to interpret and communicate this information effectively (Masere and Worth, 2021; Loki et al., 2020). Addressing these gaps is critical for ensuring that farmers can make informed decisions under increasingly changing and extreme climate conditions.

In the South African context, AAs therefore serve as key intermediaries between climate information providers such as the South African Weather Service (SAWS) and agricultural agencies and rural farmers. Their role is not only to access and disseminate information, but also to contextualize it for practical decision-making at the farm level. Understanding how AAs access climate information, which sources they use, and how farmers perceive the usefulness of this information is essential for improving extension services and supporting adaptive capacity in rural communities.

Despite the understanding and acknowledgment of AAs importance in promoting climate-smart agriculture, empirical research examining the actual flow of climate information between AAs and smallholder farmers remains limited, particularly regarding how different time scales of information (early warning, seasonal outlooks, and long-term climate projections) align with farmers' decision-making needs. For example, Ncoyini-Manciya and Manciya (2025) and Ncoyini-Manciya and Manciya (2024) found in Ugu and uMgungundlovu Districts, KwaZulu-Natal, that although farmers were aware of climate change, most received limited advisory support and had no practical adaptation strategies, highlighting inefficiencies in advisor-mediated information dissemination. At a broader regional scale, Khatibu and Ngowi (2025) reviewed climate information services (CIS) across Sub-Saharan Africa and reported that participatory, context-specific approaches improve adoption of adaptation practices, whereas top-down or generic services often fail due to lack of trust, poor relevance, and weak intermediary support. Previous studies further highlight gaps in South Africa's agricultural extension system. Makamane et al. (2025) found that although 72.6% of farmers perceived practitioners as knowledgeable about climate change, more than two-thirds had not been made aware of adaptation policies or weather and climate services, revealing a disconnect between perceived advisory capacity and effective communication. Similarly, Makamane (2023) reported that over 80% of practitioners lacked formal training in climate change adaptation, while Dinku et al. (2014) observed that many advisors across Sub-Saharan Africa have limited access to reliable climate data and insufficient technical capacity to translate complex forecasts into actionable advice.

Although the importance of AAs in promoting climate-smart agriculture is widely recognised, empirical evidence on their effectiveness as intermediaries of climate information remains limited. Existing studies largely examine either farmers' awareness of climate change or the capacity of extension systems in isolation, without explicitly analysing AAs' intermediary role or assessing whether the information they access and disseminate aligns with farmers' practical decision-making needs. Moreover, few studies simultaneously capture and compare the perceptions of both AAs and farmers, resulting in a limited understanding of possible mismatches, inefficiencies, and communication breakdowns within climate information dissemination pathways at the local level. This lack of integrated, district-level evidence constrains efforts to strengthen extension services as effective intermediaries for climate adaptation in rural South Africa. To address this gap, this study focuses on examining the experiences and perceptions of AAs and their farmer clients in the Ugu and Harry Gwala Districts of KwaZulu-Natal. Specifically, the study aims to:

1 Assess how AAs access climate information and the extent to which they disseminate it to farmers;
2 Examine AAs' perceptions of the usefulness and effectiveness of climate information dissemination;
3 Investigate whether the climate information available to AAs aligns with the practical decision-making needs of smallholder farmers; and
4 Explore farmers' perspectives on the adequacy and accessibility of the climate information they receive.

By focusing on both AAs and farmers, the study provides a nuanced understanding of climate information pathways and reveals practical gaps in the dissemination process. Clarifying these dynamics will help strengthen extension services, ensuring that climate information is not only available but also actionable, thereby enhancing adaptive capacity and resilience in rural South Africa.

This study addresses this gap by simultaneously examining the experiences and perceptions of both agricultural advisors and their farmer clients, providing a dual perspective on climate information pathways that is largely absent in existing research. While previous studies in Sub-Saharan Africa have assessed the effectiveness of climate information services (Khatibu and Ngowi, 2025) or the capacity of extension systems (Ncoyini-Manciya and Manciya, 2025; Makamane, 2023), few have explored how agricultural advisors act as intermediaries between information providers and smallholder farmers, and how the information they access aligns with farmers' practical decision-making needs. By focusing on both the supply (advisors) and demand (farmers) sides of climate information dissemination within the specific context of Ugu and Harry Gwala

Districts, this study provides locally grounded evidence that links advisor capacity, information accessibility, and perceived usefulness to actionable adaptation strategies, offering insights for strengthening extension services and enhancing resilience in rural South Africa.

2 Theoretical framework

This study is guided by three interrelated theoretical perspectives: Knowledge Transfer Theory, Diffusion of Innovation Theory, and the Adaptive Capacity Framework (Figure 1). Together, these theories explain how climate information should be accessed, disseminated, and used by AAs, and how these processes shape smallholder farmers' adoption of adaptation strategies, adaptive capacity, and resilience to climate change.

Knowledge Transfer Theory emphasizes the processes through which knowledge is generated, shared, and applied between a source and a recipient (Nonaka and Takeuchi, 1995). Knowledge transfer can occur through formal codification mechanisms, such as databases or structured documents, or through informal personalization mechanisms, such as face-to-face interactions and experiential learning (Boh, 2007; Hansen et al., 1999). In the context of climate services, AAs act as intermediaries, bridging the gap between climate information providers and farmers. In this study, this theoretical perspective is operationalised through empirical variables capturing AAs' access to climate information, sources of climate information, and their understanding of climate change and extreme weather. Limitations in advisors' knowledge of weak transfer mechanisms manifest empirically as bottlenecks in climate information flow, restricting farmers' ability to adapt (Sudhindra et al., 2017).

Diffusion of Innovation Theory complements knowledge transfer by explaining how new ideas, practices, or technologies spread within social systems (Rogers, 2003). The adoption of climate-smart agricultural practices and information-based innovations depends on their perceived relative advantages, compatibility, complexity, and observability of benefits (Zhang et al., 2015; Ayim et al., 2022). Within the conceptual framework, AAs serve as change agents whose dissemination practices influence farmers' uptake of climate information. Empirically, this theory is reflected in whether AAs disseminate climate information or communicate climate-related issues and the extent to which climate information reaches farmers, thereby shaping farmers' uptake or a lack of uptake of climate information and adoption of adaptation strategies.

The Adaptive Capacity Framework situates knowledge and learning within the broader resilience outcomes, emphasizing that households' ability to anticipate, respond to, and recover from climate risks depends on access to timely, relevant, and actionable information as well as institutional and human capacity (Adger, 2003; Adger, 2010;

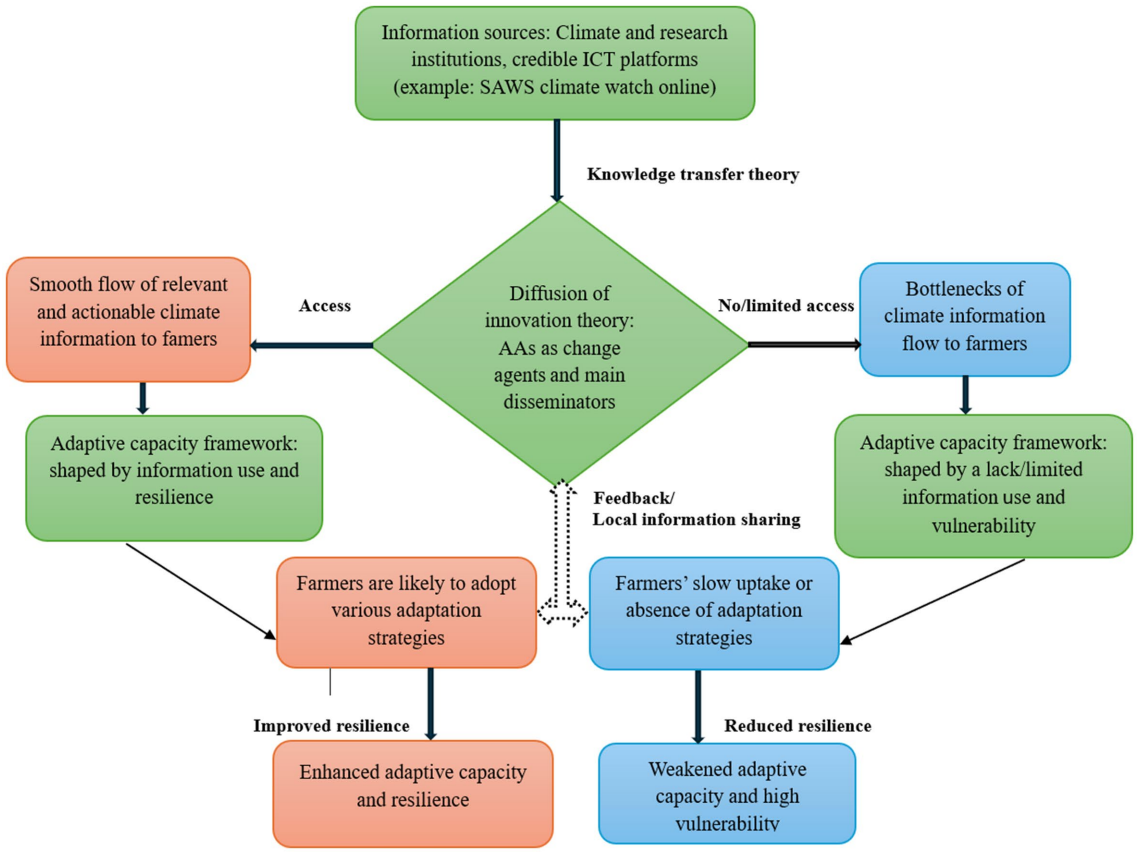

FIGURE 1
Conceptual framework illustrating the link between agricultural advisors' access to climate information sources and smallholder farmers, highlighting the role of *AAs* as change agents in climate adaptation decision-making. The framework is informed by Knowledge Transfer, Diffusion of Innovation, and Adaptive Capacity theories.

Field and Barros, 2014). In this study, adaptive capacity is operationalised through variables capturing capacity development needs, skills and institutional support (Cohen et al., 2016; de Boon et al., 2024). The framework explains how effective information use enhances resilience, whereas limited information access and weak advisory capacity increase vulnerability among smallholder farmers.

Integrating these three perspectives allows the study to explicitly link the theoretical constructs to empirical measurements. Agricultural advisors are positioned as critical mediators in the climate information system, and their access to information, dissemination practices and capacity influence farmers' adoption of adaptation strategies and resilience outcomes. Accordingly, the survey focuses on access to climate information (Section B), dissemination practices (Section C), advisors' knowledge of climate change and extreme weather (Section D), and capacity development needs (Section E). This structured alignment ensures that empirical analysis is firmly grounded in theory and that observed outcomes are interpreted through a coherent theoretical lens.

3 Methodology

3.1 Study site

KwaZulu-Natal, located in eastern South Africa, shares borders with the Eastern Cape, Free State, and Mpumalanga provinces, as well as the kingdoms of Lesotho, Eswatini, and the country of Mozambique. The province has a population of approximately 10.3 million and covers an area of about 93,350 km^2 (Stats SA, 2016; Kwazulu-Natal Provincial Government, 2023). KwaZulu-Natal Province comprises 10 district municipalities, including the Ugu District Municipality on the South Coast. The district forms a border between the KZN province and the Eastern Cape province, covering 5,866 km^2 and featuring a 112 km seashore. The Ugu District includes six local municipalities: Vulamehlo, Umuziwabantu, Umzumbe, Umdoni, Ray Nkonyeni (previously known as Hibiscus Coast), and Ezinqoleni. The district faces significant challenges in improving the quality of life due to high levels of poverty, unemployment, and low economic growth. Its population is predominantly rural, with 86% of residents living in rural areas (Duma, 2015). It has a population of 754,954 people, compared to the total population of approximately 10.3 million in KwaZulu-Natal Province (Stats SA, 2016). Among the local municipalities, Umzumbe has the highest poverty levels, with 19% of its residents living below the poverty line (COGTA, 2020). Figures 2–4 show the maps of the study sites.

The Harry Gwala District Municipality is located in the southern part of KwaZulu-Natal and borders the Eastern Cape and Lesotho, covering an area of approximately 10,618 km^2 and has a population of around 510,864 (Stats SA, 2016). The district comprises four local municipalities, which include Dr. Nkosazana Dlamini-Zuma, Greater Kokstad, Ubuhlebezwe, and uMzimkhulu. Harry Gwala is also predominantly rural and faces socio-economic challenges, including high unemployment rates, widespread poverty, and limited access to basic services. The economy is largely based on subsistence agriculture, and many residents rely on social grants for survival, highlighting the need for targeted development interventions (HGDA, 2024). Educational attainment is generally low, and infrastructure provision is limited, further constraining economic growth and resilience.

These districts were selected as study sites because they are predominantly rural, agriculturally active areas where smallholder farmers rely heavily on extension services for climate-related decision-making. They are in KwaZulu-Natal, a province characterized by significant agricultural participation and pervasive socio-economic challenges. Over 4 million residents rely on social grants (KZN Provincial Government, 2023), and unemployment exceeds 30% among both the general population and youth (Maluleke, 2023).

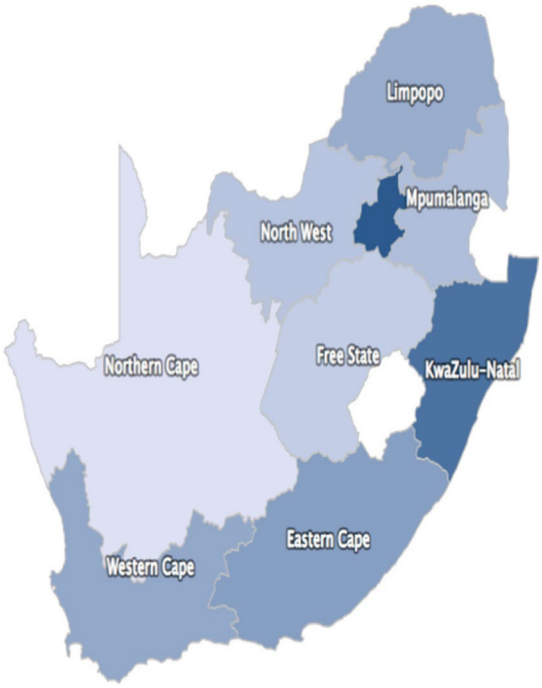

FIGURE 2
Map of South Africa (adapted from Stats SA, 2016).

FIGURE 3
KwaZulu-Natal Province (adapted from: Mnikathi et al., 2025).

3.2 Research design

The study employed a convergent mixed-methods research design, integrating quantitative and qualitative approaches to assess

FIGURE 4
Map of Harry Gwala municipality (adapted from: Municipalities.co.za, 2026).

the role of AAs in accessing, interpreting, and disseminating climate information to smallholder farmers. In this design, quantitative and qualitative data were collected concurrently and analysed separately before being integrated at the interpretation stage using triangulation. Triangulation in this study involved comparing and combining quantitative data on AAs' access to and dissemination of climate information with qualitative insights from farmers regarding the adequacy, accessibility, usefulness, and relevance of that information. This approach enabled a comprehensive understanding of both the structural flow of climate information and its practical application at the user level. This design aligns with the Knowledge Transfer Theory, which emphasizes the movement of information or knowledge from a source to a recipient (Nonaka and Takeuchi, 1995), Diffusion of Innovation Theory, which explains how innovations as informed by the newly received information spread and are adopted (Rogers, 2003), and the Adaptive Capacity Framework, which situates knowledge within resilience-building at the household level (Adger, 2003; Field and Barros, 2014). Quantitative methods captured information on AAs' access to different types of climate information, the sources from which it is obtained, and the extent to which it is disseminated to farmers. Climate information in the study can be broadly categorized into early warning, seasonal forecasts, and long-term climate projections. Early warning involves the timely provision of actionable alerts about impending climate hazards. Such information helps farmers make informed decisions on when and what to plant, how to manage irrigation and water resources, protect crops from extreme weather, and adjust other farming practices to minimise potential losses. By understanding the likely timing, intensity, and nature of climate hazards, farmers can plan activities more effectively, select suitable crop varieties, and implement preventive measures that enhance productivity and resilience. Seasonal forecasts offer predictions of rainfall and temperature patterns over several months, assisting farmers in planning cropping calendars, resource allocation, and input management. Long-term climate projections indicate potential shifts in climate patterns over years or decades, informing strategic decisions such as crop diversification, investment in resilient technologies, and long-term land-use planning. Collecting data on AAs' access to these types of information and the sources from which they obtain them, as well as whether they disseminate this information to farmers, allows for a better understanding of the flow of climate information and identification of gaps in advisory services. In addition, qualitative methods explored farmers' perspectives on the adequacy, accessibility, usefulness, and relevance of the climate information they receive. This provided a complementary, user-level perspective, not only highlighting how information is experienced on the ground and revealing practical challenges in its dissemination, but also understanding its perceived adequacy, usefulness, and relevance for farmers' decision-making.

Integrating these approaches enabled the study to combine the breadth of quantitative data with the contextual depth of qualitative insights, providing a comprehensive understanding of knowledge flows, innovation adoption, and adaptive capacity in practice (Creswell and Creswell, 2017; Bryman, 2016).

3.3 Data collection methods

Data were collected through semi-structured interviews with AAs and focus group discussions (FGDs) with farmers. The interviews captured AAs' perspectives on access to climate information and its dissemination, including climate change trends and adaptation measures. The questionnaire specifically asked participants to identify the sources of climate information they accessed, such as the SAWS or other relevant institutions, rather than the communication channels. SAWS provides extensive climate data, including historical records dating back to 1836, near real-time summaries, and station location files compatible with Google Earth (Hewitson and Crane, 2006). Focus group discussions explored farmers' experiences and perceptions regarding the advisory support they received, including the usefulness, accessibility, and relevance of climate information. This design enabled the study to assess how effectively AAs access and relay climate information and how it aligns with the decision-making needs of smallholder farmers.

A combination of purposive and random sampling was employed to ensure both practical accessibility and representativeness. Purposive sampling identified AAs and farmers directly involved in extension activities, while random sampling within this group provided each eligible participant an equal chance of inclusion. AAs were eligible if actively employed in public extension services with direct engagement with smallholder farmers. Lists of eligible AAs were obtained from district managers, and all were invited to a meeting for data collection. Participants were randomly selected from these small groups within the local municipalities, with numbers determined by the total number of active AAs in each municipality, ensuring that data were collected from at least 50% of the population frame. Specifically, participants were selected from Dr. Nkosazana Dlamini-Zuma (7), uBuhlebezwe (5), Greater Kokstad (13), uMzimkhulu (25), Umziwabantu (11), and Umzumbe (16), resulting in a total of 77 AAs included in the study. To minimize selection and response bias, participants were assured of confidentiality, and the questionnaire was pre-tested with a small group of AAs outside the study area to ensure clarity and relevance.

Data were collected using a structured questionnaire comprising four sections: demographics, access to climate information, dissemination of climate information to farmers, understanding of climate change and extreme weather, and capacity development needs of AAs. Responses on dissemination,

understanding of climate change, and AAs development needs were measured using a Likert scale (1 = strongly disagree to 5 = strongly agree). FGDs were conducted in two local municipalities (Umzumbe and Izingolweni) with six groups of 10–15 farmers each. Discussions were audio-recorded and guided by a semi-structured discussion guide covering observed climate change, climate information provided by AAs, its use and perceived usefulness, accessibility, challenges in applying the information, and AAs' capacitation needs from the farmers' perspective. Farmers were eligible if they were smallholder producers receiving advisory services from AAs within the selected municipalities. Convenient sampling was used, with farmers invited through the relevant AAs and attending based on availability. Although FGDs were relatively large, this was necessary to capture diverse perspectives within resource-constrained communities. Discussions were conducted in the presence of AAs to maintain transparency and capture shared knowledge regarding how AAs disseminate climate-related information, its reception, perceived effectiveness, and potential areas for improvement. Facilitators encouraged farmers to freely express their views despite the presence of AAs.

3.4 Ethical approval statement

The study received ethical approval from the Humanities and Social Sciences Research Ethics Committee (HSSREC, HSSREC/00003836/2022), having met all required standards. In line with HSSREC guidelines, informed consent could be provided orally, verbally, or in writing. Accordingly, participants confirmed their voluntary consent by providing initials or signatures after being informed about the study and their freedom of choice to either participate or not. During the focus group discussions (FGDs), the AA was present; however, the discussions were conducted primarily among the farmers. Participants were informed that the AA's role was solely to clarify technical points and ensure the accuracy of information, and that they were free to discuss any issues, even if it could reflect on the AA's practices. The presence of the AA facilitated clarification where needed, enabling farmers to engage openly, while reinforcing that the discussions were conducted purely for research purposes.

3.5 Data analysis methods

Quantitative data were analysed using descriptive statistics in SPSS version 28 and Microsoft Excel to summarise patterns of information access, dissemination practices, and perceived effectiveness. Frequencies, percentages, means, and standard deviations were calculated. Likert-scale responses (1 = strongly disagree to 5 = strongly agree) were used to measure AAs self-reported climate information access, dissemination practices, and perceived understanding of the climate change concept. Likert scales were chosen because they allow respondents to express degrees of agreement or disagreement, capturing nuances in attitudes, perceptions, and self-reported behaviours that binary or open-ended questions cannot quantify. This format also facilitates quantitative summarisation, comparison across groups, and integration with inferential analyses, while retaining sensitivity to detect differences in experiences and practices across districts.

In addition to descriptive analysis, Welch's two-sample t-tests (assuming unequal variances) were conducted to compare mean responses of AAs across districts (Ugu and Harry Gwala) for selected climate information dissemination indicators. This test was selected due to unequal sample sizes between districts and the likelihood of heterogeneity in variances. The assumptions of independence of observations were met, as responses were obtained from individual AAs, and the moderate sample sizes (Ugu: $n = 30$; Harry Gwala: $n = 47$) support the robustness of the t-test under the Central Limit Theorem (Kwak and Kim, 2017). The analyses were exploratory, aiming to examine how AAs' dissemination practices correspond to farmers' access to climate information across the study districts, without making province-wide generalisations.

Qualitative data from six focus group discussions (FGDs), each comprising 10–15 farmers, were audio-recorded to ensure accurate capture of participants' responses. Transcripts were prepared from the recordings for detailed analysis. An inductive, reflexive thematic analysis was conducted following Braun and Clarke's six-step approach (Braun and Clarke, 2006; Braun and Clarke, 2024), facilitated using Nvivo 14 software. The six steps included: familiarisation with the data, generating initial codes, searching for potential themes, reviewing themes, defining and naming themes, and producing the report. The analysis focused on farmers' experiences with support from AAs on climate change-related issues, particularly the dissemination of climate information. An inductive coding approach allowed themes to emerge directly from participants' responses, rather than imposing preconceived categories. Themes captured accessibility, relevance, and adequacy of climate information, alignment with farmers' practical decision-making needs, and the effectiveness of AAs in facilitating adaptation. Because the analysis was conducted by a single researcher, reflexivity was maintained by continuously reviewing coding decisions and emerging themes against the raw transcripts to ensure consistency and credibility. Reflexive notes were maintained throughout to document reasoning behind code and theme decisions. This thematic analysis provided a rigorous interpretation of farmers' perspectives, complementing quantitative findings. By linking both qualitative and quantitative data to the theoretical framework, the analysis illustrates how knowledge transfer, innovation diffusion, and adaptive capacity operate in practice, tracing the pathway from information access through dissemination to adoption and resilience building. This approach enabled a comprehensive understanding of the study objectives, integrating perspectives of both AAs and farmers while situating findings within a theoretical understanding of knowledge flows and climate adaptation processes.

Quantitative data on AAs' access to and dissemination of climate information were analysed separately from qualitative data collected from farmers and integrated at the interpretation stage through methodological triangulation. This approach involved comparing and synthesizing findings from both datasets to provide a more comprehensive understanding of information flow and farmers' needs. Triangulation ensured that patterns observed in the survey could be interpreted in the context of farmers' experiences and perspectives, enhancing the robustness and validity of the conclusions of this study.

4 Results and discussion

4.1 Demographics

The findings in Table 1 indicate that 61% of participants were from Ugu District, and 39% were from Harry Gwala District. Female participants constituted over 60% of the sample. Regarding age, the largest group of respondents was between 30 and 39 years old, followed by those aged 40–49 years. The 20–29 and 50–59 age groups comprised 20.8 and 19.5%, respectively, while only 3.9% were 60 years and older. Over two-thirds of respondents held a bachelor's degree or higher (Honours, Masters, or PhD), with 90.9% having a Bachelor of Agriculture in Agricultural Extension. The remaining participants were employed as assistant agricultural practitioners. In terms of work experience, 46.8% had more than 10 years of service as AAs, while the rest had less than 10 years.

TABLE 1 Demographic profile of participants (n = 77).

Description	Item	Frequency	Percent
District	Ugu	47	61.0
	Harry Gwala	30	39.0
Gender	Male	29	37.7
	Female	47	61.0
	Prefer not to say	1	1.3
Age (years)	20–29	16	20.8
	30–39	25	32.5
	40–49	18	23.4
	50–59	15	19.5
	≤ 60	3	3.9
Highest qualification obtained	Diploma	17	22.1
	Bachelor Degree (Incl. B Tech)	29	37.7
	Honours degree	17	22.1
	Secondary	4	5.2
	Masters	8	10.4
	Not disclosed	2	2.6
Profession	Crop scientist	2	2.6
	Agric Assistant practitioner	23	29.9
	Agricultural manager	2	2.6
	Agricultural advisors	47	61.0
	Agric-Animal production scientist	1	1.3
	Administrator	1	1.3
Experience (years)	<1	13	16.9
	1–5	18	23.4
	6–10	10	13.0
	11–20	19	24.7
	> 20	17	22.1

4.2 Access to climate information and sources of climate information used

Table 2 presents findings on Agricultural Advisors' access to climate information and its sources. The study focused on seasonal climate information, early warning alerts, and long-term climate projections relevant to agricultural production, which is highly dependent on weather, climate, and water availability. The results show that 66.2% of respondents had access to seasonal climate information and early warning systems, while 50.6% had access to long-term climate projections. Among those with access, 49.4% had been using the information for 10 years or less, indicating increased consideration of climate information since approximately 2014. Only 22.1% reported access for over 10 years, while 28.6% did not specify.

Participants identified television (39%), online platforms (35.1%), radio (19.5%), and phone applications (16.9%) as their main points of access. Given that these are communication channels rather than actual information sources, the responses indicate limited awareness among AAs about the actual sources of the accessed information. Only 7.8% cited the SAWS or the Department of Agriculture and Land Reform (DALR). This pattern suggests uncertainty among participants about distinguishing between the institutional source of climate information and the channels through which it is received.

Among participants, 16.9% of those without access to seasonal climate information, early warning alerts, or long-term projections still reported access to daily weather forecasts, whereas 11.7% lacked access to any form of climate information. In practice, these AAs tend to focus on general agronomic practices rather than climate-specific guidance. They often provide advice based on traditional seasonal calendars and their own experiential knowledge rather than on formal climate information. As a result, farmers often fail to receive actionable climate-related guidance, which highlights a critical gap in the capacity of extension services to support climate adaptation. Respondents who reported limited or no access cited several barriers: lack of information or sources (45.5%), inaccurate or unreliable information (2.6%), and perceiving climate information as unimportant (6.5%).

4.3 Agricultural advisors' views on climate change understanding

Although 6.5% of respondents perceived accessing climate information as unimportant (Table 2), the vast majority (96%; Figures 5, 6) acknowledged the importance of understanding climate change. Over 50% reported agricultural-related decision-making as the primary reason for acquiring climate knowledge, while 40.3% cited advising farmers (Figure 7). Smaller proportions mentioned broader awareness of climate effects on daily life (19.5%), general awareness (18.2%), and understanding the causes and effects of climate change (2.6%).

4.4 Likert scale analysis

The next sections cover the dissemination of climate information and the perceived climate change knowledge by Agricultural Advisors. The study employed Likert scale analysis method from Msosa (2022).

TABLE 2 Access to climate information and sources of information (n = 77).

Description	Item	Frequency	Percent
Access to seasonal climate information	Yes	51	66.2
	No	26	33.8
Access to Early warning information	Yes	51	66.2
	No	26	33.8
Access to long-term climate projection	Yes	39	50.6
	No	38	49.4
Period accessing the information (years)	<1	1	1.3
	1 – five	24	31.1
	6 – ten	13	16.9
	>10	17	22.1
	Did not specify	22	28.6
If No, specify information accessed	Daily weather forecast	13	16.9
	None	9	11.7
Sources of information+	Dept of Agriculture and Land Reform	6	7.8
	Television	30	39.0
	Online sources	27	35.1
	SAWS	6	7.8
	Radio	15	19.5
	Cell phone apps	13	16.9
	Research farm	1	1.3
	Agricultural Research Council	1	1.3
	Social media pages	4	5.2
Reason for not accessing SCI, EW and LT climate projections	Lack of information (sources and existing information)	35	45.5
	Inaccurate and unreliable information	2	2.6
	It is not important to me	5	6.5

+ more than one choice SCI-Seasonal climate information, EW- Early warning, LT- Long Term.

FIGURE 5
Map of Ugu District Municipality (adapted from: Municipalities.co.za, 2026).

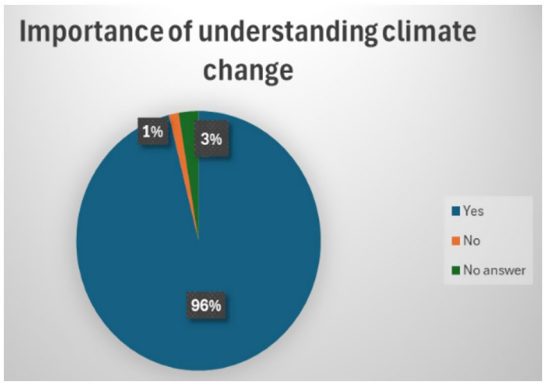

FIGURE 6
AAs view on understanding climate change.

According to this method, positive statements (strongly agree and agree) were considered as agreements, whereas negative statements (strongly disagree and disagree) indicated disagreements. The average value was used to represent the levels of agreement and disagreement. The mean value of the responses is 2.63; thus, a value equal and below 2.6 indicates disagreement, while a value above 2.6 is considered an agreement. Additionally, frequency analysis was used to give a detailed overview of participants' responses (see Appendix 1, 2).

4.4.1 Agricultural advisors' perceptions of the usefulness and effectiveness of climate information dissemination

The study revealed (Table 3) that the majority of AAs recognize their role in climate change adaptation and in communicating climate information to farmers. Specifically Appendix 1 shows that 78.5% of respondents reported creating awareness on climate change, 72.5% on climate change adaptation, and 74.5% on climate change mitigation ($M = 3.04 \pm 0.70$, 2.90 ± 0.89, 2.94 ± 0.77, respectively). Regarding seasonal climate forecasts, 51% of AAs disagreed with the statement, "It is difficult to understand the seasonal climate forecasts, so I do not disseminate the forecasts" ($M = 1.54 \pm 1.01$), while 78.4% confirmed that they ensure farmers incorporate these forecasts into their planning ($M = 3.10 \pm 0.81$). Additionally, 54.9% of AAs disagreed that they refrain from communicating forecasts because farmers rely on indigenous knowledge ($M = 1.51 \pm 1.04$), and 44.1% disagreed that forecasts are too general to correspond with local conditions ($M = 1.91 \pm 1.17$), although 31.4% agreed.

Despite actively disseminating climate information, many AAs rely on communication channels rather than directly accessing from institutional sources such as SAWS. As reported in the earlier section, the majority of AAs reported using mass media or digital platforms, including television (39%), online sources (35.1%), radio (19.5%), cellphone apps (16.9%), and social media pages (5.2%). Reliance on these generalized sources may reduce the accuracy, reliability, and overall usefulness of the information provided. Consequently, AAs may feel hesitant to advise farmers, fearing they could mislead them with information they do not fully trust. On the other hand, if farmers

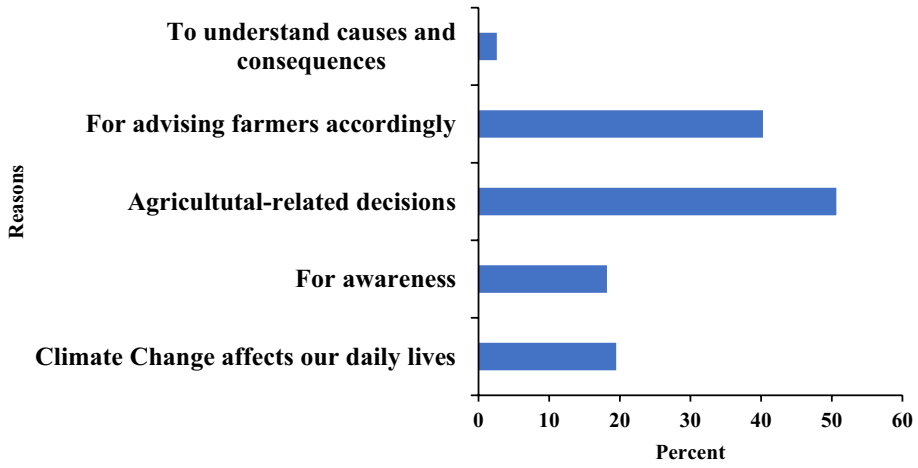

FIGURE 7
Reasons for understanding climate change (participants selected more than one reason).

act on such information and the outcomes are inaccurate, they may question the effectiveness of the guidance and lose confidence in the AAs capacity and capability. This highlights how the source and credibility of climate information can directly affect both the usefulness of dissemination and the trust between AAs and farmers.

4.4.2 Alignment of climate information with farmers' decision-making needs

This section focuses on whether the climate information available to AAs aligns with the practical decision-making needs of smallholder farmers. Although 33% of respondents reported lacking access to climate information, the study assessed AAs knowledge of climate change and potential adaptation measures based on their observations, experiences, and perceptions. Table 4 shows that AAs believe global warming is the same as climate change ($M = 2.93 \pm 0.95$). Most AAs have observed changes in their areas, recognise that these changes are likely to persist for decades, and acknowledge significant agricultural losses due to climate variability (detailed results in Appendix 2).

Despite this awareness, many AAs lack confidence in advising farmers on coping strategies. A total of 36.4% disagreed with the statement, "I have enough information on climate change to advise farmers on coping mechanisms," while 31.2% were neutral, leaving only 32.4% confident in their knowledge. Additionally, 40.3% of respondents disagreed that they receive sufficient climate information for their area, 32.5% were neutral, and only 27.2% agreed. Consequently, 39.3% indicated that no plans exist to mitigate future climate impacts, 40.6% reported insufficient understanding of available adaptation strategies, and 45.3% had not initiated any adaptation measures in their areas. Experience also appeared to influence knowledge levels, as the majority of respondents (54%) had less than 10 years of work experience, suggesting that newer AAs may lack the practical exposure needed to translate climate information into actionable advice for farmers.

These findings indicate a clear misalignment between the climate information accessed by AAs and the practical decision-making needs of smallholder farmers. While AAs may have access to climate data, limited confidence, insufficient understanding of adaptation strategies, and lack of experience restrict their ability to provide effective guidance, planning support, and actionable adaptation measures to farming communities.

4.5 Smallholder farmers' perspectives on adequacy and accessibility of climate information

The study assessed smallholder farmers' perspectives on the adequacy, relevance, and accessibility of climate information they receive. Interviews revealed that farmers generally do not receive any climate-related information from AAs and rely primarily on television, radio, and traditional practices for guidance. Farmers' statements illustrate these gaps:

> "No, I have never received any information related to climate or climate change. I face these challenges by myself without any knowledge on how to cope or deal with climate change." (Farmer from Nyavini)
>
> "We lack any information about climate; all we understand is that it's a natural phenomenon. We would appreciate receiving any information pertaining to the alterations we are witnessing these days." (Farmer from Umzumbe)
>
> "This is the first time we've encountered the term 'climate information.' No one has ever approached us to explain anything related to the changing climate. You are the first person to come and engage in discussions about these matters with us." (Farmer from Umzumbe)
>
> "No, we keep reassuring ourselves that things will improve." (Farmer from Nyuswa)
>
> "We usually hear about climate or climate change through TV and radio. We have never met anyone to inform us about climate change…" (Farmer from Umzumbe- nyavini)

TABLE 3 Agricultural advisors' perceptions of the usefulness and effectiveness of climate information dissemination (n = 77).

Statement	Average	Std. Deviation
I have a very important role to play in climate change adaptation.	3.28	0.70
I ensure that I create awareness on the subject of climate change.	3.04	0.78
I ensure that I create awareness on the subject of climate change adaptation.	2.90	0.89
I ensure that I create awareness on the subject of climate change mitigation.	2.94	0.77
It is important to communicate climate information to farmers	4.08	4.07
I always communicate climate information with farmers	3.14	0.78
I ensure that farmers incorporate seasonal climate forecasts when planning for the planting season.	3.10	0.81
It is difficult to understand the climate seasonal forecasts, so I do not disseminate the forecasts.	1.54	1.01
I only communicate climate information based on my knowledge without considering the seasonal climate forecasts issued.	1.84	1.26
I do not communicate seasonal climate forecasts because farmers still rely on indigenous knowledge	1.51	1.04
I only disseminate rainfall forecasts	1.67	1.20
I communicate early warnings in advance	2.69	1.06
Farmers can access seasonal climate information from TV and Radio.	2.92	1.11
Seasonal climate forecasts are general and normally do not correspond with the real weather and climate for my area.	1.92	1.17

TABLE 4 Alignment of climate information with farmers' decision-making needs (n = 77).

Statement	Mean	Std. Deviation
Climate change is the increase in global air temperature	2.93	0.95
Climate change is already happening and will linger for more decades to come.	3.23	0.71
Extreme weather and climate are likely to increase due to climate change.	3.35	0.73
I have observed some climate change in my area.	3.35	0.65
I have observed extreme weather and climate in my area.	3.32	0.77
I have enough information on climate change to advise farmers on coping mechanisms.	2.01	1.05
I understand the current and future projections of climate change for my area.	1.88	1.08
Climate change and extreme weather have caused tremendous yield losses in the past in my area.	3.32	0.74
I understand the possible impacts of future climate change on agricultural production in my area.	2.87	0.83
I have a plan in place to minimize losses in the future.	1.85	1.06
I receive enough information on climate change for my area	1.88	1.01
I understand the available adaptation strategies.	1.85	1.07
I have initiated some climate change adaptation responses in my area.	1.72	1.15

> "Personally, I perceive them as inexperienced because they have limited information. Whenever I seek assistance, they consistently claim not to know, making me feel like discussing issues with them is a futile effort." (Farmer from Umzumbe)

> "The advisor only inquiries about the aftermath of such events… there is no information provided on how to adapt or cope, except for the introduction of drought-tolerant maize varieties." (Farmer from Umzumbe)

> "We never considered that she might have knowledge about this issue…we never thought there could be a way to address it." (Farmer from -Nyuswa)

Most farmers indicated that they primarily need information on adaptation and coping strategies. This need stems from their clear observation of climate changes and the adverse effects they experience, yet they have no clear understanding of how to respond under these conditions. These findings correspond with the survey results from AAs, which revealed that many advisors lack confidence in providing guidance to farmers. This mismatch highlights a critical gap between farmers' needs and AAs' capacity to support them. Specifically, farmers urgently require practical information to minimize losses, but AAs often feel unprepared to deliver such guidance effectively. Regarding the specific information needed, participants commented:

> "We need access to all the information that can assist us in coping and adapting to climate change, but unfortunately, we are unsure where to find it. However, the information should be presented clearly, outlining practical implementation steps. For instance, some farmers were given rain gauges to manually measure rainfall,

TABLE 5 Comparison of agricultural advisors' responses between Ugu and Harry Gwala districts (*t*-test results).

Statement	Mean (Ugu)	Mean (Harry Gwala)	t-statistic	df	*p*-value (two-tailed)	Significance
I have enough information to advise farmers on climate change.	1.72	2.15	−11.68	54	<0.001	***
I always communicate climate information with farmers	2.55	3.07	−15.27	65	<0.001	***
I ensure that I create awareness on the subject of climate change	2.66	3.04	−13.90	56	<0.001	***

> but they ceased measurements due to uncertainty about the utility of those readings." (farmer from Umzumbe)
>
> "We plant various crops here like maize, potatoes, beans, and madumbe. We need guidance on how to plant them correctly to ensure a good harvest, especially regarding the best planting times since the usual planting times are no longer suitable." (farmer from Nyuswa)
>
> "I think we need climate information accompanied by advice on what to consider for farming under the expected weather conditions. We are farming fields without irrigation systems, so we really need information on what to produce when the climate conditions are not conducive." (Famer from Nyavini)
>
> "We need someone who will teach us about the forecast and how to respond to it because the information from TV is only helpful for planning activities like whether I'll be able to work in the garden the following day." (farmer from Nyavini)
>
> "Seasonal climate information would be very helpful because these days we are just taking chances, as the weather and climate has become so unpredictable." (farmer from Nyavini)
>
> "The timing of the first rains is critical as it dictates when we should plant." (farmer from Nyuswa)

These perspectives clearly highlight the inadequacy, inaccessibility, and misalignment of climate information for farmers. Even when AAs have access to climate data, it is not effectively reaching communities or supporting farmers' practical decision-making and adaptation needs, particularly regarding timely, actionable guidance on coping and adaptation strategies.

4.5.1 Inferential analysis of the contradiction between AAs' findings and farmers' perspectives

To better understand climate information dissemination, quantitative findings from AAs were interpreted in comparison with qualitative insights from smallholder farmers. A series of t-tests was conducted to compare responses from AAs in Ugu and Harry Gwala districts regarding three climate information dissemination practices: having sufficient information to advise farmers, always communicating climate information, and creating awareness on the subject of climate change. Across all three indicators (Table 5), AAs in Ugu reported significantly lower levels of engagement than those in Harry Gwala (Mean differences: 1.72 vs. 2.15; 2.55 vs. 3.07; 2.66 vs. 3.04; t-statistics = −11.68, −15.27, −13.90, respectively; $p < 0.001$ for all), indicating highly statistically significant differences.

Based on these results, the AA findings were interpreted in comparison with farmers' perspectives in order to validate, contextualise, and, where necessary, challenge the quantitative patterns. Regarding having sufficient information to advise farmers, the AA results suggest that although advisors generally report having the capacity to provide guidance, this variable scored notably lower among AAs in Ugu. This indicates that AAs in Ugu perceive themselves as having less adequate information compared to their counterparts in Harry Gwala. Farmers' narratives from Ugu confirm this limitation, emphasising that advisors often lacked actionable knowledge:

> "*Personally, I perceive them as inexperienced because they have limited information. Whenever I seek assistance, they consistently claim not to know, making me feel like discussing issues with them is a futile effort.*" (Farmer from Umzumbe)

This confirms the t-test results, showing that the lower self-reported confidence of Ugu AAs is reflected in farmers' lived experiences. With respect to the communication of climate information, the t-test results demonstrate that AAs in Ugu reported communicating climate information less frequently than those in Harry Gwala. Farmers' accounts further contextualise this pattern, as they indicated that direct dissemination by AAs was minimal, with most climate-related information obtained through mass media such as television and radio or through traditional practices:

> "*We usually hear about climate or climate change through TV and radio. We have never met anyone to inform us about climate change…*" (Farmer from Umzumbe-Nyavini)

This suggests that even where communication is reported by AAs, it does not always translate into effective or visible transmission of climate information at the farm level. Similarly, while several AAs reported that they actively create awareness on climate change, farmers' perspectives strongly challenge this claim. Farmers indicated little to no exposure to such guidance:

> "*No, I have never received any information related to climate or climate change. I face these challenges by myself without any knowledge on how to cope or deal with climate change.*" (Farmer from Nyavini)

This contradiction highlights a misalignment between AAs' perceived efforts and farmers' actual experiences, revealing gaps in both the adequacy and accessibility of climate information services. It is important to note, however, that farmers' perspectives largely align with the responses of AAs from Ugu, as the t-test results consistently showed lower scores for this district. The observed inconsistencies between AAs' self-reported practices and farmers' experiences may therefore be influenced by geographical factors, particularly given that the focus group discussions were conducted primarily in Ugu.

Overall, this integrated approach demonstrates that while AAs may report active engagement in climate information dissemination, the practical application and uptake of this information at the farmer level remain limited. The concentration of FGDs in Ugu helps explain the observed contradictions, as farmers' perspectives directly reflect the lower levels of engagement reported by AAs in the quantitative analysis. This highlights the importance of considering both provider and user perspectives to ensure that climate services are tailored to the actual needs of smallholder farmers. The ongoing FGDs in Harry Gwala and other districts in KwaZulu-Natal are expected to strengthen and refine the interpretation of these findings by assessing whether similar gaps exist in areas where AAs report higher levels of engagement.

5 Discussion

The findings suggest that AAs in KwaZulu-Natal generally possess high literacy levels and formal agricultural education. This contrasts with earlier studies, such as Afful (2016), who reported lower literacy among AAs in Limpopo Province, and Maponya and Mpandeli (2012), who attributed poor extension services to irrelevant qualifications. Advisors with a bachelor's degree are more likely to have received climate education (Zikhali et al., 2020), suggesting that participants in this study are relatively well-equipped with theoretical knowledge of climate change. However, the substantial proportion of respondents with less than 10 years of experience indicates potential limitations in practical, field-based expertise (Olorunfemi et al., 2020). This imbalance between theoretical knowledge and practical experience may hinder AAs ability to provide actionable guidance, leaving farmers less able to implement effective climate adaptation strategies (Masere and Worth, 2021; Makamane et al., 2025). This study acknowledges that the results presented are preliminary, as data collection and analysis are ongoing across additional districts. Consequently, the findings may not fully capture patterns in all areas of KwaZulu-Natal.

While most AAs have access to climate information, reliance on informal or channel-based sources raises concerns about the accuracy and site-specific relevance of the information disseminated to farmers (Ayim et al., 2022; Von Maltitz et al., 2024). This could discourage AAs from advising farmers confidently, as they may not trust the information themselves and fear providing misleading guidance. Consequently, farmers may also perceive AAs advice as less credible, reducing the practical usefulness of the information for local decision-making. From a Knowledge Transfer perspective, access to reliable information underpins effective codification and personalization (Boh, 2007; Sudhindra et al., 2017). Limited clarity about the institutional source weakens the personalization process, potentially reducing farmers potential adaptive capacity (Adger, 2003; Field and Barros, 2014). The relatively recent uptake of climate information among many AAs, combined with the low reference to SAWS as a source, highlights a gap in connecting farmers to authoritative climate data. These findings echo Maponya and Mpandeli (2012) and Makamane et al. (2025), who noted that farmers receiving information from AAs remain more vulnerable than those accessing information elsewhere. The implies that strengthening both access to credible sources and AAs confidence in contextualising this information is crucial to improving farmers adaptive outcomes.

The study also reveals gaps in both the availability of information and ability to translate knowledge into practical guidance. Some AAs receive fragmented or superficial information, limiting their ability to provide comprehensive advisory support. Without addressing these gaps, even when climate information is available, it may fail to enhance resilience or guide effective adaptation on the ground. Improving collaboration between meteorologists, agro-meteorologists, and extension services can enhance both codification and personalization, reinforcing knowledge transfer pathways and supporting the adaptive capacity of rural households (Kgakatsi and Rautenbach, 2014; Adger, 2003). From a Knowledge Transfer perspective, advisors recognize the value of the personalization pathway, acknowledging that their ability to advise farmers depends on solid climate knowledge. Their dual role which entails acquiring knowledge for personal agricultural decision-making and disseminating it to farmers highlights their intermediary function in knowledge flows. In addition, the Adaptive Capacity Framework emphasizes that well-informed advisors are better positioned to guide farmers in adopting effective adaptation strategies, thereby enhancing community resilience to climate risks (Adger, 2003; Field and Barros, 2014). If this intermediary function is weakened by lack of experience, limited practical guidance, or mistrusted information, the transfer of knowledge is ineffective, hindering the potential of enhanced adaptive capacity of smallholder farmers.

Despite high levels of awareness creation and forecast communication, smallholder farmers' adaptation, coping capacity, and overall climate resilience remain low (Ncoyini-Manciya and Manciya, 2025). This is attributed to the ineffectiveness of extension services in assisting farmers to adapt to climate change. Such ineffectiveness may stem from several factors, including a disconnect between the information provided and the information required for decision-making; reliance on unreliable or inaccurate information sources; the use of inappropriate dissemination channels; limited capacity to correctly interpret and apply climate information; and challenges related to the timing of information access and dissemination. This highlights a clear gap between climate information dissemination and practical adaptive outcomes. This means that the AAs limited technical expertise and reliance on secondary information sources limit the ability of farmers to implement climate-smart practices effectively, undermining the utility and impact of disseminated information (Jha and Gupta, 2021). From a Diffusion of Innovations perspective, disagreement among AAs with statements regarding reliance on indigenous knowledge and general forecasts indicates that farmers are receptive to climate information, mitigating barriers such as perceived complexity and low compatibility with existing practices. Yet, without competent advisory support, timely, site-specific forecasts alone are insufficient to drive adoption and enhance resilience.

The observed inconsistencies between AAs' self-reported engagement and farmers' perceptions can be interpreted through the lens of Diffusion of Innovation theory, which underscores the critical role of trusted intermediaries in facilitating the adoption of new practices (Rogers, 2003; Kom et al., 2022). Within this framework, AAs function as key change agents responsible for translating technical climate information into contextually relevant and actionable knowledge for farmers. However, limited interaction with farmers or uneven engagement across districts, as observed in this study, may weaken this intermediary role and hinder the effective diffusion of climate-smart agricultural practices. Even when farmers are open to climate information, inadequate or inconsistent advisory support can constrain adoption processes. This is particularly relevant when innovations are perceived as complex, poorly aligned with existing farming systems, or lacking visible benefits; factors that Diffusion of Innovation theory identifies as major barriers to adoption (Myeni and Moeletsi, 2020). The findings therefore suggest that deficiencies in advisory capacity and communication not only disrupt information flows but also exacerbate farmers' perceptions of climate-smart practices as inaccessible or impractical. Strengthening the consistency, credibility, and contextual relevance of extension support is thus essential to enhance the diffusion and uptake of climate adaptation strategies among smallholder farmers.

From an Adaptive Capacity Framework perspective, access to climate information alone is insufficient to enhance resilience. Adaptive capacity remains constrained when information is inadequately interpreted, poorly contextualised, or not translated into practical guidance that farmers can apply within their specific production contexts (Adger, 2003; Field and Barros, 2014; Khwidzhili and Worth, 2019; Shikwambana et al., 2022). The findings, therefore, underscore an urgent need for targeted capacity-building among AAs, focusing not only on strengthening technical climate knowledge but also on improving advisory, communication, and translation skills. Enhancing these competencies is essential to ensure that climate information supports actionable adaptation strategies, thereby strengthening smallholder farmers' resilience to climate variability and change.

6 Conclusion and recommendations

This study examined how AAs in KwaZulu-Natal access and disseminate climate information, their perceptions of its usefulness, and whether the information aligns with the practical decision-making needs of smallholder farmers. The findings indicate that while most AAs have access to seasonal forecasts, early warnings, and long-term climate projections, many rely on indirect channels such as radio, television, and online platforms rather than authoritative sources like the SAWS. Although AAs recognize the importance of climate knowledge for both their own decision-making and for guiding farmers, farmers reported minimal engagement with advisors on climate issues, often relying on traditional knowledge or mass media.

From a Knowledge Transfer perspective, these results highlight gaps in the personalization pathway, as codified climate knowledge is not consistently translated into actionable guidance for farmers. Diffusion of Innovation Theory further explains that limited facilitation by AAs which is manifested through insufficient guidance, low observability of recommended practices, and minimal opportunities for farmers to trial climate-smart innovations reduces the likelihood that farmers will adopt new adaptation strategies. Even when climate information is available, factors such as perceived complexity, low compatibility with existing farming practices, and a lack of demonstrated benefits hinder its effective diffusion among smallholder farmers. The Adaptive Capacity Framework emphasizes that mere access to climate information does not automatically translate into improved resilience. Farmers require actionable guidance, support in interpreting forecasts, and context-specific advice to transform knowledge into practical adaptation measures. Without these critical interactions and support mechanisms, the potential for climate information to enhance decision-making, adaptive capacity, and resilience remains limited.

To address these gaps, the study recommends the following:

1 Department of Agriculture, Land Reform and Rural Development (DALRR) and provincial extension services should implement targeted capacity-building for AAs to enhance their ability to translate climate knowledge into practical guidance, including strengthening their understanding of climate change concepts, seasonal forecasts, and adaptation strategies. Capacity-building should focus on both technical expertise and advisory skills to improve confidence in guiding farmers.
2 SAWS should collaborate with DALRR should collaborate to ensure AAs receive timely, reliable, and site-specific forecasts. Regular workshops or briefings can support advisors in contextualizing this information for local farming communities.
3 At the extension–farmer interface, strengthening advisory facilitation and farmer engagement is essential to support AAs in becoming proactive change agents. AAs should develop structured outreach strategies including farmer field days (hands-on workshops), peer-learning sessions, community radio programs and mobile-based alerts, to ensure climate information reaches farmers effectively and consistently. Such approaches enhance the observability, trialability, and perceived benefits of climate-smart innovations among farmers, thereby encouraging adoption. In addition, AAs should establish regular mechanisms for farmers to provide feedback on the relevance and clarity of climate information. This will support adaptive refinement of advisory practices and increase farmers' trust and engagement.
4 At the institutional and policy level, the provincial Department of Agriculture, Land Reform and Rural Development (DALRR) should ensure stronger alignment between provincial climate adaptation policies and local extension services is required. DALRR, in collaboration with SAWS and provincial extension offices, should establish robust monitoring and evaluation mechanisms to assess the effectiveness of AAs' climate information dissemination and farmers' adoption of adaptation strategies. This coordinated approach would enable evidence-based adjustments and continuous improvement of climate adaptation programmes.

The study underscores that improving climate resilience among smallholder farmers requires more than access to information; it necessitates competent, trusted advisors who can translate knowledge into actionable, context-specific adaptation strategies. By addressing both technical and relational gaps in advisory services, these recommendations

aim to enhance the effectiveness of climate information dissemination and strengthen the adaptive capacity of smallholder farmers.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of KwaZulu-Natal (UKZN) Humanities and Social Sciences Research Ethics Committee (HSSREC). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ZN-M: Methodology, Investigation, Writing – original draft, Formal analysis, Resources, Funding acquisition, Writing – review & editing. SM: Data curation, Project administration, Writing – review & editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. We acknowledge the funding for the project titled 'Capacitation and Training Needs of Agricultural Advisors (AAs) on the Concept of Climate Change and Extreme Weather' provided by the National Research Foundation under the Thuthuka Grant (TTK2204123222).

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was used in the creation of this manuscript. The authors utilized AI language tool such as ChatGPT solely to assist with grammar and language refinement in the preparation of this manuscript. The research design, data analysis, interpretation, and intellectual content are entirely the author's own work.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2026.1746574/full#supplementary-material

References

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Econ. Geogr.* 79, 387–404.

Adger, W. N. (2010). "Social capital, collective action, and adaptation to climate change" in Der Klimawandel. ed. M. Voss (Wiesbaden: VS Verlag für Sozialwissenschaften). doi: 10.1007/978-3-531-92258-4_19

Afful, D. B. (2016). Public extension agents' need for new competencies: evidence from a climate variability study in Limpopo Province, South Africa. *South African Journal of Agricultural Extension (SAJAE)* 44, 59–70. doi: 10.17159/2413-3221/2016/v44n2a387

Ayim, C., Kassahun, A., Addison, C., and Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agric. Food Secur.* 11:22. doi: 10.1186/s40066-022-00364-7

Bahar, N. H., Lo, M., Sanjaya, M., Van Vianen, J., Alexander, P., Ickowitz, A., et al. (2020). Meeting the food security challenge for nine billion people in 2050: what impact on forests? *Glob. Environ. Change* 62:102056. doi: 10.1016/j.gloenvcha.2020.102056

Boh, W. F. (2007). Mechanisms for sharing knowledge in project-based organizations. *Inf. Organ.* 17, 27–58. doi: 10.1016/j.infoandorg.2006.10.001

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Braun, V., and Clarke, V. (2024). Supporting best practice in reflexive thematic analysis reporting in palliative medicine: a review of published research and introduction to the reflexive thematic analysis reporting guidelines (RTARG). *Palliat. Med.* 38, 608–616. doi: 10.1177/02692163241234800

Bryman, A. (2016). Social research methods. 5th Edn. New York, USA: Oxford University Press.

COGTA, 2020. Ugu district municipality: profile and analysis district development model. Available online at: https://www.cogta.gov.za/ddm/wp-content/uploads/2020/07/Ugu-District-Municipality.pdf. (Accessed 2 September 2024).

Cohen, P. J., Lawless, S., Dyer, M., Morgan, M., Saeni, E., Teioli, H., et al. (2016). Understanding adaptive capacity and capacity to innovate in social–ecological systems: applying a gender lens. *Ambio* 45, 309–321. doi: 10.1007/s13280-016-0831-4

Creswell, J. W., and Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approach. Thousand Oaks, CA, USA: Sage publications.

De Boon, A., Sandström, C., and Rose, D. C. (2024). To adapt or not to adapt, that is the question. Examining farmers' perceived adaptive capacity and willingness to adapt to sustainability transitions. *J. Rural. Stud.* 105:103171. doi: 10.1016/j.jrurstud.2023.103171

Dinku, T., Block, P., Sharoff, J., Hailemariam, K., Osgood, D., del Corral, J., et al. (2014). Bridging critical gaps in climate services and applications in Africa. *Earth Perspect.* 1:15. doi: 10.1186/2194-6434-1-15

Drammeh, W., Hamid, N. A., and Rohana, A. J. (2019). Determinants of household food insecurity and its association with child malnutrition in sub-Saharan Africa: a review of the literature. *Curr. Res. Nutr. Food Sci. J.* 7, 610–623. doi: 10.12944/CRNFSJ.7.3.02

Duma, C. M. (2015). Water access and provisioning in UMzumbe local municipality under the Ugu District municipality, KwaZulu-Natal. Doctoral dissertation. Zululand: University of Zululand.

Field, C. B., and Barros, V. R. (2014). Climate change 2014. Impacts, adaptation and vulnerability: Global and sectoral aspects. IPCC Working Group II report. Cambridge: Cambridge University Press.

Hansen, M. T., Nohria, N., and Tierney, T. (1999). What's your strategy for managing knowledge? *Harv. Bus. Rev.* 77, 106–116.

HGDA. (2024). Growth and development strategy of the Harry Gwala District. Harry Ixopo, South Africa: Gwala district Municipality. Available online at: https://www.hgda.co.za/images/downloads/2024/08/07/515/Growth_and_Development_Strategy_of_the_Harry_Gwala_District__May2024.pdf (accessed August 19, 2025).

Hewitson, B., and Crane, R. (2006). Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. *Int. J. Climatol.* 26, 1315–1337. doi: 10.1002/joc.1314

Jha, C. K., and Gupta, V. (2021). Do better agricultural extension and climate information sources enhance adaptive capacity? A micro-level assessment of farm households in rural India. *Ecofeminism and Climate Change* 2, 83–102. doi: 10.1108/EFCC-10-2020-0032

Kgakatsi, I. B., and Rautenbach, C. D. (2014). The contribution of seasonal climate forecasts to the management of agricultural disaster-risk in South Africa. *Int. J. Disaster Risk Reduct.* 8, 100–113. doi: 10.1016/j.ijdrr.2014.01.002

Khatibu, S., and Ngowi, D. E. E. (2025). Effectiveness of climate information services in sub-Saharan Africa's agricultural sector: a systematic review of what works, what doesn't work, and why. *Front. Clim.* 7:1616691. doi: 10.3389/fclim.2025.1616691

Khwidzhili, R. H., and Worth, S. (2019). Evaluation of South Africa's public agricultural extension in the context of sustainable agriculture. *SAJAE* 47, 20–35. doi: 10.17159/2413-3221/2019/v47n1a486

Kom, Z., Nethengwe, N. S., Mpandeli, S., and Chikoore, H. (2022). Indigenous knowledge indicators employed by farmers for adaptation to climate change in rural South Africa. *J. Environ. Plan. Manag.* 66, 2778–2793. doi: 10.1080/09640568.2022.2086854

Kwak, S. G., and Kim, J. H. (2017). Central limit theorem: the cornerstone of modern statistics. *Korean J. Anesthesiol.* 70, 144–156. doi: 10.4097/kjae.2017.70.2.144

Kwazulu-Natal Provincial Government. (2023). Annual Report 2023. Available online at: https://www.kznonline.gov.za/index.php?Itemid=582&id=219&option=com_content&view=article (accessed August 7, 2024).

Loki, O., Mudhara, M., and Pakela-Jezile, Y. (2020). Factors influencing farmers' use of different extension services in the eastern cape and KwaZulu-Natal provinces of South Africa. *SAJAE* 48, 84–98. doi: 10.17159/2413-3221/2020/v48n1a528

Makamane, A. S. (2023). Capacity of extension and advisory services in supporting farmers to adapt to climate change in the eastern cape. Bloemfontein, South Africa: Doctoral dissertation, University of the Free State.

Makamane, A., Loki, O., Swanepoel, J., Zenda, M., and Van Niekerk, J. (2025). Farmers' perceptions on the capacity of extension practitioners on climate change in the eastern Cape Province of South Africa. *Front. Clim.* 7:1534254. doi: 10.3389/fclim.2025.1534254

Maluleke, R. (2023). Quarterly labour force survey (QLFS) Q2:2023. Available online at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.statssa.gov.za/publications/P0211/Presentation%20QLFS%20Q2%202023.pdf (accessed June 30, 2024).

Maponya, P., and Mpandeli, S. (2012). Climate change adaptation strategies used by Limpopo Province farmers in South Africa. *J. Agric. Sci.* 4:39. doi: 10.5539/jas.v4n12p39

Masere, T. P., and Worth, S. (2021). Influence of public agricultural extension on technology adoption by small-scale farmers in Zimbabwe. *South Afr. J. Agric. Ext.* 49, 25–42.

Mbatha, M. W. (2024). The provision of agricultural extension services to rural farmers as a strategy to improve agricultural practices in South Africa. *South Afr. J. Agric. Ext.* 52, 1–19. doi: 10.17159/2413-3221/2024/v52n1a12717

Mnikathi, S. J., Hlatshwayo, S. I., Temitope, O., and Ngidi, M. S. C. (2025). Participation of emerging commercial farmers in the strategic private-sector investment interventions. *Agriculture* 15:450. doi: 10.3390/agriculture15050450

Mogess, Y. K., Eshete, Z. S., and Alemaw, A. T. (2023). Economic growth and poverty reduction: evidence from sub-Saharan African (SSA) countries. *Poverty Public Policy* 15, 251–278. doi: 10.1002/pop4.364

Msosa, S. K. (2022). Assessing students' perspectives towards entrepreneurship in South Africa. *Business Ethics Leadership* 6, 12–23. doi: 10.21272/bel.6(2).12-23.2022

Municipalities.co.za (2026.) Map of Ugu District municipality, KwaZulu-Natal. Available at: https://municipalities.co.za (Accessed: 15 January 2026).

Myeni, L., and Moeletsi, M. E. (2020). Factors determining the adoption of strategies used by smallholder farmers to cope with climate variability in the eastern Free State. *South Africa. Agriculture* 10, 410–425. doi: 10.3390/agriculture10090410

Ncoyini-Manciya, Z., and Manciya, S. (2024). Validating small-scale sugarcane farmers' climate perceptions through scientific climate data to enhance awareness of climate change: the case of Swayimana area in KZN midlands, South Africa. *South Afr. J. Agric. Ext.* 52, 36–54. doi: 10.17159/2413-3221/2024/v52n3a15448

Ncoyini-Manciya, Z., and Manciya, S. (2025). Ineffective agricultural advisors (AAs) support on climate information and adaptation strategies dissemination in Ugu District, KwaZulu-Natal. *SAGE Open* 15:21582440251338385. doi: 10.1177/215824402513383

Ngumbela, X. G., Khalema, E. N., and Nzimakwe, T. I. (2020). Local worlds: vulnerability and food insecurity in the eastern cape province of South Africa. *J. Disaster Risk Studies* 12, 1–10. doi: 10.4102/jamba.v12i1.830

Nonaka, I., and Takeuchi, H. (1995). The knowledge-creating company: How Japanese companies create the dynamics of innovation. New York, NY: Oxford University Press.

Olorunfemi, T. O., Olorunfemi, O. D., and Oladele, O. I. (2020). Determinants of the involvement of extension agents in disseminating climate smart agricultural initiatives: implication for scaling up. *J. Saudi Soc. Agric. Sci.* 19, 285–292. doi: 10.1016/j.jssas.2019.03.003

Owolade, A. J. J., Abdullateef, R. O., Adesola, R. O., and Olaloye, E. D. (2022). Malnutrition: an underlying health condition faced in sub Saharan Africa: challenges and recommendations. *Ann. Med. Surg.* 82:104769. doi: 10.1016/j.amsu.2022.104769

Qwabe, Q. N., Swanepoel, J. W., Zwane, E. M., and Van Niekerk, J. A. (2022). Nexus between the invisibility of agricultural extension services and rural livelihoods development: assertions from rural farming communities. *S. Afr. J. Agric. Ext.* 50, 26–41. doi: 10.17159/2413-3221/2022/v50n1a14407

Rogers, E. M. (2003). Diffusion of innovations. (5th ed.) Free Press.

Shikwambana, S., Malaza, N., and Ncube, B. (2022). Enhancing the resilience and adaptive capacity of smallholder farmers to drought in the Limpopo Province, South Africa. *Conservation* 2, 435–449. doi: 10.3390/conservation2030029

Stats SA (2016). Mid-year population estimates: Statistics South Africa. Pretoria: Statistics South Africa.

Sudhindra, S., Ganesh, L. S., and Arshinder, K. (2017). Knowledge transfer: an information theory perspective. *Knowl. Manag. Res. Pract.* 15, 400–412. doi: 10.1057/s41275-017-0060-z

Tantoh, H. B., and Mckay, T. J. (2023). Utilizing the water-land-food security nexus to review the underperformance of smallholder farmers in the eastern cape, South Africa. *Front. Sustain. Food Syst.* 7:1143630. doi: 10.3389/fsufs.2023.1143630

Van Niekerk, J. A., Stroebel, A., Van Rooyen, C. J., Whitfield, K. P., and Swanepoel, F. C. J. (2011). Towards redesigning the agricultural extension service in South Africa: views and proposals of smallholder farmers in the eastern cape. *S. Afr. J. Agric. Ext.* 39:862. Available online at: https://hdl.handle.net/10520/EJC120892

Von Maltitz, L., Van Niekerk, J. A., and Davis, K. (2024). The digital readiness of agricultural advisory professionals: a south African case study. *S. Afr. J. Agric. Ext.* 52, 47–65. doi: 10.17159/2413-3221/2022/v50n1a14407

World Bank. (2019). Poverty overview. Available online at: https://www.worldbank.org/en/topic/poverty/overview (accessed June 16, 2024).

Zhang, X., Yu, P., Yan, J., and Ton Am Spil, I. (2015). Using diffusion of innovation theory to understand the factors impacting patient acceptance and use of consumer e-health innovations: a case study in a primary care clinic. *BMC Health Serv. Res.* 15:71. doi: 10.1186/s12913-015-0726-2

Zikhali, Z. M., Mafongoya, P. L., Mudhara, M., and Jiri, O. (2020). Climate change mainstreaming in extension agents training curricula: a case of Mopani and Vhembe District, Limpopo Province, South Africa. *J. Asian Afr. Stud.* 55, 44–57. doi: 10.1177/0021909619857098