American Journal of Environment and Climate (AJEC)

ISSN: 2832-403X (ONLINE

VOLUME 5 ISSUE 3 (2026)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environment and Climate (AJEC)

Volume 5 Issue 3, Year 2026
ISSN: 2832-403X (Online)
DOI: https://doi.org/10.54536/ajec.v5i3.8586
https://journals.e-palli.com/home/index.php/ajec

Role of Weather and Climate Information Services in Adoption of Climate- Smart Technologies in Africa: A Systematic Review

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Article Information

Received: November 25, 2025

Accepted: September 12, 2026

Published: September 22, 2026

Keywords

Climate-Smart Technologies, Smallholder Farmers, Technology Adoption, Weather Climate Information Services

ABSTRACT

As the threat of climate change to agricultural productivity in Africa remains and exacerbates, the demand for climate-smart technologies (CSTs) to build climate-resilient and sustainable production grows. Weather and Climate Information Services (WCIS) are crucial in supporting farmers' decision-making. However, existing studies have largely examined WCIS access and uptake of CSTs separately, with limited synthesis on how WCIS influences technology adoption pathways. A systematic literature review (SLR) using PRISMA 2020 guidelines synthesized studies from 2019 to 2026 on WCIS utilization patterns and their associated impacts on CST adoption in Africa. Secondary data or literature were sourced from Scopus, Web of Science, ScienceDirect and Google Scholar. Results showed that there has been a significant improvement in access to WCIS, mainly via mobile and radio channels. However, utilization patterns remain uneven, with weather and climate information primarily applied to short-term decision-making such as planting, and less frequently used for long-term farm planning and management. Further, the review indicates that the effects of WCIS on CSTs uptake are moderate and very context-specific. Financial constraints, absence of extension services, institutional capacity weaknesses, and non-incorporation of weather and climate information in decision-making are some of the barriers to CSTs adoption. The study also shows that although WCIS play a pivotal role in the promotion of CSTs, it significantly relies on inclusion of extension services, financial support, and access to inputs. This review highlights critical knowledge gaps and points to the need for user-centered and integrated approaches in understanding mechanisms of climate information and technology uptake.

INTRODUCTION

Climate change remains a major challenge for agricultural systems worldwide and is having a deep impact on food security, rural livelihoods, and sustainable development. Climate Change impacts the productivity of agriculture and increases the uncertainty in farming systems as the frequency and intensity of extreme events in precipitation patterns have increased, along with an increase in temperature (IPCC, 2023; Dasgupta *et al.*, 2021). These changes affect the reliability of traditional farming practices and highlight the need for adaptive information-driven solutions that enhance the resilience of agricultural systems. Sub-Saharan Africa is one of the area's most vulnerable to climate change impacts and least capable of adapting to the effects of climate change, as it relies heavily on rain-fed agriculture and is the poorest and least developed region. Millions of smallholder farmers still rely on agriculture for their livelihood, but the productivity of agriculture remains low and is highly vulnerable to climatic variability (AGRA, 2022; Sultan *et al.*, 2019). Farmers in the region face many constraints, including access to agricultural inputs, extension services, institutional support and reliable weather and climate information, that reduce their ability to respond and adapt appropriately to climate-related risks (Amare *et al.*, 2021; Jayne *et al.*, 2021; Burke *et al.*, 2025). So, improving farmers' adaptive capacity has become a major priority in achieving resilient and sustainable agricultural production. Climate-smart technologies (CSTs) have received a great deal of attention and are considered one of the adaptation tools that can be used to increase agricultural productivity, enhance resilience to climate variability and promote sustainable natural resource management. These CSTs include a wide variety of practices aimed at boosting the efficiency of the use of resources while minimizing exposure to climate-related shocks (Makate, 2026; Dang & Serajuddin, 2025). Evidence collected shows positive effects of the adoption of CSTs on agricultural productivity, resilience and climate adaptation among smallholder farmers (Abegunde *et al.*, 2022; Odoom *et al.*, 2023; Ochieng *et al.*, 2026). However, the adoption of CSTs is still low in African farming systems and is influenced by socio-economic, institutional and behavioral factors that hinder farmers' capacity to adopt these technologies. Weather and climate information services (WCIS) have emerged as an effective tool for climate adaptation by giving farmers knowledge to guide their farming activities in the face of climatic uncertainties. These services offer location-specific, timely, reliable information which aids in making decisions about crop planning, input management, and risk reduction (Carr *et al.*, 2020; Hansen *et al.*, 2019). Access to WCIS has also

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expanded greatly, particularly in the form of radio, mobile phones and digital platforms, providing smallholder farmers with increased access to weather and climate information and opportunities to utilize it for decision-making on farm operations, as mentioned by Mabhaudhi *et al.* (2026) and Tesfaye *et al.* (2022).

Although these advances in access to weather and climate information have been achieved, it does not guarantee that this information is effectively used to harness uptake of climate-smart technologies. The evidence currently available shows that, while weather and climate information is largely used to make short-term operational decisions such as planting time, use for long-term planning such as soil fertility management, input allocation, and adaptation planning is low (Clarkson *et al.*, 2022; Simutowe *et al.*, 2025; Zougmoré *et al.*, 2024). Additionally, a range of socio-economic, institutional and cognitive factors, including farmers' financial capability, access to extension services, institutional support, and the effective interpretation and utilization of climate information, are also likely to impact technology uptake (Amare *et al.*, 2021; Ochieng *et al.*, 2026; Danso-Abbeam *et al.*, 2022). The results show that the relationship between the adoption of WCIS and CSTs is not linear and simple but depends on the farming system and the institutional context. While there is an increasing body of literature on WCIS and the adoption of CSTs, these topics have been studied separately. Hence, there is limited integration of the science of how WCIS influences farmers' decisions about adopting CSTs across different farming types in Africa. Recent studies have called for a more holistic approach to the WCIS supporting climate-smart agriculture (CSA) and improving the outcomes of technology adoption (Mabhaudhi *et al.*, 2026; Gardezi *et al.*, 2025). There is, however, a need to review existing evidence in the African context in order to make informed decisions on research, practice and policy on 'climate-smart' interventions that connect climate information and agricultural innovation sufficiently. This systematic review aimed to fill this knowledge gap by consolidating the existing literature on the role and function of WCIS in the adoption of CSTs in Africa. Specifically, it examined the links between access and utilization of WCIS and their role in the adoption of CSTs, socioeconomic and institutional conditions that affect these links, and knowledge gaps that require research and policy/practice adaptation toward climate-resilient agricultural systems.

MATERIALS AND METHODS

Study Design

The current study used a systematic literature review that synthesizes the evidence on the role of weather and climate information services (WCIS) in the uptake of climate-smart technologies (CSTs) in Africa. A systematic review approach was thought to be suitable because it allows evidence from a variety of studies to be comprehensively identified, critically evaluated and synthesized. It also minimizes selection bias and increases transparency and reproducibility. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework was adopted from Page *et al.* (2021) was followed for the review process, and was developed to include internationally recognized standards to conduct and report systematic reviews.

LITERATURE REVIEW

The four major databases (Scopus, Web of Science, Google Scholar and ScienceDirect) were searched. The selected databases include large amounts of literature in agriculture, climate change, environment and sustainable development and are peer-reviewed. The literature search was constrained to publications from January 2019 to June 2026 to encompass the latest activities in the evolution of weather and climate information services and in climate-smart technologies. This search was conducted during March – July 2026. A structured search strategy was employed to ensure that all relevant studies that fulfilled the selection criteria were retrieved, and a combination of keywords and Boolean operators (AND, OR) was used. The following keywords: Weather and Climate Information Services, Climate information, Climate-smart technologies, Climate-smart agriculture, Technology adoption, Smallholder farmers, Africa or Sub-Saharan Africa, were used. The reference lists of selected studies were also hand-screened to find any other relevant publications for additional comprehensiveness.

Eligibility Criteria

In order to guarantee consistency and methodological rigor, inclusion/exclusion criteria were established prior to the screening process. Studies were considered if published in peer reviewed journals, written in English, in an African country and related to weather/climate information services, climate smart technologies, or

Table 1: Eligibility Criteria for Study Selection

Criterion	Inclusion Criteria	Exclusion Criteria
Publication type	Peer-reviewed journals articles	Books, editorials, theses, conference abstracts
Publication period	2019-2026	Before 2019
Language	English	Not English
Geographic scope	African countries	Outside Africa
Study focus	WCIS, CSTs, or technology adoption	Unrelated topics
Study content	Empirical or conceptual evidence	Insufficient or irrelevant data

climate smart technologies and technology adoption. Only conceptual studies published in the period 2019 - 2026 were considered. The studies that were excluded were duplicate studies, studies that were not peer-reviewed (such as conference abstracts, editorials, books, theses and reports) and studies that were not directly relevant to the aims of the review and those not carried out in Africa. More information about the eligibility criteria applied in this study can be found in Table 1 above.

Study Selection Process

The process of study selection involved four steps: identification, screening, eligibility assessment and inclusion and was conducted in accordance with the PRISMA 2020 flow diagram (Fig. 1). All retrieved records were entered into reference management software and deleted any duplicate records. The other studies were then screened by title and abstract for relevance to the objectives of the review. Then, the full-text articles of potentially eligible studies were evaluated for the predefined inclusion criteria. Studies were only included in the final synthesis if they met all inclusion criteria.

Data Extraction and Synthesis

The data extraction process was standardized to achieve uniformity in extracting relevant data from the included studies. The data collected and extracted were the author(s), year of publication, country of the study, study design, study population, type of weather and climate information service (WCIS), climate-smart technologies analyzed, key determinants of adoption, major findings and policy implications. Through this method, a systematic comparison was made across studies. The extracted evidence was synthesized using a thematic narrative approach. Individual studies were initially reviewed to identify recurring patterns and emerging concepts. Similar findings were subsequently grouped into broader analytical themes aligned with the objectives of the review.

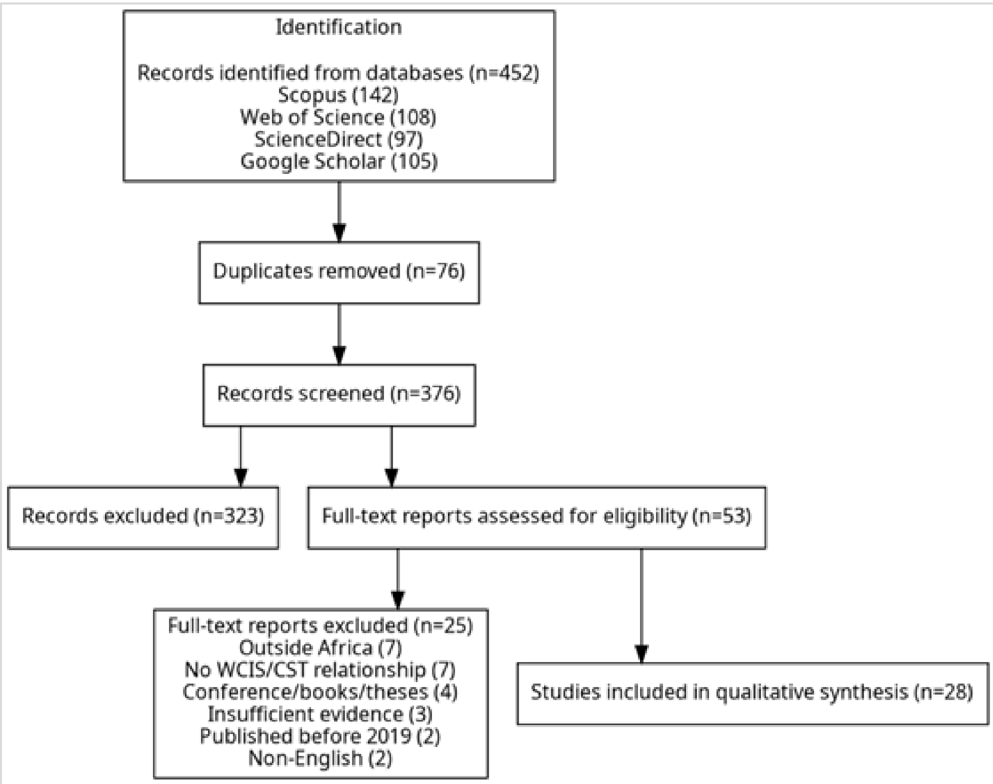

Figure 1: PRISMA 2020 Flow Diagram

The synthesis focused on key themes, including access to weather and climate information services, utilization of climate information in agricultural decision-making, factors influencing the adoption of climate-smart technologies, and the relationship between weather and climate information services and technology adoption. This approach enabled the identification of common trends, inconsistencies, contextual variations, and knowledge gaps across the literature. This study used only secondary data from published literature, and did not engage any human subjects, thus not requiring ethical approval.

RESULT AND DISCUSSION

Access to Weather and Climate Information Services

In the past few years, there has been a lot of progress in the provision of weather and climate information services (WCIS) in Africa. The availability of communication technologies, such as mobile phones, radio and digital platforms, has improved the availability of climate information to smallholder farmers (Mabhaudhi *et al.*, 2026; Tesfaye *et al.*, 2022; Ogutu & Cavane, 2026). The use of radio and mobile-based services is still high because of their coverage and accessibility, and the timeliness and location-specific information they provide to assist farmers in farm decision making, respectively (Gardezi *et al.*, 2025; Ochieng *et al.*, 2020; Fikadu & Radeny, 2024). The improvements show that some of the factors that impede access were mitigated thanks to technological progress and policy measures. Empirical evidence suggests that there are a significant proportion of smallholder farmers in Africa today who are now able to access at least one WCIS. High access to weather forecasts via mobile-based forecasts and radio services has been reported in both East and West Africa (Tesfaye *et al.*, 2022; Ogutu & Cavane, 2026; Fikadu & Radeny, 2024). Similarly, Nhamo *et al.* (2025) highlight the exceptional expansion of digital WCIS in Africa and Gardezi *et al.* (2025) emphasizes the rising importance of digital innovations for delivering services to rural communities. This research suggests that barriers to access have been minimized in some fields as a result of technological innovations and greater investment in climate information systems.

Access is different in different countries and different population groups, however. Some studies reported high level of access to digital services in areas with strong digital infrastructure, which was attributed to good digital network coverage, good infrastructure and institutional support, while others indicated that in remote and marginalized areas access to digital services was low due to poor digital network coverage, poor infrastructure and lack of institutional support (Amare *et al.*, 2021; Burke *et al.*, 2025; Odoom *et al.*, 2023; Tesfaye *et al.*, 2022; Fikadu & Radeny, 2024). This variation shows that access improvements are not uniform in nature and are significantly related to local conditions. Access to WCIS is also influenced by socio-economic issues. Some studies have found that an increase in farmers' education and income is related to increased WCIS use (Tesfaye *et al.*, 2022; Ogutu & Cavane, 2026; Ochieng *et al.*, 2020). It is important to note, however, that other studies have been conducted on the long-standing disparities and challenges, particularly those faced by women and low-income families who may encounter affordability issues, lack digital literacy, or have limited access to communication technologies (Mabhaudhi *et al.*, 2026; Gardezi *et al.*, 2025; Fikadu & Radeny, 2024). The results indicate that access is not only technological, but socio-economic as well.

Besides access disparities, quality, relevance and reliability of the WCIS are also a concern. The improved forecasting systems have resulted in more accurate and timely climate information, thereby enhancing farmers' access to climate information (Tesfaye *et al.*, 2022; Ogutu & Cavane, 2026; Nhamo *et al.*, 2025). Other studies, however, suggest that WCIS is typically too broad and segmented, not specific enough to the local area context, and is not related to farmers' needs, hampering the use of climate information at the farm level (Clarkson *et al.*, 2022; Zougmoré *et al.*, 2024; Mogaka *et al.*, 2026). Sometimes the time taken and the errors in climate forecasts decrease farmers' confidence in climate services. Evidence in the literature suggests that in Africa, while there has been a significant improvement in the supply of WCIS, there are still numerous issues in equity of access, quality of information and user trust in the information. The limitations suggest that it is not enough for the WCIS to be enhanced to make them effective.

Utilization of Weather and Climate Information in Agricultural Decision-Making

Use of weather and climate information services (WCIS) is an important enabler for effectiveness in agriculture. Although access to WCIS has improved, its use in decision-making is not uniform across contexts, with some unevenness (Tesfaye *et al.*, 2022; Gardezi *et al.*, 2025; Nhamo *et al.*, 2025). However, access alone is not enough; farmers must also be able to interpret, trust and apply the information in a meaningful way for effective utilization. Several studies have shown that farmers mainly rely on WCIS for their short-term operational decision-making, such as planting dates, land preparation, and crop management (Clarkson *et al.*, 2022; Simutowe *et al.*, 2025; Zougmoré *et al.*, 2024). This indicates that WCIS is valuable in decreasing uncertainty for the farmers' on-farm activities. Other research, however, shows that farmers are also using WCIS in other decision-making processes, such as crop diversification, risk management and adaptation planning, in certain situations (Tesfaye *et al.*, 2022; Ogutu & Cavane, 2026; Nhamo *et al.*, 2025). This variation suggests that the intensity of the use of the product is determined by local capacity, institutional support, and availability of other resources.

Even with these progressions, WCIS is not used for long-term and strategic decision-making in most instances. There is limited evidence that farmers, in some instances, use WCIS in decision-making processes on input use, irrigation planning, soil management and investment in new technologies (Amare *et al.*, 2021; Odoom *et al.*, 2023; Mogaka *et al.*, 2026). However, other research indicates that in contexts with a high level of extension support, climate information can impact farm management as a whole and promote adaptive strategies (Gardezi *et al.*, 2025; Ochieng *et al.*, 2020; Fikadu & Radeny, 2024). The differences suggest the need for institutional support to improve the use of climate information in practice. The ability of farmers to understand the climate information is also crucial to its use. The use of the information is seen to be constrained by low levels of education and limited technical knowledge, as indicated by several studies (Odoom *et al.*, 2023; Ochieng *et al.*, 2020; Fikadu & Radeny, 2024). There are other studies, however, which indicate that other communication formats such as simplified communication, local languages, and participatory approaches can greatly enhance understanding and uptake (Tesfaye *et al.*, 2022; Gardezi *et al.*, 2025; Nhamo *et al.*, 2025). This indicates that design and delivery of information is a key factor affecting utilization.

Using WCIS is also dependent on trust in its accuracy and reliability. Some studies have found that if the forecast can be trusted and is consistent, utilization will increase

(Clarkson *et al.*, 2022; Ogutu & Cavane, 2026; Nhamo *et al.*, 2025) but when encountering a past forecast that was inaccurate or delayed, trust in the forecast and utilization will decrease (Tesfaye *et al.*, 2022; Zougmoré *et al.*, 2024; Mogaka *et al.*, 2026). The results underscore the need for enhanced quality and credibility of climate information services. Results from the literature indicate that WCIS tools are available across all parts of the world, but their use is uneven and context-specific and has implications on agriculture decision-making.

Factors Influencing Adoption of Climate-Smart Technologies

Different socio-economic, institutional, and environmental conditions are important drivers of the adoption of climate smart technologies by smallholder farmers in Africa. While there is great potential for climate-smart practices to boost productivity and resilience, uptake of these practices is context-dependent (Abegunde *et al.*, 2022; Odoom *et al.*, 2023). This variation also indicates the complexity in the processes of decision-making and the possibility of several constraints that are experienced by farmers. Economic factors play a key role in decision-making on the uptake of climate-smart technologies. The availability of financial resources, such as credit and savings, greatly affects farmers' investments in new technologies (Amare *et al.*, 2021; Ochieng *et al.*, 2026). There is a need to invest capital for many of the climate-smart practices, and smallholder farmers with low income may not have the means for this investment. In addition, the high input costs and the uncertain returns diminish farmers' willingness to promote new technology that is viewed as risky (Odoom *et al.*, 2023; Danso-Abbeam *et al.*, 2022). The financial limitations are still a huge obstacle.

Other socio-demographic traits of farmers are also important in farmers' adoption. Education level, farming experience and access to information affect the opportunities for implementing climate-smart practices (Abegunde *et al.*, 2022; Tesfaye *et al.*, 2022). Generally, farmers who have higher levels of education have the ability to understand and apply new technologies, and farmers with more farming experience are more likely to assess the risks and benefits of new technologies. Gender is also different since women farmers are generally more disadvantaged compared to men in some aspects of inputs and information, including technology adoption (Burke *et al.*, 2025; Fikadu & Radeny, 2024). Institutional determinants also have an impact on adoption outcomes. Extension services have been mentioned as one of the key determinants of adoption of climate-smart technology (Amare *et al.*, 2021; Ochieng *et al.*, 2026). The extension services provide technical support, training and information to the farmers to understand and adopt the new practice. Furthermore, market accessibility has an impact on adoption as it enables upgrading of quality and production levels (Odoom *et al.*, 2023; Ochieng *et al.*, 2026). A lack of access to the market may make farmers less willing to invest in valuable technology that would benefit the farm.

Other factors or conditions, including environment and farm-based factors, also have an effect on adoption decisions. Climate-smart technologies (CST) can only be adopted on a farm if they are suitable and effective based on the agro-ecological farm conditions such as soil properties, rainfall variability and farm size (Abegunde *et al.*, 2022; Nhamo *et al.*, 2025). Farmers are likely to take up technologies that are adaptive to the local environment and practices. Other technologies that will need a great deal of change in traditional practices may be met with resistance, especially when benefits are not clear. Farmers' decisions are also impacted by their perceptions and attitudes towards climate change and technology uptake. The studies revealed that the farmers who do not regard climate change as a great threat are less inclined to adopt the practices (Odoom *et al.*, 2023; Tesfaye *et al.*, 2022). However, risk aversion and lack of confidence in the effectiveness of new technologies can affect the adoption of new technologies, especially in the absence of information and support systems (Amare *et al.*, 2021; Danso-Abbeam *et al.*, 2022). It's a reminder that it is important to build confidence and showcase the benefits of climate-smart technologies. In general, the literature shows that several economic, socio-demographic, institutional and environmental factors influence the adoption of climate-smart technologies. These constraints not only limit uptake, but also limit the extent to which farmers can utilize the climate information. To design interventions that can promote the uptake of climate-smart technologies, it is important to understand these factors.

Relationship Between WCIS and Climate-Smart Technology Adoption

Weather and Climate Information Services and climate-smart technologies are not always linked in a simple and direct manner, but depend on the context. WCIS is expected to help in agricultural decision-making because it is able to remove the uncertainty and disseminate real-time, location-specific information (Tesfaye *et al.*, 2022; Gardezi *et al.*, 2025; Nhamo *et al.*, 2025). A study by Amare *et al.* (2021), Ogutu and Cavane (2026) and Mogaka *et al.* (2026) suggests that the provision of climate information can increase awareness of climate risks among farmers and promote farmer adaptation measures. However, other studies show that it is not always the case that providing climate information translates to adoption of climate-smart technologies. The major use of the climate information is for short-term decisions like planting dates, and not long-term investment decisions (Clarkson *et al.*, 2022; Simutowe *et al.*, 2025; Zougmoré *et al.*, 2024). This indicates that the role of WCIS is a facilitative effect, and not a direct effect.

There have also been empirical studies in recent years that suggest variation in the strength of this relationship. There are positive findings on the link between climate information use and adoption of climate-smart practices in some studies (Tesfaye *et al.*, 2022; Nhamo *et al.*, 2025) and moderate findings in some others, which depend on other factors including access to inputs, institutional support and financial capacity (Odoom *et al.*, 2023; Gardezi *et al.*, 2025; Kalenya *et al.*, 2026; Nyangao *et al.*, 2026). The results from the various findings are in contrast, indicating that WCIS does not have a consistent effect. Farmers' ability to understand and utilize the information also plays a role in the effectiveness of WCIS as a tool for adoption. It has been demonstrated that providing extension services and knowledge about climate information contributes to high uptake rates and the decision-making process (Amare *et al.*, 2021; Burke *et al.*, 2025; Ogutu & Cavane, 2026). However, the effect of the information on promoting adoption is less if it is not trusted, is not available in time or is hard to understand (Zougmoré *et al.*, 2024 Fikadu & Radeny, 2024; Mogaka *et al.*, 2026). Overall, the literature indicates that weather and climate information services have a significant but modest impact on the uptake of climate-smart technologies. They are effective only if combined with other resources such as money, institutions and farmers' decision-making power. This underscores the importance of integrated approaches, including linking WCIS with wider agricultural support systems.

Summary Discussion

Increased access to weather and climate information services (WCIS) does not always translate into use has been one of the key results of the synthesis. Few farmers use WCIS for longer-term planning and decision-making, and the use of the information is still largely focused on short-term decisions, such as those on planting and crop management. This pattern is an indicator that access to WCIS is not sufficient and that farmers' interpretations, trust and use of the information in their context is essential to the effectiveness of such information. These are similar observations that have been published in recent empirical studies (Amare *et al.*, 2021; Odoom *et al.*, 2023). There is also a significant variation in the scope of the use of WCIS in the review. In some circumstances, WCIS is used to inform decision-making and climate adaptation, while in others it is not used because of complexities of information, non-localization of information and low trust. The differences suggest that institutional and communication issues play an important role in determining utilization outcomes. In addition, this study has been found to be congruent with other studies which found that effective extension services are critical in the process of transforming climate information into climate action knowledge (Ogutu & Cavane, 2026; Mogaka *et al.*, 2026).

In terms of the adoption of climate-smart technologies, the results indicate that both economic, institutional and socio-demographic factors influence the decision-making process. Financial constraints, limited inputs and small market linkages constrain the uptake of climate information even in cases where it is available. Yet again, availability of climate information is not enough to ensure uptake of technology. Instead, the outcomes of uptake depend on the enabling environment in which farmers are operating (Ochieng *et al.*, 2026; Gardezi *et al.*, 2025). Of significance, the relationship between WCIS and the adoption of climate-smart technologies is indirect and depends on the context. WCIS can increase awareness of climate risks as well as support progressive changes in farming practices, but it is not enough to drive progress to new technologies. Many times, farmers rely on climate information to respond to the threats they face, but not for investments. This is due to the fact that the effect of WCIS on adoption of CSTs is still moderate and depends on other factors, based on recent studies (Nhamo *et al.*, 2024; Kalenya *et al.*, 2026; Nyangao *et al.*, 2026).

Another challenge emerging from this review was the critical need for trust and information quality for the effective use of climate information services. A higher sense of accuracy, timeliness, and relevance of climate information to the farm increases the likelihood that farmers will use it. However, confidence and use are undermined by inaccuracies in forecasts, delays when getting information and lack of specificity of the information. The results highlight the need for enhanced access to WCIS as well as reliability and contextualization of services. The overall picture suggests that there is a need for a paradigm change from the information delivery mode to integrating and coordinating information. WCIS has progressed with its coverage but cannot be effective if it is used alone. Financial and input access and extension services are essential complements to WCIS. Integrated approaches have a greater likelihood of supporting farmers to make decisions based on information and promoting ongoing adoption of CSTs.

Research Gaps

While there has been a growing body of literature on weather and climate information services (WCIS) and climate-smart technologies (CSTs), there are several gaps that hinder understanding of the relationship and effectiveness of these services in Africa. First, there is a lack of integrated studies that explicitly explore the linkages between WCIS and CSTs adoption. There is a tendency to study access to WCIS and the adoption of CSTs as different fields of study. This disjointed approach does not allow for an understanding of how climate information impacts on behavior and fails to provide a basis for developing coordinated adaptation strategies that integrate the provision of information with the adoption of technology. Secondly, the current literature is more focused on accessibility of climate information than on how it is being effectively used. Although numerous studies document improvements in access to climate information, fewer studies focus on how farmers understand, believe, and use climate information in decision-making. This divide limits the knowledge of the mechanisms that link climate information to decisions and what that means for agriculture.

Thirdly, there is scarce empirical data on the long-term effects of WCIS on agriculture. Most of the studies concentrate on short-term decision-making, especially with respect to seasonal adjustment and planting dates. This means that there is limited understanding of the long-term effects of continued access to climate information and subsequent uptake of climate-smart technologies, productivity improvement and long-term resilience outcomes over time. Fourthly, the contribution of institutional and support systems to strengthen the effectiveness of WCIS is yet to be explored. Limited research examines the interactions among extension services, financial access, market linkages and WCIS, and their impact on CST adoption; some studies do recognize the importance of extending these services. This disconnect hinders the capacity to develop multi-sectoral solutions which can tackle multiple constraints at once and enhance the overall effectiveness of adaptation measures.

Lastly, there is a lack of focus on contextual factors that influence the WCIS and CST uptake. There is little consistency between existing studies and the variations in socio-economic conditions, agro-ecological environments and institutional frameworks across African countries. This reduces the applicability of the results and underscores the importance of context-specific studies that reflect these variations and guide more targeted and effective policy action. Filling these gaps is critical to improve the effectiveness of weather and climate services and their contribution to the uptake of climate smart technologies in Africa.

CONCLUSION

This review aimed to fully understand the role of weather and climate information services (WCIS) in the uptake of climate-smart technologies (CSTs) in Africa. The results indicated that the availability of climate information has greatly improved, but the use and application of this information is not uniform, and the impact of climate information on CST uptake is moderate and context-dependent. Climate information is mostly used by farmers for short-term decisions, and only to some extent for long-term investments in climate-smart practices. The review also shows that complex interactions between economic, institutional and socio-demographic conditions influence the uptake of CSTs. The constraints further constrain how much farmers can do with the available climate information, further solidifying the information space gap and the gap between information and agricultural transformation. The overall picture from the evidence indicates that by itself, weather and climate information services (WCIS) have only a facilitating but not conclusive impact on climate-smart technologies. They are effective if they are integrated into the extension services, adequately funded, and have access to inputs. The gap needs to be addressed through multi-dimensional and coordinated approaches, with a strengthening of the availability and use of climate information. The review adds to the existing body of knowledge by synthesizing the link between WCIS and CST uptake, and pinpoints key gaps that demand research and policy attention. This relationship needs to be strengthened to progress towards climate-resilient agricultural systems in Africa.

Recommendations

Based on the results of this review, there are several recommendations proposed to improve the effectiveness of weather and climate information services (WCIS) to support the uptake of climate-smart technologies (CSTs) in Africa. First, there is a need to go beyond increasing climate information availability to making it more usable and relevant. The climate information should be made local, timely and presented in easily digestible formats for smallholder farmers. This includes communication and user-centered design using local languages, simplified communication and thinking. Forecasts need to be more accurate and reliable to increase trust in the forecasting and develop further usage. Secondly, extension services need to be strengthened as an important instrument to convert climate information into appropriate agricultural advice. Extension is a critical bridge that can assist farmers to better grasp and apply climate information to their decision-making. Capacity building and rollout of integrated advisory services, which integrate climate information with CSTs into services, are thus needed.

Thirdly, enhanced access to financial services and agricultural inputs are important in driving the adoption of CSTs. Policies and programmes should promote access to credit and low-cost climate-smart inputs and put in place risk-sharing mechanisms. These measures can help reduce financial limitations, supporting farmers to make investments that they can in adaptation to climate information. Fourth, there should be a linkage with other agricultural and rural development programmes. Providing only climate information is not enough, and providing it in the context of a comprehensive support system (market access, infrastructure development and institutional support) can make a big difference in terms of impact. Last but not least, there is a need for targeted interventions to tackle inequalities in access and use of WCIS. Consider special focus on women farmers and women in remote areas, they may be further constrained. Information, resources and support services are key to maximizing the potential of climate-smart agriculture strategies, and they can be delivered in an inclusive manner.

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