The sub Saharan Journal of Social Sciences and Humanities
(SJSSH)
ISSN: 2619-8894 (Online), 2619- 8851 (Print)

Farmers' Perceptions of the Effectiveness of Climate Information Services in Predicting Hazard Occurrences in Kondoa and Kiteto Districts, Tanzania

[1]Salma Khatibu, [2]Edwin E. Ngowi and Davis G. Mwamfupe[3]

[1]Institute of Development Studies, University of Dodoma, Dodoma, Tanzania
[2]Department of Development & Strategic Studies, Sokoine University of Agriculture, Morogoro, Tanzania
[3]Department of Geography and Environmental Studies, University of Dodoma, Dodoma, Tanzania
Correspondence: kifile06tz@yahoo.com or edwin.ngowi@sua.ac.tz

Received: September 12, 2024; **Accepted:** November 28, 2024; **Published:** December 12, 2024

Abstract: *The heightened occurrence of climate-related disasters such as droughts, floods, and storms has amplified agricultural vulnerability in developing countries, particularly affecting farmers' decision-making processes. Despite the availability of Climate Information Services (CIS), their perceived effectiveness in accurately predicting climate hazards remains underexplored. This study examines farmers' perceptions of the effectiveness of CIS in predicting climate-related hazards in Kondoa and Kiteto districts, Tanzania, where 360 farmers who have access to the Global Framework for Climate Service Adoption in Africa (GFCS-APA) program were surveyed. Using a 5-point Likert scale, Kendall's W-test, and Chi-squared tests, the study revealed significant variation in the perceived relevance and utility of different CIS. The findings highlight that droughts and erratic rainfall are the most prevalent hazards, affecting 88.91% and 75.21% of farmers, respectively. Meanwhile, flooding impacts 86.35% of farmers in Bukulu and 56.03% in Emarty, with pest and disease outbreaks affecting approximately 41-43% of households. Farmers ranked drought as the most critical hazard (mean rank 2.61), followed by erratic rainfall (2.82) and pest outbreaks (3.09). The Kendall's W-test ($W = 0.185$, $p < 0.001$) confirmed moderate agreement on these rankings, with considerable heterogeneity in perceptions. Regarding CIS effectiveness, farmers ranked agrometeorological advisory services highest (mean score 4.72), followed by seasonal weather forecasts (4.36). However, extreme weather predictions were perceived as less useful (mean score 3.53). The Kendall's W coefficient for CIS rankings was 0.411 ($p < 0.001$), indicating strong consensus among farmers. Despite these services' availability, qualitative data suggested that their technical language and lack of location-specific details limited practical application. The study recommends enhancing CIS through participatory approaches and improved dissemination strategies to better tailor services to farmers' needs, ultimately fostering more resilient agricultural practices in the face of climate variability.*

Keywords: *Climate information services (CIS), farmers' perceptions, climate hazards, agricultural decision-making*, *Kondoa and Kiteto Districts*

1. Background Information

The Intergovernmental Panel on Climate Change (IPCC) predicted a notable increase in climate-related hazards globally, which necessitated enhanced decision-making processes for on-farm activities (IPCC, 2020). Sub-Saharan Africa (SSA) had been particularly vulnerable to the effects of climate variability, with farmers in the region demonstrating limited adaptive capacity (Ogada *et al.*, 2021). Climate fluctuations and a rise in severe hydrometeorological events increasingly disrupted agricultural production, exacerbating food insecurity across the region (Zeleke *et al.*, 2023). Despite farmers' persistent efforts to secure yields, crop production declined steadily. For instance, research by Wollburg et al. (2024) indicated that crop production in SSA decreased by an average of 3.5% over the previous 12 years. This reduction fell significantly short of the Comprehensive Africa Agricultural Development Program's (CAADP) target of achieving 6% annual growth in African agriculture (Muroyiwa, 2022). Climate-related hazards were identified as the primary contributors to these crop failures (Zougmoré *et al.*, 2018; Bedeke, 2023; Affoh *et al.*, 2022; MacCarthy *et al.*, 2021). The vulnerability of agricultural systems in SSA was largely attributed to the fragility of ecosystems and soil degradation (Tofu & Wolka, 2023; Affoh *et al.*, 2022; Diop *et al.*, 2022).

In rural SSA, communities were particularly susceptible to climate hazards due to their limited capacity to implement effective risk reduction and climate adaptation strategies (Okolie *et al.*, 2023; Omotoso *et al.*, 2023; Affoh *et al.*, 2022). This situation was exacerbated by insufficient resources allocated by national governments for climate adaptation policies. Consequently, proactive measures were required to enhance adaptation strategies and mitigate the effects of climate variability on agriculture (Kombat et al., 2021). Various developing countries initiated efforts to boost agricultural production and enhance food security, particularly in semi-arid areas (Haggar *et al.*, 2021; Jayne *et al.*, 2021; Kavhiza *et al.*, 2022; Blockeel *et al.*, 2023).

Like other SSA nations, Tanzanian farmers faced significant challenges due to climate variability. Crop productivity in Tanzania was influenced by multiple factors, with 20% to 80% of annual yield fluctuations attributed to extreme weather events. Climate-related hazards accounted for 5% to 10% of the country's total agricultural production (FAO, 2019). Reports indicated a 4% to 5% annual decline in crop yields, far below the national target of 6% to 10% growth (FAO, 2019). Farmers in semi-arid areas, in particular, faced difficult decisions in managing the complex impacts of a rapidly changing climate (Jobbins *et al.*, 2016; Mutayoba & Kusiluka, 2018; Mutunga *et al.*, 2017). The implementation of Climate Information Services (CIS) was widely recommended in the literature as an essential tool to improve farmers' decision-making and mitigate the adverse effects of climate variability (Ouédraogo *et al.*, 2018; Tall *et al.*, 2018; Popoola *et al.*, 2020; Findlater *et al.*, 2021; Antwi-Agyei *et al.*, 2021; Van der Horst *et al.*, 2022). According to the World Meteorological Organization (WMO, 2019), CIS provided farmers with relevant data to help them make informed decisions about their farming practices. Sharafi *et al.* (2021) and Kumar et al. (2021) argued that providing farmers with accurate climate information reduced uncertainty and enhanced decision-making, thereby decreasing vulnerability.

In Tanzania, the Tanzania Meteorological Authority (TMA) served as the principal government body responsible for developing and disseminating CIS, although other actors, including development partners, were also involved (Kijazi *et al.*, 2021). Despite the crucial role of CIS in fostering informed decision-making in the face of climate variability, Tanzanian farmers faced numerous barriers in accessing these services. The low adoption of CIS was attributed to various factors, including mismatches between farmers' information needs, lack of relevance, untimeliness, and limited use of CIS in decision-making (Heinrich *et al.*, 2024; Gemeda *et al.*, 2023; Partey *et al.*, 2020). According to Nyadzi *et al.* (2022), these challenges primarily arose from a lack of involvement and collaboration in the co-production of information, which is essential for modern information systems. To address these uncertainties, the TMA implemented significant initiatives between 2013 and 2019 through the Global Framework for Climate Services Adaptation Programme in Africa (GFCS-APA), focusing on the production and dissemination of CIS. These efforts aimed to support government initiatives to enhance CIS utilization, particularly in semi-arid regions. Data indicated that GFCS-APA successfully strengthened institutional capacity and human resource capabilities, enabling many farmers to request and manage agricultural weather and agrometeorological services effectively (Kijazi *et al.*, 2021). By the end of 2018, over 4,500 farmer households reportedly benefited from the program's services (West *et al.*, 2018). The GFCS-APA approach emphasized empowering farmers to acquire knowledge and make informed decisions, shifting from a supply-driven to a demand-driven model of service delivery.

Despite the increased availability of CIS in Tanzania, it remained unclear how farmers perceived its impact on their capacity to mitigate climate-related risks. Although CIS played a crucial role in providing essential information about upcoming seasons, limited research explored its effectiveness. Studies suggested that farmers often used CIS only when it was readily accessible and easy to interpret (Nyoni *et al.*, 2024; Warner *et al.*, 2022; Chiputwa *et al.*, 2020; Guido *et al.*, 2020; Muema, 2018). For example, Vaughan et al. (2019) found that Malian farmers' use of CIS was influenced by their roles, responsibilities, and social identities, including factors like seniority and gender. In Malawi, both men and women reported having access to CIS but chose not to use it, relying instead on personal experience and indigenous knowledge, which they considered more reliable and contextually relevant (Amoak *et al.*, 2023). Therefore, this study aimed to explore farmers' perceptions of CIS effectiveness in the Kondoa and Kiteto districts in predicting hazards and informing farm decisions. This research contributed to the relatively underexplored field of comparative studies on pluralistic CIS approaches.

2.0 Methodology

The study was conducted in two districts of Tanzania: Kondoa, located in Dodoma Region, and Kiteto, situated in the Manyara Region. These districts were selected because the majority of their farming communities had participated in the multi-agency Global Framework for Climate Services—African Programme for Agriculture (GFCS-APA). This initiative aimed to enhance the adoption of Climate Information Services (CIS) for informed farming decisions, recognizing that agriculture is the predominant livelihood for most individuals in these areas. Both districts are characterized as semi-arid regions, experiencing a short rainy season that begins with low intensity in December, peaks in January and February, and diminishes by March and April, followed by an extended dry period from April to December. The primary economic activities in these regions revolve around agropastoral practices (Hamisi, 2019).

The study population comprised farmers exposed to the GFCS-APA initiative in Bukulu village (Kondoa) and Emarty village (Kiteto). A multistage sampling technique was employed to select respondents from the farmer households in these villages. Specifically, simple random sampling was utilized to choose 360 farmers from the two strata: Bukulu and Emarty villages. This approach ensured a representative sample of farmers, enabling a more comprehensive understanding of their perceptions regarding the effectiveness of CIS.

Data collection methods included focus group discussions (FGDs), key informant interviews (KIIs), and a household survey using self-administered structured questionnaires. Data obtained from FGDs and KIIs were recorded using both physical notebooks and digital audio recording devices, which facilitated accurate capture of participants' insights. The audio recordings were subsequently transcribed into English and systematically organized for analysis, ensuring that the qualitative data retained its original context (Creswell, 2014).

Quantitative data analysis involved descriptive statistics, the Chi-squared test, and Kendall's coefficient of concordance to assess the effectiveness of various CIS and their perceived impact on farmers' decision-making in both districts. The test statistics were calculated using a chi-square distribution, under the assumption that the data were independent and normally distributed, a condition often valid due to the Central Limit Theorem (Ghasemi & Zahediasl, 2012). A two-tailed test was employed to assess the independence of the data. The chi-square test ascertained the statistical significance of discrepancies between anticipated and observed frequencies across different categories (Field, 2018).

Kendall's W, a non-parametric statistical measure, was used to quantify the level of agreement among respondents regarding the effectiveness of CIS (Corder & Foreman, 2009; Kendall & Babington, 1939). The W statistic ranges from 0, indicating no agreement, to 1, indicating complete agreement among survey participants. Intermediate values of W reflect varying levels of consensus among respondents, which provided insight into the perceived effectiveness of the CIS across different ranks. Unlike the traditional Pearson correlation coefficient, Kendall's W does not require assumptions about the underlying probability distribution and can accommodate various ranking scenarios.

The mean Spearman's rank correlation coefficients were analyzed to determine linear connections among pairs of rankings provided by farmers. The null hypothesis posited that there was no correlation between the ranks assigned by the farmers. This analysis emphasized positive relationships among the rankings (Legendre, 2005). The methodology for conducting significance tests using the W statistic, along with an adapted version that accounted for ties in rankings, was discussed by Legendre. Marozzi (2014) extended Legendre's work by incorporating copula elements into the F-test, showing that the F-test is more precise and less conservative compared to both the Friedman test and the concordance permutation test.

Qualitative data from FGDs and KIIs were synthesized into concise summaries and direct quotations to reinforce quantitative findings. Initially, a primary document family was constructed, categorizing interviewees into groups such as extension officers and local farmers. Each sentence was assigned a code, with multiple codes merged to identify themes or patterns. This thematic analysis enabled an evaluation of the efficacy of each category in addressing the study's objectives, leading to refinement and selection of key themes (Braun & Clarke, 2006).

3.0 Results and Discussion

This study investigated farmers' perceptions of the effectiveness of Climate Information Services (CIS) in predicting hazard occurrences in Kondoa and Kiteto Districts, Tanzania. The analysis utilized Kendall's W-test to evaluate how farmers ranked the CIS and their frequency of use. The findings revealed significant insights into the common climate-related hazards faced by farmers, the distribution of CIS, and the perceived effectiveness of these services.

3.1 Common Climate-Related Hazards

The analysis identified distinct trends in climate-related hazards in Bukulu and Emarty Villages. Table 1 presents the findings, which highlight the prevalence of drought and erratic rainfall as the most significant hazards. Specifically, 88.91% of farmers in Emarty reported severe drought conditions, while Bukulu faced greater challenges with irregular rainfall, impacting 75.21% of households. Both villages reported comparable issues with pest and disease outbreaks (approximately 41-43%). Flooding was particularly pronounced in Bukulu (86.35%) compared to Emarty (56.03%). Temperature extremes, though infrequent, were slightly more common in Emarty (9.30%) than in Bukulu (5.01%). These disparities underscore the necessity for tailored climate information services to effectively mitigate the diverse impacts of these hazards on agricultural productivity.

Table 1: Common Climate-Related Hazards

Climate Related Hazards	Bukulu (%)	Emarty (%)
Drought	51.20	88.91
Erratic Rainfall	75.21	37.72
Pest and Disease Outbreaks	41.01	43.06
Flooding	86.35	56.03
Temperature Extreme	5.01	9.30

The qualitative data further revealed that climate-related hazards significantly impacted farmers' on-farm management decisions. A farmer from Emarty articulated this need, stating, "*We need rainfall amount data to inform us about the conditions in at least one of our regions,*" during a Focus Group Discussion (FGD) in August 2023. Additionally, a key informant from the Kiteto District Council suggested that the government could enhance support for farmers: "*I concur that there has been an increased extreme weather beyond farmers' ability to predict them using indigenous knowledge. However, employing intermediaries, implementing participatory approaches, and providing training could significantly enhance farmers' awareness about these climate-related hazards*," stated the Senior Agricultural Extension Officer during an interview in August 2023.

3.2 Climate Information Services Distributed for Use in Predicting Climate-Related Hazards

This study categorized climate information services into three primary groups: agrometeorological advice, seasonal weather forecasts, and the probability of extreme events. The results, as shown in Table 2, indicate a consensus among farmers regarding the ranking of these services. The calculated Kendall's W coefficient of 0.411, with a chi-square value of 1376.511, demonstrated statistical significance ($p < 0.001$), indicating a robust agreement on the preference for seasonal weather information services, which received the highest average rank of 2.62.

Table 2: Results of Kendall's W-Test of Main Climate Information Services Used

Climate Information Services	Mean Rank	Std. Dev.	Min	Max
Seasonal Weather Information	2.62	2.112	1	3
Agronomic Advice	2.91	2.422	1	3
Occurrence of Extreme Events	3.90	1.781	1	3
Kendall's W	***0.411******			
Chi-square	***1376.511***			

These findings emphasize the significance of seasonal weather information in enhancing farmers' decision-making processes regarding climate-related hazards.

3.3 Effectiveness of Climate Information Services

The study further assessed the perceived effectiveness of different Climate Information Services (CIS) in enabling farmers to predict and mitigate climate-related hazards. Utilizing a Likert scale ranging from 1 (least effective) to 5 (most effective), the results presented in Table 3 indicate that all CIS scored above 50%, reflecting their considerable influence on farmers' planning and management decisions.

Among the various CIS evaluated, the agronomic advisory service emerged as the most impactful, boasting a mean value of 4.72. This high rating suggests that farmers find this service particularly beneficial for their agricultural practices. The agronomic advisory service likely encompasses a range of information, including tailored agronomic recommendations based on current climate data, insights into optimal planting and harvesting times, and guidance on crop selection that is resilient to climate fluctuations. This service empowers farmers to make informed decisions, thereby enhancing their resilience to climate change and improving their overall productivity.

Table 3: Perceived Effectiveness of the Climate Information Services (CIS)

Climate Information Service	Mean	Std. Dev.	Ranking
Agrometeorological Advisory Service	4.72	0.872	1st
Seasonal Weather Information Service	4.36	1.169	2nd
Occurrence of Extreme Weather Events	3.53	1.343	3rd
Kendall's W	***0.111******		
Chi-square	***1267.311***		

The evidence revealed that farmers perceive agrometeorological and seasonal weather information services as vital, underscoring their roles in enabling farmers to navigate climate variability. Nonetheless, the study highlighted a critical need for improving the dissemination and effectiveness of information related to severe weather phenomena to better meet farmers' decision-making needs. Such improvements could significantly bolster farmers' resilience and adaptation strategies.

3.4 Synthesis of Results and Implications

This study reinforces the existing literature regarding the predominant challenges of drought and erratic rainfall faced by farmers in the Bukulu and Emarty regions. The findings align with Mafie's (2022) observations that highlight the detrimental impact of these climatic hazards on agricultural productivity and rural livelihoods. Droughts and inconsistent rainfall patterns not only diminish crop yields but also threaten food security and the overall economic stability of farming communities. However, the results of this study raise significant questions regarding the adequacy of current support mechanisms designed to assist farmers in adapting to these persistent challenges. The systemic failure to equip farmers with the necessary tools for resilience—despite the increasing global emphasis on climate adaptation strategies—remains a pressing concern.

Moreover, the study revealed that many farmers often continue their agricultural activities even in the face of crop failures, driven largely by the pressing need to meet familial and community demands. This phenomenon reflects Mabon's (2020) assertion that climate change exacerbates existing vulnerabilities among farming households, where the concept of a "competitive edge" may indeed represent a form of forced adaptation rather than a genuine advantage. In many cases, farmers are compelled to pursue agricultural practices that do not align with sustainable principles, raising critical questions about their agency and decision-making processes in response to climatic challenges. This contradiction necessitates a deeper exploration of how farmers navigate the complexities of their circumstances and adapt to changing environmental conditions.

In this context, Awolala *et al.* (2023) emphasized the critical importance of Climate Information Services (CIS) in mitigating uncertainties related to climate variability. However, our findings revealed that the effectiveness of these services varied significantly across different climate hazards, underscoring the need to question their appropriateness and relevance within local contexts. Such variability emphasizes the necessity for more localized, context-specific approaches to CIS delivery, moving away from a uniform model that may fail to address the unique needs of different farming communities. The delivery of CIS should be tailored to the specific climatic and socio-economic realities of each region to ensure that farmers receive actionable and relevant information.

The study further noted improvements in the availability of CIS through initiatives such as the Global Framework for Climate Services – African Programme for Action (GFCS-APA). This initiative aims to facilitate participatory approaches between service providers and farmers, promoting collaboration in the development of climate information. However, it is imperative to critically assess the true participatory nature of these initiatives and their effectiveness in genuinely incorporating farmers' knowledge and preferences into the design and dissemination of climate information. Belay *et al.* (2017) highlighted the necessity for detailed and timely information, such as precise data on the timing and duration of rainy seasons, to support effective agricultural planning. Yet, the dissatisfaction expressed by farmers regarding the technical language used in disseminating this information points to significant gaps in the co-production of knowledge. This suggests that enhancing the practical accessibility and actionability of climate information must be a priority in efforts to empower farmers.

Additionally, the study underscored the critical role of agricultural extension services in translating technical climate information into practical guidance for farmers. The disparity between the demand for these services and the supply of qualified personnel poses significant constraints on the effectiveness of CIS, particularly in rural areas. This finding corroborates the conclusions of Tumbo *et al.* (2018), who emphasized the challenges faced by agricultural extension systems in reaching farmers with relevant information. Addressing the low literacy levels among farmers is essential for improving the communication of technical information. This necessitates innovative strategies that leverage local knowledge systems and simplify the delivery of information to ensure that it is comprehensible and usable by all farmers, regardless of their educational background.

In general, the results of this study underscore the importance of tailoring climate information services to meet the specific needs of farmers while simultaneously addressing the structural barriers that impede their effective implementation. The insights gained from this research provide valuable guidance for enhancing the delivery of CIS and improving the resilience of farmers in the face of climate variability. Therefore, by fostering a more inclusive and adaptive approach to climate information, stakeholders can better support farmers in navigating the complexities of climate change, ultimately contributing to more sustainable agricultural practices and improved livelihoods for rural communities.

4.0 Conclusions and Recommendations

This study has critically assessed farmers' perceptions of the effectiveness of Climate Information Services (CIS) in predicting climate-related hazards in the Kondoa and Kiteto Districts of Tanzania. The findings reveal that farmers face significant climate-related challenges, primarily drought and erratic rainfall, which substantially impact their agricultural productivity. The effective use of CIS is crucial for enabling farmers to adapt to these hazards, yet the perceived effectiveness of these services varies depending on the type of information provided. Notably, agronomic advisory services emerged as the most effective in aiding farmers' decision-making, highlighting the importance of localized and actionable climate information.

The analysis indicates a strong need for enhancing the accessibility and relevance of CIS to better align with the unique challenges faced by farmers in different contexts. Although initiatives to improve CIS availability exist, there remains a gap in addressing the needs of farmers, particularly regarding their understanding and utilization of climate information. Therefore, the success of CIS in aiding farmers' resilience hinges on continuous evaluation and adaptation of service delivery methods that incorporate farmers' knowledge and practices.

Based on the study findings, several key recommendations are proposed to enhance the effectiveness of Climate Information Services (CIS) for farmers in the Kondoa and Kiteto Districts. First, it is essential to develop and disseminate CIS that are specifically tailored to the unique climatic challenges of each village. This approach should include detailed local forecasts and agronomic advice that take into account seasonal variations and historical weather patterns, ensuring that the information is relevant and applicable to local conditions.

In addition to tailoring services, enhancing communication strategies is critical. Simplifying the technical language used in disseminating CIS will ensure that information is easily understandable and actionable for all farmers, regardless of their literacy levels. Employing visual aids and local dialects can further improve comprehension and facilitate better engagement with the information provided.

Strengthening agricultural extension services is also necessary to bridge the gap between technical climate data and practical farming advice. Investing in training and expanding the number of extension officers deployed in rural areas will facilitate direct communication and support for farmers, allowing them to make informed decisions based on reliable climate information.

Moreover, implementing participatory frameworks that actively involve farmers in the co-production of climate information is vital. Such frameworks can enhance the relevance of CIS by empowering farmers to contribute their local knowledge and experiences, leading to more contextually appropriate solutions.

Regular capacity-building and training programs for farmers on climate risk management and the effective use of CIS should be established. These programs will enhance farmers' understanding and capability to utilize the information provided effectively, ultimately improving their resilience to climate-related hazards.

Additionally, establishing a strong monitoring and evaluation framework is essential to continuously assess the effectiveness of CIS. This framework should include feedback mechanisms that allow farmers to voice their concerns and suggest improvements, ensuring that services remain responsive to their needs.

Lastly, further research into the socio-economic barriers that hinder farmers from fully utilizing CIS is encouraged. Understanding these barriers is crucial for creating more effective and inclusive climate information strategies that can truly support farmers in navigating the challenges posed by climate variability and change.

Declaration of Conflict of Interest

I declare that there are no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

References

Affoh, R., Zheng, H., Dangui, K., & Dissani, B. M. (2022). The impact of climate variability and change on food security in sub-saharan africa: Perspective from panel data analysis. *Sustainability*, *14*(2), 759.

Amoak, D., Ishola, T. O., Batung, E., Mohammed, K., Lupafya, E., & Luginaah, I. (2023). Does climate information source matter in smallholder farmers' climate resilience? Comparative insights from Malawi and Ghana. *Environmental Development*, *48*, 100931.

Amwata, D. A., Omondi, P. O., & Kituyi, E. (2018). Uptake and Use of Climate Information Services To Enhance Agriculture and Food Production Among Smallholder Farmers in Eastern and Southern Africa Region. *International Journal of Advanced Research*, *6*(5), 859–873. https://doi.org/10.21474/ijar01/7106

Antwi-Agyei, P., Amanor, K., Hogarh, J. N., & Dougill, A. J. (2021). Predictors of access to and willingness to pay for climate information services in north-eastern Ghana: A gendered perspective. *Environmental development*, *37*, 100580.

Arvila, N., Fischer, A., León, J. G., Kuivalainen, M., & Mehtälä, J. (2018). Enhancing Uptake and Use of Climate Information Services (CIS) by Smallholder Farmers in Tanzania. In *Capstone in Creative Sustainability*.

Awolala, D., Mutemi, J., Adefisan, E., Antwi-Agyei, P., Taylor, A., Muita, R., ... & Nkiaka, E. (2023). Economic value and latent demand for agricultural drought forecast: Emerging market for weather and climate information in Central-Southern Nigeria. *Climate Risk Management*, *39*, 100478.

Bedeke, S. B. (2023). Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: a review on concepts, approaches and methods. *Environment, development and sustainability*, *25*(2), 1017-1051.

Belay, A., Recha, J. W., Woldeamanuel, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture and Food Security*, *6*(1), 1–13. https://doi.org/10.1186/s40066-017-0100-1

Blockeel, J., Schader, C., Heidenreich, A., Grovermann, C., Kadzere, I., Egyir, I. S., ... & Stolze, M. (2023). Do organic farming initiatives in Sub-Saharan Africa improve the sustainability of smallholder farmers? Evidence from five case studies in Ghana and Kenya. *Journal of Rural Studies*, *98*, 34-58.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101.

Chengula, F., & Nyambo, B. (2016). The Significance of Indigenous Weather Forecast Knowledge and Practices Under Weather Variability and Climate Change : A Case Study of Smallholder Farmers on the Slopes of Mount Kilimanjaro. *International Journal of Agricultural Education and Extension*, *2*(2), 031–043.

Cherotich, K. V, Saidu, O., & Bebe, O. B. (2012). Access to Climate Change Information and Support Services by the Vulnerable Groups in Semi-arid Kenya for Adaptive Capacity Development. *African Crop Science*, *20*(2), 169–180. https://doi.org/1021-9730/2012

Chiputwa, B., Wainaina, P., Nakelse, T., Makui, P., Zougmoré, R. B., Ndiaye, O., & Minang, P. A. (2020). Transforming climate science into usable services: The effectiveness of co-production in promoting uptake of climate information by smallholder farmers in Senegal. *Climate services*, *20*, 100203.

Coulibaly, J. Y., Mango, J., Swamila, M., Tall, A., Kaur, H., & Hansen, J. (2015). What climate services do farmers and pastoralists need in Tanzania?Baseline study for the GFCS Adaptation Program in Africa. In *Copenhagen, Denmark: Vol. CCAFS Work* (Issue 11).

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

Diop, M., Chirinda, N., Beniaich, A., El Gharous, M., & El Mejahed, K. (2022). Soil and water conservation in Africa: State of play and potential role in tackling soil degradation and building soil health in agricultural lands. *Sustainability*, *14*(20), 13425.

Diouf, N. S., Ouedraogo, I., Zougmoré, R. B., Ouedraogo, M., Partey, S. T., & Gumucio, T. (2019). Factors Influencing Gendered Access to Climate Information Services for Farming in Senegal. *Gender, Technology and Development*, *23*(2), 93–110. https://doi.org/10.1080/09718524.2019.1649790

Dobardzic, S., Dengel, C. G., Gomes, A. M., Hansen, J., Bernardi, M., Fujisawa, M., & Intsiful, J. (2019). 2019 State of Climate Services: Agriculture and Food Security. In *World Meteorological Organization (WMO)* (Issue 1242).

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics*. SAGE Publications.

Findlater, K., Webber, S., Kandlikar, M., & Donner, S. (2021). Climate services promise better decisions but mainly focus on better data. *Nature Climate Change*, *11*(9), 731-737.

Gebre, G. G., Amekawa, Y., Fikadu, A. A., & Rahut, D. B. (2023). Do climate change adaptation strategies improve farmers' food security in Tanzania?. *Food Security*, *15*(3), 629-647.

Gemeda, D. O., Korecha, D., & Garedew, W. (2023). Determinants of climate change adaptation strategies and existing barriers in Southwestern parts of Ethiopia. Climate Services, 30, 100376.

Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: A guide for non-statisticians. *International Journal of Endocrinology and Metabolism*, 10(2), 486-489.

Guido, Z., Knudson, C., Campbell, D., & Tomlinson, J. (2020). Climate information services for adaptation: what does it mean to know the context? *Climate and Development*, *12*(5), 395–407. https://doi.org/10.1080/17565529.2019.1630352

Haggar, J., Nelson, V., Lamboll, R., & Rodenburg, J. (2021). Understanding and informing decisions on sustainable agricultural intensification in Sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *19*(5-6), 349-358.

Hamisi, M. (2019). *Assessing the impact of climate change on agricultural production in semi-arid regions of Tanzania*. [Unpublished Master's thesis]. Sokoine University of Agriculture.

Hamisi, S. H. (2019). *A Geography of Kondoa District* (Vol. 4, Issue 3).

Heinrich, V. J., Stewart, E. J., Liggett, D., Carrasco, J. F., Dawson, J., Lamers, M., ... & Thoman, R. (2024). The Use of Weather, Water, Ice, and Climate (WWIC) Information in the Polar Regions: What Is Known after the Decadelong Polar Prediction Project?. *Weather, Climate, and Society*, *16*(3), 369-387.

Integovernmetal Panel for Climate Change. (2020). Climate Change and Land Ice. In *iItergoverntal Panel for Climate Change*. ipcc. https://doi.org/10.1002/9781118786352.wbieg0538

Jayne, T. S., Fox, L., Fuglie, K., & Adelaja, A. (2021). Agricultural productivity growth, resilience, and economic transformation in sub-Saharan Africa. *Association of Public and Land-grant Universities (APLU)*.

Jobbins, G., Conway, D., Fankhauser, S., Gueye, B., Liwenga, E., Ludi, E., ... & Suleri, A. (2016). Resilience, equity and growth in semi-arid economies a research agenda.

Johnson, D., Almaraz, M., Rudnick, J., Parker, L. E., Ostoja, S. M., & Khalsa, S. D. S. (2023). Farmer adoption of climate-smart practices is driven by farm characteristics, information sources, and practice benefits and challenges. *Sustainability*, *15*(10), 8083.

Kavhiza, N. J., Zargar, M., Prikhodko, S. I., Pakina, E. N., Murtazova, K. M. S., & Nakhaev, M. R. (2022). Improving crop productivity and ensuring food security through the adoption of genetically modified crops in sub-Saharan Africa. *Agronomy*, *12*(2), 439.

Kendall, M. G., & Babington, K. (1939). A new measure of rank correlation. *Biometrika*, 30(1/2), 81-93.

Khatibu, S., Ngowi, E., & Mwamfupe, D. (2022). Climate Information Services and Crop Production Enhancement among Sorghum and Maize Farmers in Kondoa and Kiteto Districts, Tanzania. *The Sub Saharan Journal Of Social Sciences And Humanities (SSJSSH)*, 1(2), 1-11. Retrieved from http://ssjsshco.wwwmi3-ss122.a2hosted.com/EAJSSH/index.php/EAJSSH/article/view/104

Kijazi, A. L., Chang'a, L. B., Muruke, W. T., Ndaki, M. M., Babyegeya, M. M., Kisama, S. Y., & Juma, O. H. (2021). Best practices and lessons learned in the implementation of global framework for climate services—Adaptation programme in Africa: Tanzania-experience. *Atmospheric and Climate Sciences*, *11*(4), 749-766.

Kijazi, A., Luhunga, P., Kidebwana, E. T., Chang'a, L., Ng'ongolo, H., Merchades, M., & Levira, P. (2019). The Contribution of the Global Framework for Climate Services Adaptation Programme in Africa (GFCS APA) in National Adaptation Plan (NAP) Process for Tanzania. *Atmospheric and Climate Sciences*, *09*(04), 650–661. https://doi.org/10.4236/acs.2019.94040

Kombat, R., Sarfatti, P., & Fatunbi, O. A. (2021). A review of climate-smart agriculture technology adoption by farming households in sub-saharan africa. *Sustainability (Switzerland)*, *13*(21), 1–16. https://doi.org/10.3390/su132112130

Kumar, U., Werners, S. E., Paparrizos, S., Datta, D. K., & Ludwig, F. (2021). Co-producing climate information services with smallholder farmers in the Lower Bengal Delta: How forecast visualization and communication support farmers' decision-making. *Climate Risk Management*, *33*, 100346.

Kumar, U., Werners, S., Roy, S., Ashraf, S., Hoang, L. P., Datta, D. K., Ludwig, F., Naab, F. Z., Abubakari, Z., & Ahmed, A. (2020). Role of Information in Farmers' Response to Weather and Water Related Stresses in the Lower Bengal Delta, Bangladesh. *Sustainability (Switzerland)*, *12*(16), 0–1. https://doi.org/10.3390/su12166598

Legendre, P. (2005). Analyzing biological data. *International Society for Ecological Modelling*.

Mabon, L. (2020). Making climate information services accessible to communities: What can we learn from environmental risk communication research? *Urban climate*, *31*, 100537.

MacCarthy, D. S., Adam, M., Freduah, B. S., Fosu-Mensah, B. Y., Ampim, P. A., Ly, M., ... & Adiku, S. G. (2021). Climate change impact and variability on cereal productivity among smallholder farmers under future production systems in West Africa. *Sustainability*, *13*(9), 5191.

Mafie, G. K. (2022). The impact of climate change on agricultural productivity in Tanzania. *International Economic Journal*, *36*(1), 129-145.

Maponya, P., & Mpandeli, S. (2013). The Role of Extension Services in Climate Change Adaptation in Limpopo province , South Africa. *Journal of Agricultural Extension and Rural Development*, *5*(7), 137–142. https://doi.org/10.5897/JAERD12.117

Marozzi, M. (2014). Comparing the Friedman and concordance tests in the context of data analysis. *Journal of Statistical Research*, 48(2), 205-218.

Muema, E. M. (2018). *Determinants of access and use of climate information services among smallholder farmers in Makueni County, Kenya* (Doctoral dissertation, University of Nairobi).

Mulwa, C., Marenya, P., Rahut, D. B., & Kassie, M. (2017). Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate Risk Management*, *16*. https://doi.org/10.1016/j.crm.2017.01.002

Muroyiwa, B. (2022). Agricultural Transformation in Africa: Lessons learnt from the Domestication of the Comprehensive African Agriculture Development Programme (CAADP) Processes in Lesotho. *Journal of African Union Studies*, *11*(3), 5.

Mutayoba, V., & Kusiluka, M. A. (2018). The Linkage among Cashew nut Processors in Mtwara region, Tanzania: Volume and Quality Optimization Option. *Mwalimu Nyerere Memorial Academy, Dar es Salaam*.

Mutunga, E. J., Charles, K. N., & Patricia, M. (2017). Smallholder farmers perceptions and adaptations to climate change and variability in Kitui county, Kenya.

Nesheim, I., Barkved, L., & Bharti, N. (2017). What Is the Role of Agro-Met Information Services in Farmer Decision-Making? Uptake and Decision-Making Context among Farmers within Three Case Study Villages in Maharashtra, India. *Agriculture*, *7*(8), 70. https://doi.org/10.3390/agriculture7080070

Nyadzi, E., Nyamekye, A. B., & Ludwig, F. (2022). Making climate services actionable for farmers in Ghana: the value of co-production and knowledge integration. In *Indigenous Knowledge and Climate Governance: A Sub-Saharan African Perspective* (pp. 97-110). Cham: Springer International Publishing.

Nyoni, R. S., Bruelle, G., Chikowo, R., & Andrieu, N. (2024). Targeting smallholder farmers for climate information services adoption in Africa: a systematic literature review. *Climate Services*, *34*, 100450.

Ogada, M. J., Radeny, M., Recha, J., & Dawit, S. (2021). Adoption of complementary climate-smart agricultural technologies: lessons from Lushoto in Tanzania. *Agriculture and Food Security*, *10*(1), 1–10. https://doi.org/10.1186/s40066-021-00321-w

Okolie, C. C., Danso-Abbeam, G., & Ogundeji, A. A. (2023). Livelihood vulnerability to the changing climate: the experiences of smallholder farming households in the Free State Province, South Africa. *Climate Services*, *30*, 100371.

Ouedraogo, I., Diouf, N. S., Ouédraogo, M., Ndiaye, O., & Zougmoré, R. B. (2018). Closing the Gap Between Climate Information Producers and Users: Assessment of Needs and Uptake in Senegal. *Climate*, *6*(1), 1–16. https://doi.org/10.3390/cli6010013

Ouédraogo, M., Barry, S., Zougmoré, R. B., Partey, S. T., Somé, L., & Baki, G. (2018). Farmers' Willingness to Pay for Climate Information Services: Evidence From Cowpea and Sesame Producers in Northern Burkina Faso. *Sustainability (Switzerland)*, *10*(3). https://doi.org/10.3390/su10030611

Partey, S. T., Dakorah, A. D., Zougmoré, R. B., Ouédraogo, M., Nyasimi, M., Nikoi, G. K., & Huyer, S. (2020). Gender and climate risk management: evidence of climate information use in Ghana. *Climatic Change*, *158*, 61-75.

Popoola, O. O., Yusuf, S. F. G., & Monde, N. (2020). Information sources and constraints to climate change adaptation amongst smallholder farmers in Amathole District Municipality, Eastern Cape Province, South Africa. *Sustainability*, *12*(14), 5846.

Sharafi, L., Zarafshani, K., Keshavarz, M., Azadi, H., & Van Passel, S. (2021). Farmers' decision to use drought early warning system in developing countries. *Science of the Total Environment*, *758*, 142761.

Tall, A., Coulibaly, J. Y., & Diop, M. (2018). Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. *Climate Services*, *11*, 1-12.

Tofu, D. A., & Wolka, K. (2023). Transforming food insecure farmers from climate variability and land degradation susceptibility to resilient livelihoods. *Research in Globalization*, *7*, 100168.

Tumbo, S. D., Mwalukasa, N., Fue, K. G., Mlozi, M. R. S., Haug, R., & Sanga, C. A. (2018). Exploring Information Seeking Behavior of Farmers' in Information Related to Climate Change Adaptation through ICT (CHAI). *International Review of Research in Open and Distance Learning*, *19*(3), 299–319. https://doi.org/10.19173/irrodl.v19i3.3229

Ukhurebor, K. E., Adetunji, C. O., Olugbemi, O. T., Nwankwo, W., Olayinka, A. S., Umezuruike, C., & Hefft, D. I. (2022). Precision agriculture: Weather forecasting for future farming. In *Ai, edge and iot-based smart agriculture* (pp. 101-121). Academic Press.

Van der Horst, S., Goosen, H., van Selm, M., Koomen, I., Matsaba, E. O., Wesonga, J., ... & klein Holkenborg, M. (2022). Co-creation of a Scalable Climate Service for Kenyan Smallholder Farmers. *Frontiers in Climate*, *4*, 859728.

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P., & Carr, E. (2019). Evaluating Agricultural Weather and Climate Services in Africa: Evidence, Methods, and a Learning Agenda. *Wiley Interdisciplinary Reviews: Climate Change*, *10*(4), 1–33. https://doi.org/10.1002/wcc.586

Vogel, J., Letson, D., & Herrick, C. (2017). A Framework for Climate Services Evaluation and Its Application to the Caribbean Agrometeorological Initiative. *Climate Services*, *6*(July), 65–76. https://doi.org/10.1016/j.cliser.2017.07.003

Warner, D., Moonsammy, S., & Joseph, J. (2022). Factors that influence the use of climate information services for agriculture: A systematic review. *Climate Services*, *28*, 100336.

West, J. J., Meaghan, D. E., & Yanda, P. Z. (2018). Evaluating User Satisfaction with Climate Services in Tanzania 2014 -2016. In *CICERO REPORT*.

WMO (2019). 2019, *State of Climate Services; Agriculture and Food Security* (Issue 1242). World Meteorological Organization (WMO).

Wollburg, P., Bentze, T., Lu, Y., Udry, C., & Gollin, D. (2024). Crop yields fail to rise in smallholder farming systems in sub-Saharan Africa. *Proceedings of the National Academy of Sciences*, *121*(21), e2312519121.

Zeleke, G., Teshome, M., & Ayele, L. (2023). Farmers' livelihood vulnerability to climate-related risks in the North Wello Zone, northern Ethiopia. *Environmental and Sustainability Indicators*, *17*, 100220.

Zougmoré, R. B., Partey, S. T., Ouédraogo, M., Torquebiau, E., & Campbell, B. M. (2018). Facing climate variability in sub-Saharan Africa: analysis of climate-smart agriculture opportunities to manage climate-related risks. *Cahiers Agricultures (TSI)*, *27*(3), 1-9.