Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 12 ~ Issue 5 (May 2026) pp: 37-48
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Integrating Citizen Science in Climate Forecast Interpretation for Climate Resilience Among Smallholder Farmers in Busia County, Kenya

Wandera, C. [1] & Gichuki, C. [2]

[1]*School of Agriculture and Environmental Sciences of Kenyatta University [K.U], Nairobi, Kenya*
[2]*School of Agriculture and Environmental Sciences of Kenyatta University [K.U], Nairobi, Kenya*

Abstract
Climate variability poses significant challenges to smallholder farmers, who rely on timely and accurate weather information for agricultural decision-making. Despite advances in meteorological services, many farmers struggle to interpret seasonal and sub-seasonal forecasts, limiting their ability to respond effectively to changing climatic conditions. This study investigates the role of citizen science in transforming climate forecasts into actionable knowledge that enhances adaptive capacity and resilience among smallholder farmers in Kenya. Specifically, it explores farmers' understanding of periodic and sub-periodic forecasts issued by the Kenya Meteorological Department and examines how this knowledge informs adaptation measures. A mixed-methods approach was employed, combining structured questionnaires, semi-structured interviews, and participatory observation within farming communities. Data analysis involved descriptive statistics and inferential analysis to assess forecast understanding, utilization, and adoption of adaptive strategies. Among the sampled 249 participants, most were young and middle-aged adults between 25–44 years. Forecasts were primarily accessed via radio (38% acted on short-term forecasts) and television (47%), while SMS and social media were moderately used. Short-term forecasts were acted upon more frequently (58%) than seasonal forecasts (47%). Awareness of the Kenya Meteorological Department was significantly associated with education and farming experience ($p < 0.05$), while understanding of forecast terminology showed no demographic differences. Farmers reported experiencing prolonged droughts (33%) and rising temperatures (31%), with 65% rating impacts as very severe, leading to food insecurity (63%) and poverty (28%). The study concludes that while access to climate information is high, effective adaptation depends on confidence, clarity, and relevance. The study recommends integrating citizen science, prioritizing short-term advisories, strengthening multi-channel communication, and providing targeted training for younger and less-educated farmers.

Keywords: Citizen Science, Climate Forecasts, Smallholder Farmers, Adaptive Capacity, Climate Resilience, Kenya, Participatory Climate Services

Received 06 May., 2026; Revised 14 May., 2026; Accepted 16 May., 2026

I. Introduction

Citizen science refers to the involvement of local communities in scientific research processes, including data collection, monitoring, observation, and reporting (Zeray et al., 2022; Walker et al., 2020). Although local communities are often perceived as lacking formal scientific knowledge and skills, their participation has been shown to add significant value by contributing context-specific insights that may otherwise be overlooked (Starkey et al., 2017). As such, citizen science provides an opportunity to bridge the gap between scientific knowledge and local experience. Climate change forecasting remains a major challenge in developing countries such as Kenya, particularly in rural areas where livelihoods heavily depend on climate-sensitive activities like agriculture (Baklanov et al., 2018; Gornall et al., 2010; Roudier et al.). The accuracy, interpretation, and usability of seasonal and sub-seasonal climate forecasts are therefore critical for supporting agricultural decision-making. However, limited understanding and accessibility of such forecasts among smallholder farmers constrain their effective use. Recent studies emphasize the need to involve local communities more actively in climate-related processes to enhance resilience and adaptation (Campbell et al., 2016). Integrating citizen science into climate forecast interpretation can improve the relevance, comprehension, and uptake of climate information. In this regard, this paper focuses on how community participation in interpreting climate forecasts issued by the Kenya Meteorological Department can enhance their usability and support climate change adaptation and resilience among smallholder farmers in Nambale Sub- County, Busia County, Kenya.

II. Problem Statement

Smallholder farmers worldwide are increasingly vulnerable to the adverse effects of climate change, with the impacts being more pronounced in low- and middle-income countries (Alpízar et al., 2020). In Kenya, agriculture plays a critical role in the economy, contributing significantly to GDP, employment, and exports (Eichsteller et al., 2022). However, climate variability has negatively affected food availability, particularly among smallholder farmers, thereby posing a major national concern (Kabubo-Mariara, 2015). In Nambale Sub- County, smallholder farmers have experienced persistent crop losses over the past two decades due to factors such as land degradation, population pressure, land fragmentation, and increasingly unpredictable seasonal and sub-seasonal climate conditions (Chavula & Turyasingura, 2022; Jepkosgei, 2023). These challenges are exacerbated by limited understanding of climate risks and forecasts, as well as the inability to effectively utilize climate information and climate-smart technologies for sustainable agricultural production (Linne et al., 2013). Despite the availability of climate forecasts from institutions such as the Kenya Meteorological Department, their uptake remains low among smallholder farmers. This suggests a disconnect between the production of scientific climate information and its interpretation and application at the local level. There is therefore a need to explore participatory approaches, such as citizen science, that can enhance the interpretation, integration, and utilization of climate forecasts by bridging the gap between scientists and end users.

III. Purpose of the study:

This study aims to investigate the role of citizen science in transforming the interpretation of seasonal and sub-seasonal climate forecasts into actionable knowledge that enhances adaptive capacity and climate resilience among smallholder farmers. More specifically, the study seeks to:

i. To explore the degree of citizen understanding of periodic and sub-periodic climate change forecasts issued by the Kenya Meteorological Department.
ii. To establish the extent of understanding of changing climate consequences as a basis for enhancing adaptation measures suitable for building resilience against outcomes of changing climate among small-scale farmers.

IV. Literature Review

Climate change impacts and vulnerability have been experienced worldwide, with significant consequences for agricultural activities due to the lack of steady, accurate, and timely rainfall forecasts (Ravi et al., 2011; Waqas et al., 2023). Most agricultural systems in Africa are rain-fed, and farmers often have limited knowledge of modern farming technologies, which constrains their ability to adapt to climate variability (Girvetz et al., 2019). These conditions, coupled with socio-economic challenges, make smallholder farmers highly susceptible to climatic shocks.

4.1 Citizen Science for Climate Resilience and Adaptation in Farming

Citizen science involves engaging local communities in scientific research activities, including defining project objectives, making observations, collecting data, and contributing to methodological approaches (Mourad et al., 2020). Studies have shown that citizen science datasets can achieve substantial agreement with professional data, with approximately 62% consistency (Aceves-Bueno et al., 2017). Despite concerns about data accuracy, there is growing recognition of the value of involving local communities in scientific research (Gunko et al., 2022).

In agricultural contexts, citizen science has been applied to identify climate-resilient crop varieties and support community-based climate adaptation (Van Etten et al., 2019). Citizen science approaches have also contributed to building resilience and reducing hydrological risks (Paul et al., 2018) and engaging youth in disaster risk reduction (Marchezini et al., 2017).

In Kenya, citizen science remains underutilized in climate change adaptation initiatives (Weeser et al., 2018). Notable exceptions include indigenous forecasting initiatives, such as the Nganyi rain makers of Vihiga County, who collaborate with scientific experts to provide community-level weather predictions and support resilience among subsistence farmers (Ngaira, 2019). However, such approaches are largely rudimentary and have not yet been widely applied to improve interpretation of climate forecasts for smallholder farmers in Busia County.

4.2 Understanding Climate Forecasts for Adaptation

The ability to interpret seasonal and sub-seasonal climate forecasts is essential for effective adaptation among smallholder farmers. Limited comprehension of climate risks, forecasts, and climate-smart technologies has been linked to repeated crop losses and low adaptive capacity (Linne et al., 2013). Engaging local communities through citizen science can bridge this gap, transforming technical climate information into actionable knowledge that informs adaptation strategies (Gotor et al., 2021).

Capacity building and participatory approaches empower vulnerable communities to anticipate and respond to extreme climatic events, such as droughts, floods, and erratic rainfall (Shikwambana & Malaza, 2022). By involving farmers in the interpretation of climate forecasts, citizen science can enhance both understanding of potential climate consequences and the adoption of resilience measures suitable for smallholder agricultural systems.

4.3 Research Gap

Despite the availability of climate forecasts from the Kenya Meteorological Department, smallholder farmers in Busia County, particularly in Nambale Sub-county, have limited understanding and application of these forecasts (Wandera et al., 2024). Constraints include inadequate awareness, limited access to technology, and insufficient use of indigenous knowledge (Muita et al., 2021; Ng'endo & Kariuki, 2025; Davies et al., 2023).

This underutilization highlights a critical gap: the need to integrate citizen science approaches to enhance interpretation of climate forecasts, thereby enabling farmers to transform forecast information into adaptive actions and strengthen resilience against climate variability.

V. Research Methodology

This study employed a Mixed-Methods Participatory Action Research (PAR) design to examine how citizen science enhances smallholder farmers' understanding of seasonal and sub-seasonal climate forecasts and promotes adaptive capacity and resilience in Nambale Sub- County, Busia County, Kenya. PAR enabled the integration of quantitative climate data with qualitative insights from farmers, empowering them to interpret scientific forecasts alongside their traditional knowledge.

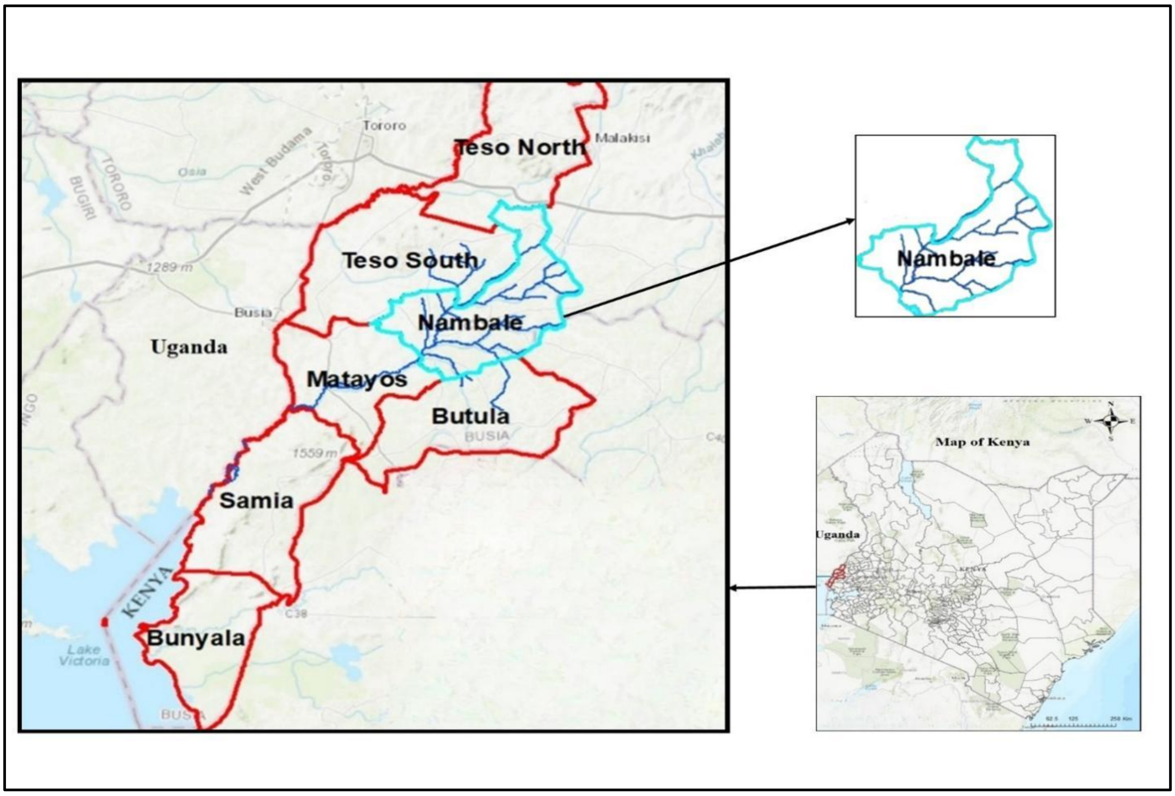

Figure 1: *A Map of Nambale Sub-county in Busia County*

The study targeted smallholder farmers across the four wards of Nambale Sub-county, a region with an area of approximately 237.8 km² and a population of 111,636 (KNBS, 2019). The area is predominantly agricultural, with crops including maize, beans, groundnuts, and sugarcane. Stratified random sampling was used to select participants proportionally from the four wards, supported by snowball sampling to ensure accurate identification of farmers knowledgeable about local climate conditions. A total of 399 farmers participated, with the final dataset screened to remove incomplete or inconsistent responses.

Data were collected using structured questionnaires that captured farmers' understanding of climate forecasts, perceptions of climate change impacts, and adaptation strategies, along with socio-demographic variables. The questionnaire was pre-tested with 40 farmers from similar socio-economic and agro-ecological contexts to ensure clarity, cultural appropriateness, and reliability. Research assistants administered the questionnaires, providing explanations and, where necessary, translations into the local language. Quantitative data were analyzed using descriptive statistics to assess levels of understanding and thematic categorization to explore integration of indigenous knowledge with scientific forecasts. Binary Logistic Regression identified factors predicting comprehension of climate forecasts. This approach allowed the study to evaluate both the determinants of understanding and the potential of citizen science to support climate adaptation and resilience among smallholder farmers.

VI. Results

6.1 Respondent Characteristics and Implications for Climate Information Use

A total of 249 smallholder farmers participated in the study, with a near-equal gender distribution (51% female, 49% male), suggesting balanced representation in access to climate information. The majority of respondents (62%) were aged between 25 and 44 years, indicating a predominantly economically active farming population. Farming experience was significantly associated with age ($\chi^2 = 16.454$, $p = 0.012$), confirming that older farmers possessed more cumulative agricultural knowledge.

While education levels varied across respondents, no significant association was observed between gender and education ($\chi^2 = 1.610$, $p = 0.657$), suggesting relatively equitable access to formal education. These characteristics are important in interpreting subsequent findings, as education and experience have been widely linked to climate information uptake and adaptive decision-making. In this study, however, their influence appeared to operate more strongly through awareness and confidence rather than basic comprehension.

6.2 Understanding and Utilization of Climate Forecasts

6.2.1 Sources of Climate Information and Communication Pathways

The study examined how forecast frequency varied across communication channels which provided valuable insight into the extent to which farmers could integrate climate information into daily and seasonal farming decisions as presented in figure 2

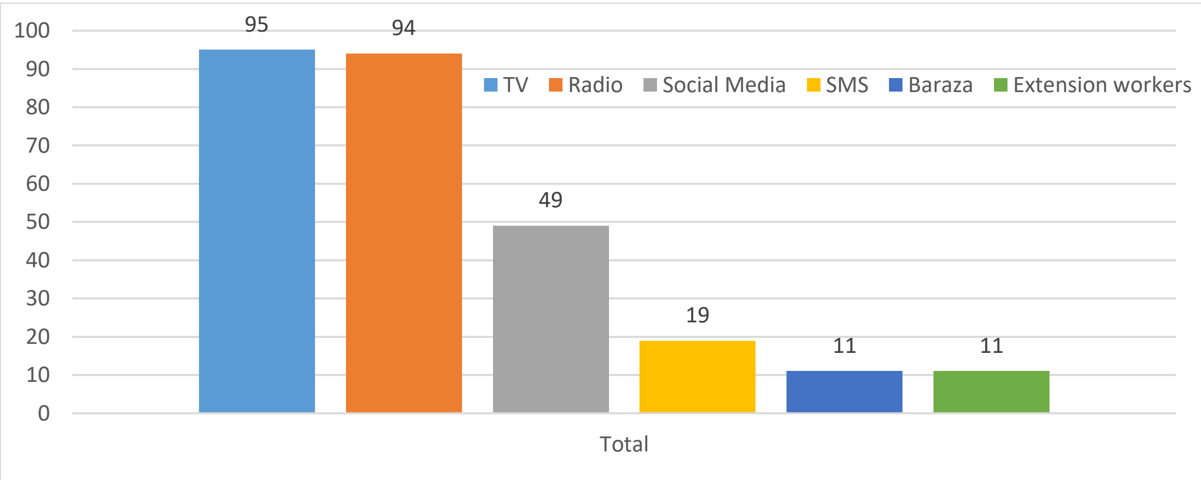

Figure 2: *Sources of climate information by Small Scale Farmers in Busia*

The findings revealed that smallholder farmers relied heavily on radio (n=94) and television (n=95) as primary sources of climate information. This aligned with earlier studies that showed that radio and TV remained the most reliable and widespread agricultural information channels in rural East Africa (Henriksson et al., 2021). These traditional channels deliver forecasts across multiple temporal scales, enabling both short-term (daily/weekly) and long-term (seasonal) decision-making. Their dominance underscored their continued relevance in rural communication systems.

Social media emerged as a moderately used platform (49 users), particularly strong for monthly forecasts, but less trusted for daily updates. This pattern reflected the digital divide identified in recent research, where younger and more educated farmer's accessed online climate information more frequently, while older farmers remained anchored in traditional media (Guido et al., 2020). SMS played a clear role in short-term forecasting, with most users accessing weekly or daily updates highlighting its usefulness for rapid, actionable advisories. In contrast, barazas and extension workers, while limited in reach (11 users each), still contributed to seasonal and weekly forecast dissemination, suggesting that community-level and face-to-face engagement remained important for reinforcing climate messages.

Combined, the above results revealed that systematic preferences of farmers with regards to the preferred source of climate information were very influential in determining the frequency at which farmers received forecasts and this was equally influential in the capacity of the farmers to utilize these forecasts to enhance better planning and food security. Radio, TV, SMS, and similar channels were the most relevant in enhancing meaningful use of climate forecasts because of their ability to provide prompt information regularly. Yet, the fact of underutilization of extension workers and barazas implied the prospects of enhancing the communication on the last mile, especially in the case of farmers who had fewer opportunities to use digital or broadcast media.

6.2.2 From Access to Action: Utilization of Forecasts

The extent to which farmers acted on climate forecasts varied significantly by forecast type and source of information, as shown in Table 1.

Table 1: *Farmers Ability to Act on Short and Seasonal Forecast by Sources of Information*

Source of climate information	Acted on Seasonal forecast from KMD		Acted on Short-Term Forecast	
	No	**Yes**	**No**	**Yes**
Radio	47	47	47	47
Baraza	5	6	7	4
SMS	7	12	8	11
Social media	26	23	17	32
Television	58	37	36	59
Extension workers	5	6	3	8
Total	**148**	**131**	**118**	**161**

The findings indicate that farmers' ability to act on climate forecasts varies significantly by both the type of forecast and the source of information. Overall, short-term forecasts were more widely acted upon (57.7%) than seasonal forecasts (47.0%), reflecting their immediate relevance to farm-level decision-making. Traditional media, particularly radio and television, reached the largest number of farmers, but their influence on action differed. Radio showed a balanced pattern between action and non-action, suggesting that access alone does not guarantee utilization. In contrast, television was more effective in prompting action on short-term forecasts, likely due to its ability to deliver detailed and timely information, although it was less influential for seasonal decisions. Digital platforms showed differentiated roles. Social media was more effective for short-term forecasts, reinforcing its role as a rapid information source, while SMS demonstrated consistent effectiveness across both seasonal and short-term forecasts due to its direct and personalized delivery. Although extension workers and barazas had limited reach, they showed relatively stronger influence in prompting action, particularly for short-term forecasts, highlighting the importance of interpersonal communication in reinforcing climate information.

Overall, the results suggest that forecast utilization is driven more by immediacy, trust, and clarity of communication rather than access alone, with farmers showing a clear preference for short-term, actionable climate information. These findings mirrored patterns reported in recent climate information studies across sub-Saharan Africa. Khatibu et al. (2025) noted that short-term forecasts were more widely acted upon because farmers found them more accurate, specific, and easier to integrate into daily farm decisions. The results strongly reflected this trend, with more farmers acting on short-term forecasts across nearly all information channels. Nocezo *et al*., (2024) similarly observed that farmers acted more frequently on weekly and daily forecasts due to their immediate risk-reduction value. The strong performance of radio and TV aligned with findings from (Kaske *et al*., 2023) which confirmed that traditional media remained the most trusted and accessible sources for weather and climate information. The mixed performance of social media in these results was effective for short-term but less so for seasonal forecasts and consistent with (Freiling & Matthes, 2023), who documented that farmers trust online sources for quick updates but remained skeptical of long-term forecasts delivered through unregulated digital channels. The moderate influence of extension workers and barazas were comparable to finding by Ngigi & Muange (2022), which highlighted that face-to-face communication-built trust but lacked the frequency and reach needed for widespread forecast uptake. As seen in the findings, these channels remained important but limited components of the climate information ecosystem.

6.2.3 Awareness of KMD and Structural Determinants

This section examined whether key socio-demographic factors namely: age, gender, education level, and years of farming experience influence farmers' awareness of the Kenya Meteorological Department (KMD) as a source of climate information, as presented in Table 2. Understanding awareness of KMD is critical, as it represents the entry point for accessing official climate forecasts, interpreting technical information, and acting on advisories that inform agricultural decision-making.

Table 2: *Classification Table Showing KMD Awareness Based on Age Group, Gender, Education Level and Year of Farming*

Observed			Predicted KMD Aware		Percentage Correct
			No	Yes	
Step 0	KMD Aware	No	0	57	0.0
		Yes	0	192	100.0
	Overall Percentage				77.1

a. Constant is included in the model.

b. The cut value is 500

			Score	Df	Sig.
Step 0	Variables	Age group	0.027	1	0.871
		Gender	4.263	1	0.039
		Education level	7.707	1	0.006*
		Years of farming	5.647	1	0.017*
	Overall Statistics		15.187	4	0.004*

Key to statistical significance: *= $p < 0.05$, ** $p < 0.01$

The results indicated that awareness of the Kenya Meteorological Department (KMD) was significantly influenced by the level of education ($p = 0.006$), farming experience ($p = 0.017$), and gender ($p = 0.039$), while age had no significant effect ($p = 0.871$). The overall model was statistically significant ($\chi^2 = 15.187$, $p = 0.004$), indicating that socio-economic factors shape awareness more strongly than demographic age differences. These findings suggests that exposure to formal education and accumulated experience enhances engagement with institutional climate services. Farmers with higher education levels are more likely to recognize KMD as a credible source, while experienced farmers may have had more opportunities to interact with climate information systems over time. The absence of an age effect indicates that awareness gaps are not generational but structural, pointing to disparities in access to information and institutional outreach rather than inherent differences in interest or capacity.

6.2.4 Understanding Versus Interpretation: The Role of Confidence

Despite variations in awareness, the study found no significant differences in farmers' understanding of climate forecast terminology across demographic groups. This suggests that basic comprehension of forecast terms is relatively uniform among farmers.

However, a different pattern emerged when examining confidence in interpreting forecasts. As shown in Table 3, confidence was strongly associated with perceived forecast accuracy.

Table 3: *Respondent Confidence to Interpret the KMD Forecast*

Confidence in interpreting KMD forecasts	Forecast Matched actual weather events					Total
	Never	Rarely	Sometimes	Often	Always	
Not confident	12	4	34	15	16	81
Somewhat confident	0	6	23	17	6	52
Confident	0	2	11	2	7	22
Very confident	7	5	20	17	45	94
Total	19	17	88	51	74	249

The cross-tabulation showed a strong relationship between farmers' confidence in interpreting KMD forecasts and their perceptions of forecast accuracy. Respondents who were not confident largely fell in the categories of "Sometimes" and "Always" matched events, but they also recorded the highest number in the "Never" category

(12 cases), indicating substantial uncertainty and variability in their experiences. Farmers who were somewhat confident showed a moderate pattern, with most responses clustering around "Sometimes" and "Often," reflecting partial trust in forecast performance. Those who reported being confident showed relatively low counts overall, but still tended toward "Sometimes," suggesting mixed but generally cautious perceptions. Among farmers who were very confident in interpreting forecasts, most perceived KMD forecasts as accurate, with 45 respondents indicating that forecasts "Always" matched actual weather events and 17 reported "Often." This group also had the lowest counts in the "Never" and "Rarely" categories, implying that high confidence aligned strongly with positive forecast experiences. Overall, the table revealed a direct positive relationship: as confidence in interpreting forecasts increased, perceived forecast accuracy also increased.

Table 4: *Chi square Test of Association Between Confidence in Interpreting KMD Forecasts and Occurrences of Events after Forecast*

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	47.034[a]	12	.000
Likelihood Ratio	52.125	12	.000
Linear-by-Linear Association	15.674	1	.000
N of Valid Cases	249		

a. 5 cells (25.0%) have expected count less than 5. The minimum expected count is 1.50.

The relationship between confidence and perceived accuracy was statistically significant ($\chi^2 = 47.034$, $p < 0.001$), indicating a strong positive association. Farmers with higher confidence were more likely to perceive forecasts as accurate and, by implication, more likely to use them. This finding highlights a critical distinction: while farmers may understand forecast terminology, their ability to interpret and trust the information depends on confidence. Confidence therefore acts as a key intermediary between information access and behavioral response, shaping how forecasts are translated into action.

6.3 Extent of Understanding Climate Change and Its Consequences

6.3.1 Perceived Climate Variability and Severity

This section examined farmers' understanding of climate change through their perceptions of climate variability and the severity of its impacts on farming activities. Respondents reported experiencing multiple forms of climate variability over the past 10–20 years, and their perceived severity is presented in Table 5.

Table 5: *Observed climate changes over the last 10–20 years and their perceived severity of impact on farming activities*

Changes in weather or climate in the last 10-20 years	Effect of climate changes on farming activities			Total
	Moderate	Severe	Very severe	
Decline in crop yields	0	11	31	42
Floods and heavy rains	0	17	25	42
Increasing temperature	13	16	48	77
Prolonged droughts	6	22	54	82
Unpredictable rainfall patterns	0	3	3	6
Total	**19**	**69**	**161**	**249**

The results indicate that a substantial majority of farmers (65%) perceived the impacts of climate variability as very severe, with prolonged droughts and increasing temperatures emerging as the most significant stressors. These findings highlight the prominence of both water scarcity and heat-related challenges in shaping agricultural outcomes.

To further examine the relationship between observed climate changes and their perceived severity, a chi-square test of association was conducted, as presented in Table 6.

Table 6: *Test of Association between Reported Climate Variability and Severity of Its Effects on Farming*

	Value	**Df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	21.453[a]	8	.006
Likelihood Ratio	25.688	8	.001
Linear-by-Linear Association	1.747	1	.186
N of Valid Cases	249		

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .46.

The results reveal a statistically significant association between the type of climate variability experienced and the severity of its impact on farming ($\chi^2 = 21.453$, $p = 0.006$). This suggests that certain climate events, particularly droughts and rising temperatures, exert disproportionately greater pressure on agricultural systems compared to others.

Overall, these findings demonstrate that farmers possess a strong experiential understanding of climate variability and its effects. However, the high proportion of respondents reporting severe impacts underscores the vulnerability of smallholder farming systems and highlights the need to translate this awareness into effective adaptation and resilience-building strategies.

6.3.2 Linking Climate Variability to Livelihood Outcomes

This study examined how observed climate variability translates into tangible livelihood outcomes at the household and community levels. While the preceding analysis established farmers' perceptions of climate variability and its severity, it is equally important to understand how these changes affect key aspects of rural livelihoods, including food security, income stability, and health. By linking specific climate stressors to their associated consequences, this analysis provides insight into the pathways through which climate change impacts smallholder farming systems. The results, presented in Figure 4.5, highlight the major livelihood outcomes associated with different climate-related events as reported by farmers.

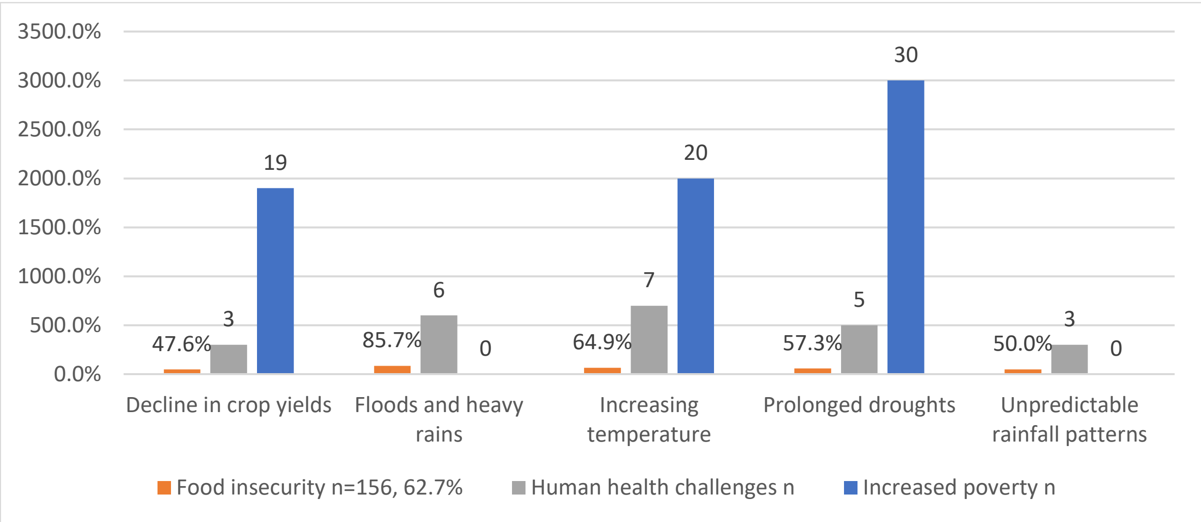

Figure 2: *Impacts of Climate Change on Environment and the Associated Consequences at Community level*

The dominant consequence of climate variability identified by farmers was food insecurity (62.7%), followed by increased poverty (27.7%) and health challenges (9.6%). Food insecurity was consistently associated with both drought and excessive rainfall, indicating that both water scarcity and flooding disrupt agricultural production systems.

This pattern highlights the systemic vulnerability of smallholder agriculture, where multiple climate stressors converge to undermine food production and household livelihoods. The strong linkage between climate variability and food insecurity reinforces the importance of timely and actionable climate information in mitigating these risks.

6.3.3 Adaptive Capacity and Confidence in Coping

The study further examined farmers' confidence in their ability to cope with climate change. Results from the multinomial logistic regression indicated that younger farmers (aged 25–44 years) were significantly more likely to report uncertainty ($p < 0.01$), while education emerged as a strong determinant of confidence.

Table 7: *Determinants of farmers' confidence in household ability to cope with climate change*

Ability for the household to cope with impacts of climate change[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% CI (Lower–Upper)
Don't know	Intercept	-0.776	0.977	0.631	1	0.427		
	25–34	-2.242	0.804	7.773	1	0.005*	0.106	0.022-0.514

35-44	-2.853	0.899	10.067	1	0.002*	0.058	0.01-0.336
45-54	-21.419	0.000		1		4.989E-10	-
>54	0[b]			0			-
Female	0.640	0.640	1.002	1	0.317	1.897	0.542-6.643
Male	0[b]			0			
None	-19.092	0.000		1		5.112E-09	-
Primary	0.417	0.920	0.206	1	0.650	1.518	
Secondary	0.685	0.949	0.520	1	0.471	1.983	0.308-12.7050
Tertiary	0[b]			0			
< 5 years	-0.023	0.829	0.001	1	0.978	0.977	0.192-4.962
5-10 years	-0.072	0.710	0.010	1	0.920	0.931	0.231-37.44
>10 Years	0[b]			0			

a. The reference category is: Very effective.

b. This parameter is set to zero because it is redundant.

Farmers with no formal education were particularly likely to express uncertainty, suggesting that knowledge and awareness play a central role in shaping adaptive capacity. In contrast, gender and farming experience were not significant predictors, indicating that confidence in coping is less about demographic identity and more about access to knowledge and information. These findings suggest that adaptive capacity is not solely determined by exposure to climate risks but is strongly influenced by the ability to interpret and respond to climate information.

6.3.4 Barriers to Translating Information into Action

Despite high levels of awareness, farmers face significant barriers in acting on climate information. As shown in Table 8, the most common challenges include lack of financial resources, limited access to reliable information, and contradictory information.

Table 8: Key Challenges in Acting on Climate Information

Challenge	Frequency	Percent
Lack of financial resources	107	42.9%
Limited access to reliable info	99	39.8%
Contradictory information	43	17.3%
Total	249	100.0%

Financial constraints emerged as the most critical barrier, limiting farmers' ability to implement adaptation strategies even when they possess relevant information. Limited access to reliable information further constrains decision-making, while contradictory information creates uncertainty and reduces trust.

Age was the only demographic factor significantly associated with these challenges ($p = 0.005$). Younger farmers were more affected by inconsistent information, reflecting their greater reliance on multiple information sources, including digital platforms. Middle-aged farmers, on the other hand, were more constrained by financial limitations, likely due to higher investment in farming activities.

These findings highlight that access to information alone is insufficient; effective adaptation requires addressing both economic and informational barriers.

6.3.5 Support Needs and Implications for Citizen Science

Farmers identified community awareness campaigns (56.2%) and training in climate-smart agriculture (28.1%) as their primary support needs, while fewer prioritized access to climate information (15.7%). This suggests that the challenge is not merely the availability of information, but the capacity to understand, interpret, and apply it effectively.

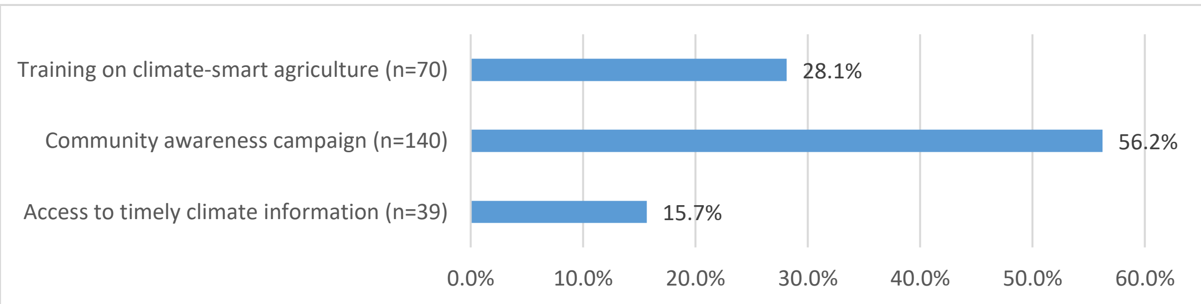

Figure 3: *Farmers' Priority Support Needs for Climate Change Adaptation*

These results align closely with the study's focus on citizen science. By promoting participatory approaches to climate information generation and interpretation, citizen science can enhance farmers' confidence, contextual understanding, and trust in climate forecasts. Community-based learning platforms can also address information gaps and reduce reliance on fragmented or contradictory sources.

6.4 Summary of the findings

The overall findings demonstrated that while smallholder farmers actively access climate forecasts, the transformation of this information into actionable knowledge is shaped by a combination of confidence, access, and structural constraints. Short-term forecasts are more readily utilized due to their immediate relevance, while seasonal forecasts remain underutilized.

Awareness of institutional sources such as KMD is influenced by education and experience, but understanding of forecast terminology is relatively uniform. Instead, confidence emerges as the critical factor determining whether information is trusted and acted upon.

At the same time, farmers exhibit high awareness of climate variability and its impacts, particularly drought and temperature increases, which are strongly linked to food insecurity. However, adaptive capacity is constrained by financial limitations, information gaps, and lack of practical training.

Overall, the results suggest that enhancing climate resilience among smallholder farmers requires moving beyond information dissemination toward participatory, context-specific approaches that build confidence, improve interpretation, and address structural barriers.

VII. Conclusion

The study concludes that while farmers have broad access to climate information through radio, television, and mobile platforms, the effective use of this information depends primarily on confidence, clarity, and relevance, rather than access alone. Short-term forecasts were acted upon more frequently than seasonal forecasts, reflecting their immediate utility in farming decisions. Awareness of formal sources, such as the Kenya Meteorological Department, was influenced by education and farming experience, while understanding of forecast terminology was generally consistent across respondents. The findings further show that farmers possess strong experiential knowledge of climate variability and its consequences, particularly droughts and rising temperatures, which are closely associated with food insecurity and livelihood vulnerability. However, translating this understanding into practical adaptation is constrained by financial limitations, inconsistent information, and limited access to context-specific guidance.

In line with the purpose of the study, strengthening adaptive capacity and resilience requires actionable interventions. The study recommends integrating citizen science into climate services to promote participatory interpretation of forecasts, simplifying and localizing climate information into actionable advisories, and prioritizing short-term, decision-oriented forecasts. Multi-channel communication strategies combining traditional media, mobile platforms, and extension services should be strengthened to improve last-mile delivery. Capacity-building initiatives, including climate-smart agriculture training and community awareness programs, are critical to enhance practical application. Addressing financial barriers through access to credit and support mechanisms will enable farmers to act on climate information, while targeted interventions for younger and less-educated farmers can improve adaptive capacity and reduce vulnerability.

REFERENCES

[1]. Abegunde, V. O., Sibanda, M., & Obi, A. (2019). The dynamics of climate change adaptation in sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. *Climate*, *7*(11). https://doi.org/10.3390/cli7110132

[2]. Aceves-Bueno, E., Adeleye, A. S., Feraud, M., Huang, Y., Tao, M., Yang, Y., & Anderson, S. E. (2017). The Accuracy of Citizen Science Data: A Quantitative Review. *The Bulletin of the Ecological Society of America*, *98*(4), 278–290. https://doi.org/10.1002/bes2.1336

[3]. Alpízar, F., Saborío-Rodríguez, M., Martínez-Rodríguez, M. R., Viguera, B., Vignola, R., Capitán, T., & Harvey, C. A. (2020). Determinants of food insecurity among smallholder farmer households in Central America: recurrent versus extreme weather-driven events. *Regional Environmental Change*, *20*(1). https://doi.org/10.1007/s10113-020-01592-y

[4]. Baklanov, A., Grimmond, C. S. B., Carlson, D., Terblanche, D., Tang, X., Bouchet, V., Lee, B., Langendijk, G., Kolli, R. K., & Hovsepyan, A. (2018). Urban Climate From urban meteorology , climate and environment research to integrated city services. *Urban Climate*, *23*, 330–341. https://doi.org/10.1016/j.uclim.2017.05.004

[5]. BCIDP. (2018). *Busia County Integrated Development Plan: 2018-2022*. https://www.cog.go.ke/downloads/category/106-county-integrated-development-plans-2018-2022?download=324:busia-county-integrated-development-plan-2018-2022

[6]. Campbell, B. M., Vermeulen, S. J., Aggarwal, P. K., Corner-dolloff, C., Girvetz, E., Maria, A., Ramirez-villegas, J., Rosenstock, T., Sebastian, L., Thornton, P. K., & Wollenberg, E. (2016). Reducing risks to food security from climate change. *Global Food Security*, *11*, 34–43. https://doi.org/10.1016/j.gfs.2016.06.002

[7]. Chavula, P., & Turyasingura, B. (2022). Land Tenurial System Influence among Smallholder Farmers' Climate Smart Agriculture Technologies Adoption, Sub-Sahara Africa: A Review Paper. *International Journal of Food Science and Agriculture*, *6*(1), 8–16. https://doi.org/10.26855/ijfsa.2022.03.003

[8]. Eichsteller, M., Njagi, T., & Nyukuri, E. (2022). The role of agriculture in poverty escapes in Kenya – Developing a capabilities approach in the context of climate change. *World Development*, *149*, 105705. https://doi.org/10.1016/j.worlddev.2021.105705

[9]. Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., Moorthy, I., Arias, R., Piera, J., Oliver, J. L., Masó, J., Penker, M.,

& Fritz, S. (2020). Mapping citizen science contributions to the UN sustainable development goals. *Sustainability Science*, *15*(6), 1735–1751. https://doi.org/10.1007/s11625-020-00833-7

[10]. Freiling, I., & Matthes, J. (2023). Correcting climate change misinformation on social media: Reciprocal relationships between correcting others, anger, and environmental activism. *Computers in Human Behavior, 145*, 107769. https://doi.org/10.1016/j.chb.2023.107769.

[11]. Fuso Nerini, F., Sovacool, B., Hughes, N., Cozzi, L., Cosgrave, E., Howells, M., Tavoni, M., Tomei, J., Zerriffi, H., & Milligan, B. (2019). Connecting climate action with other Sustainable Development Goals. *Nature Sustainability*, *2*(8), 674–680. https://doi.org/10.1038/s41893-019-0334-y

[12]. Girvetz, E., Ramirez-Villegas, J., Claessens, L., Lamanna, C., Navarro-Racines, C., Nowak, A., Thornton, P., & Rosenstock, T. S. (2019). Future Climate Projections in Africa: Where Are We Headed? In *The Climate-Smart Agriculture Papers*. https://doi.org/10.1007/978-3-319-92798-5_2

[13]. Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., & Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Phil. Trans. R. Soc*, 2973–2989. https://doi.org/10.1098/rstb.2010.0158

[14]. Gotor, E., Pagnani, T., Paliwal, A., Scafetti, F., van Etten, J., & Caracciolo, F. (2021). Smallholder Farmer Engagement in Citizen Science for Varietal Diversification Enhances Adaptive Capacity and Productivity in Bihar, India. *Frontiers in Sustainable Food Systems*, *5*(October), 1–17. https://doi.org/10.3389/fsufs.2021.726725

[15]. Guido, Z., Zimmer, A., Lopus, S., Hannah, C., Gower, D., Waldman, K., Krell, N., Sheffield, J., Caylor, K., & Evans, T. (2020). Farmer forecasts: Impacts of seasonal rainfall expectations on agricultural decision-making in Sub-Saharan Africa. *Climate Risk Management, 30*, 100247. https://doi.org/10.1016/j.crm.2020.100247.

[16]. Gunko, R., Rapeli, L., Scheinin, M., Vuorisalo, T., & Karell, P. (2022). How accurate is citizen science? Evaluating public assessments of coastal water quality. *Environmental Policy and Governance*, *32*(2), 149–157. https://doi.org/10.1002/eet.1975

[17]. Hadley, L., Aoko, E., Orega, D., & Jackline Sunda. (2023). *Climate information and Kenya's women smallholder farmers: A needs assessment*. Unpublished. https://doi.org/10.13140/RG.2.2.28843.21288.

[18]. Henriksson, R., Vincent, K., Archer, E., & Jewitt, G. (2021). Understanding gender differences in availability, accessibility and use of climate information among smallholder farmers in Malawi. *Climate and Development, 13*(6), 503–514. https://doi.org/10.1080/17565529.2020.1806777.

[19]. Hirons, L., Thompson, E., Dione, C., Indasi, V. S., Kilavi, M., Nkiaka, E., Talib, J., Visman, E., Adefisan, E. A., de Andrade, F., Ashong, J., Mwesigwa, J. B., Boult, V. L., Diédhiou, T., Konte, O., Gudoshava, M., Kiptum, C., Amoah, R. K., Lamptey, B., … Woolnough, S. (2021). Using co-production to improve the appropriate use of sub-seasonal forecasts in Africa. *Climate Services*, *23*(September). https://doi.org/10.1016/j.cliser.2021.100246

[20]. ICPAC. (2021). *ICPAC guide for engagement in co-producing climate services* (Issue March). https://www.icpac.net/documents/413/A_Guide_for_Engagement_in_Co-Producing_Climate_Services_-2_5MlXTgE.pdf

[21]. Issahaku, G., Abdul-Rahaman, A., & Amikuzuno, J. (2021). Climate change adaptation strategies, farm performance and poverty reduction among smallholder farming households in Ghana. *Climate and Development*, *13*(8), 736–747. https://doi.org/10.1080/17565529.2020.1860884

[22]. Jepkosgei, C. (2023). *Evaluating the Factors Influencing Farmers' Choices of Maize-Based Cropping Patterns and Assessing The Potential of Desis Hyperspectral Satellite Data to Discriminate the Cropping Patterns* (Issue June) [University of Twente]. http://essay.utwente.nl/96740/1/Jepkosgei_MSE_ITC.pdf

[23]. Kabubo-Mariara, J. (2015). Climate Change and Food Security in Kenya Does Climate Change Affect Food Insecurity in Kenya ? *Routledge*, 3. https://www.efdinitiative.org/sites/default/files/publications/drb_15-05_dec_2015_revised_jan_18_2016_0.pdf

[24]. Kaske, K. D., Ganewo, G. Z., Alemu, S. A., Seyoum, H. A., & Kassahun, G. T. (2023). Climate information: Does dissemination channels matter? Analysis of the coffee agroforestry system in the Sidama Region of Ethiopia. *Cogent Food & Agriculture, 9*(2), 2292372. https://doi.org/10.1080/23311932.2023.2292372.

[25]. Khatibu, S., & Ngowi, 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. *Frontiers in Climate, 7*, 1616691. https://doi.org/10.3389/fclim.2025.1616691.

[26]. KNBS. (2019). *2019 Kenya Population And Housing Census Volume I: Population By County And Sub-County: Vol. I* (Issue November). https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county

[27]. KNBS. (2020). *Kenya Comprehensive Poverty Reoport*. https://www.knbs.or.ke/comprehensive-poverty-report/

[28]. Linne, K., Osumba, J., & Jacobi, P. (2013). Climate Risk and Vulnerability Profiles for Homa Bay and Busia Counties, Kenya. In *Cities and Climate Change* (Issue January). https://www.greenlinne.com/wp-content/uploads/ACCI_Homa-Bay-and-Busia-Risk-Profile_1-13.pdf

[29]. Marchezini, V., Trajber, R., Olivato, D., Muñoz, V. A., de Oliveira Pereira, F., & Oliveira Luz, A. E. (2017). Participatory Early Warning Systems: Youth, Citizen Science, and Intergenerational Dialogues on Disaster Risk Reduction in Brazil. *International Journal of Disaster Risk Science*, *8* (4), 390–401. https://doi.org/10.1007/s13753-017-0150-9

[30]. Mekuria, W. (2018). The link between agricultural production and population dynamics in Ethiopia: a review. *Advances in Plants & Agriculture Research*, *8*(4), 348–353. https://doi.org/10.15406/apar.2018.08.00336

[31]. Mourad, K. A., Hosseini, S. H., & Avery, H. (2020). The role of citizen science in sustainable agriculture. *Sustainability (Switzerland)*, *12*(24), 1–15. https://doi.org/10.3390/su122410375

[32]. Ndolo, P. J., Mcharo, T., Carey, E. E., Gichuki, S. T., Ndinya, C., & Maling'a, J. (2001). Participatory on-farm selection of sweetpotato varieties in western Kenya. *African Crop Science Journal*, *9*(1), 1–7. https://doi.org/10.4314/acsj.v9i1.27623

[33]. Ngaira, J. K. V. (2019). *The Role of Citizen Science in Building Community Resilience: How New Technologies are Facilitating Citizen Science for Building Resilience*. https://unctad.org/meetings/en/Presentation/ecn162019_p15_ JKNgaira_en.pdf

[34]. Ngigi, M. W., & Muange, E. N. (2022). Access to climate information services and climate-smart agriculture in Kenya: A gender-based analysis. *Climatic Change, 174*(3–4), 21. https://doi.org/10.1007/s10584-022-03445-5.

[35]. Nkiaka, E., Taylor, A., Dougill, A. J., Antwi-Agyei, P., Fournier, N., Bosire, E. N., Konte, O., Lawal, K. A., Mutai, B., Mwangi, E., Ticehurst, H., Toure, A., & Warnaars, T. (2019). Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa. *Environmental Research Letters*, *14*(12). https://doi.org/10.1088/1748-9326/ab4dfe

[36]. Nocezo, Y.-I., Manyike, J. Z., Zhou, L., & Ngarava, S. (2024). The impact of access to climate services on smallholder farmers' cropping decisions and household food security in Elundini municipality, Eastern Cape province. *Frontiers in Climate, 6*, 1458999. https://doi.org/10.3389/fclim.2024.1458999.

[37]. Omusotsi, O. G., Dennis, A. T., Kilimo, C. J., Alex, M., Kipchirchir, K. K., Cynthia, J., Mercy, L., Oloo, N. W., & Ogutu, K. F. (2019). Assessing the Social, Cultural, Economic and Environmental Conditions of Nambale Town in Busia County, Kenya. *Urban and Regional Planning*, *4*(1), 16. https://doi.org/10.11648/j.urp.20190401.13

[38]. Paul, J. D., Buytaert, W., Allen, S., Ballesteros-Canovas, J. A., Bhusal, J., Cieslik, K., Clark, J., Dugar, S., Hannah, D. M., Stoffe, M., Dewulf, A., Dhita, M. R., Liu, W., Nayava, J. L., Neupane, B., Schiller, A., Smith, P. J., & Supper, R. (2018). Citizen science for hydrological risk reduction and resilience building. *Wiley Interdisciplinary Reviews: Water*, *5*(1), 1–15. https://doi.org/10.1002/WAT2.1262

[39]. Ravi, S. K., Nagasree, K., Venkateswarlu, B., & Maraty, P. (2011). Constraints and suggestions in adopting seasonal climate forecasts by farmers in South India. *Journal of Agricultural Education and Extension*, *17*(2), 153–163. https://doi.org/10.1080/1389224X.2011.544456

[40]. Roudier, P., Muller, B., Aquino, P., Roncoli, C., Soumaré, M. A., Batté, L., & Sultan, B. (2014). The role of climate forecasts in smallholder agriculture : Lessons from participatory research in two communities in Senegal. *Climate Risk Management*, *2*, 42–55. https://doi.org/10.1016/j.crm.2014.02.001

[41]. Shikwambana, S., & Malaza, N. (2022). Enhancing the Resilience and Adaptive Capacity of Smallholder Farmers to Drought in the Limpopo Province, South Africa. *Conservation*, *2*(3), 435–449. https://doi.org/10.3390/conservation2030029

[42]. Starkey, E., Parkin, G., Birkinshaw, S., Large, A., Quinn, P., & Gibson, C. (2017). Demonstrating the value of community-based (' citizen science ') observations for catchment modelling and characterisation. *Journal of Hydrology*, *548*, 801–817. https://doi.org/10.1016/j.jhydrol.2017.03.019

[43]. Tamru, S., Hansen, J., Zebiak, S., Tesfaye, A., Minten, B., Demissie, T., Radeny, M., Tesfaye, K., & Solomon, D. (2025). Climate information services enhance farmers' resilience to climate change: Impacts on agricultural productivity. *Climate Risk Management, 49*, 100724. https://doi.org/10.1016/j.crm.2025.100724.

[44]. van Etten, J., de Sousa, K., Aguilar, A., Barrios, M., Coto, A., Dell'Acqua, M., Fadda, C., Gebrehawaryat, Y., van de Gevel, J., Gupta, A., Kiros, A. Y., Madriz, B., Mathur, P., Mengistu, D. K., Mercado, L., Mohammed, J. N., Paliwal, A., Pè, M. E., Quirós, C. F., … Steinke, J. (2019). Crop variety management for climate adaptation supported by citizen science. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(10), 4194–4199. https://doi.org/10.1073/pnas.1813720116

[45]. Walker, D. W., Smigaj, M., & Tani, M. (2020). The benefits and negative impacts of citizen science applications to water as experienced by participants and communities. *WIREs Water*, *September 2020*, 1–32. https://doi.org/10.1002/wat2.1488

[46]. Waqas, M., Humphries, U. W., Wangwongchai, A., Dechpichai, P., & Ahmad, S. (2023). Potential of Artificial Intelligence-Based Techniques for Rainfall Forecasting in Thailand: A Comprehensive Review. *Water (Switzerland)*, *15*(16). https://doi.org/10.3390/w15162979

[47]. Weeser, B., Stenfert Kroese, J., Jacobs, S. R., Njue, N., Kemboi, Z., Ran, A., Rufino, M. C., & Breuer, L. (2018). Citizen science pioneers in Kenya – A crowdsourced approach for hydrological monitoring. *Science of the Total Environment*, *631–632*, 1590–1599. https://doi.org/10.1016/j.scitotenv.2018.03.130

[48]. Zeray, H., Fikadu, E., & Walker, D. W. (2022). Evaluation of WRF model rainfall forecast using citizen science in a data-scarce urban catchment : Addis Ababa , Ethiopia. *Journal of Hydrology: Regional Studies*, *44*, 101273. https://doi.org/10.1016/j.ejrh.2022.101273.