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Assessing climate events, farmer adaptation, and the role of social media in climate and varietal information delivery among Tanzanian farmers

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Limited climate information on weather patterns and adaptable varieties hinders decision-making and lowers productivity under climate change. Social media is vital on facilitating fast information access and dialog. This comparative study identifies observed climate changes, utilized adaptation measures, and social media usage patterns and its potential to deliver climate information to farmers in Tanzania. Data from 315 households were collected through semi-structured interviews in four regions across Northern and Southern Tanzania. Secondary data included 2 years of WhatsApp records and 30 years of NASA Power climate data to validate survey responses. Survey and WhatsApp data were analyzed using R statistical packages, while climate data were processed in ESRI ArcGIS software. Increased rainfall (100%) was identified as the most significant climate challenge over the past decade, yet 57% of farmers had taken no adaptation measures due to lack of knowledge. Farmers (18.4%) are connected to social media, and 9.5% (16.7% women) access climate information through the platforms. Despite low use, particularly among women, its potential is growing, with 68% of farmers trusting and utilizing the information. WhatsApp (67%) is the most widely used channel, and seed-related topics dominate discussions, though only 10% access information on which variety to plant. Best engagement times are 19:00–20:00 and the off-season. Location and education significantly influence adoption of climate information and social media use. The study emphasizes enhancing education on social media use and leveraging multiple channels to reach farmers across diverse geographies and socio-economic groups.

KEYWORDS

social media, climate information, adaptation, common bean, WhatsApp, Tanzania

1 Introduction

Climate change is the foremost concern of our time and the most debated subject on social media platforms (Gokcimen and Das, 2024). Climate variability is dictating farming methods such as the use of climate-resilient crop varieties, an essential strategy for adaptation (Acevedo et al., 2020). Absence of climate information matched to suitable varieties is posing significant challenges to majority of smallholder farmers in Sub-Saharan Africa. Therefore, bridging climate and varietal information gaps is pivotal in ensuring that varieties are placed in environments conducive to their inherent strengths. Traditional agricultural communication methods in Tanzania, such as radio, TV, flyers, demonstration farms, and extension services have shown limited outreach due to budget constraints, a narrow focus on specific demographics, and a lack of interactive dialog (Mtega, 2018). Social networks can be used as a tool for climate information exchange and adaptation. Recently, Newman et al. (2024) have shown that social media has emerged as a major source of information, if not the primary, source of news dissemination for substantial portions of the global population. According to Gebre et al. (2023), regular access to climate information is positively correlated with the use of drought-tolerant varieties and crop diversification.

Common bean (*Phaseolus vulgaris*) is a powerhouse crop due to its environmental benefits, nutritional value, and economic importance (Philipo et al., 2021a; Kalemera et al., 2022; Buruchara et al., 2011). Common bean is also a food security crop for most Tanzanian farmers due to its short planting cycle and market price stability. The crop provides employment to farmers, especially youth and women. Common bean demand is anticipated to increase in East African diets in response to rising incomes and urbanization and heathy diets (Beebe, 2020). In response to farmer, market and environmental demand, the Tanzania Agricultural Research Institute (TARI) released 14 bean varieties between 2018 and 2022. Yet farmers and traders are still lacking information on where to obtain seed of these new varieties (Sperling et al., 2020), and potential adaptable environments. Limited access to information about climate-resilient varieties and where to obtain their seed pushes farmers to recycle old varieties (Kessy et al., 2020) and produce them in unsuitable environments. Today, the country's bean production stands at 1.4 tons/ha, far below the potential 3 tons/ha for bush bean varieties (Philipo et al., 2021b).

Earlier legume studies have shown that inadequate information concerning variety traits, productivity, and local agroecological suitability constitutes a pivotal impediment to improved varietal adoption (Sperling et al., 2020; Ojiewo et al., 2020). Increasing awareness about variety traits, availability, climate needs, performance, is crucial for adoption of any seed-based technology (Amondo et al., 2019). Climate information includes weather forecasts, seasonal outlooks, and long-term climate change projections (Antwi-Agyei et al., 2021). Climate information becomes valuable to farmers when it informs decisions on which varieties to plant. Publicly funded agricultural extension has struggled to meet the evolving needs of farming communities in Tanzania (Wambura et al., 2015). Ortiz-Crespo et al. (2021) noted that limited financial resources and staffing shortages create challenges for extension agents, increasing their workload and limiting their capacity to effectively support farmers throughout Tanzania.

According to Ifejika et al. (2019), social media plays a crucial role in rapidly disseminating agricultural technologies and creating real-time awareness about development knowledge. Social media offers wide-reaching, cost-effective, and real-time communication and feedback, facilitating knowledge exchange and community support (Nkuba et al., 2023). This is most crucial for smallholder farmers who struggle to access specific varietal characteristics, seed and extension services due to limited resources and distance. Social media can bridge gaps where conventional methods fall short, especially in disseminating complex information (Valujeva et al., 2023). A study conducted in Nigeria found that farmers use social media to seek knowledge about climate change and share adaptation strategies (Abuta et al., 2021). Customized messages in social media for specific regions and demographics may allow farmers to access information on markets, varieties, weather patterns, and climate-adaptation techniques. Hence emerging information and communication technologies can simplify and reduce the cost of delivering tailored information to these farms (Finger, 2023).

A study by Acevedo et al. (2020) across low- and middle-income countries revealed that farmers' adaptation decisions to climate-resilient crops were significantly influenced by the perceived usefulness of advisory services, education level, socio-economic status, gender, and age. Similarly, Dawid and Boka (2025) highlighted the critical role of education, household size, cooperative membership, access to extension services, availability of climate information, awareness of climate change, and farm income in influencing adaptation strategies. Gebre et al. (2023) further emphasized that being male, having higher education, a larger household, greater landholdings, higher farm income, frequent interaction with extension services, participation in training, and improved access to information significantly affected farmers' adoption of climate adaptation measures.

Marimo et al. (2021) highlighted that access to information and seed is unevenly distributed, often shaped by socio-demographic factors such as age, sex, education, and economic status. In a similar vein, Abuta et al. (2021) demonstrated that in Nigeria, sex, education level and age, facilitated greater use of social media for climate change communication. These studies underscore how socio-demographic differences create disparities in decision making toward climate adaptation and access to agricultural information.

The increasing ownership of mobile phones and social media use among Tanzanian farmers presents an opportunity to enhance varietal and seed knowledge, promote climate-resilient practices, and create online marketplaces. According to DataPortal (2023), Tanzania had 21.82 million internet users (31.9% penetration), 5.65 million social media users (8.3% of the population). While mobile connections are above 67.72 million active mobile connections, which is equivalent to 99%. A study conducted in Dodoma region revealed that 62% of small-scale farmers were using mobile phone technology to support their agricultural production and marketing activities (Mwaseba et al., 2024). However, this study do not clearly separate smartphone ownership from general mobile phone use. Similarly, the study by Quandt et al. (2020), on mobile phone use and agricultural productivity in Tanzania does not explicitly distinguish between smartphone and basic phone ownership in its reported data. The focus is on mobile phone use broadly rather than detailed phone types, indicating a gap in reporting specific smartphone ownership figures among farmers. Although the number of farmers owning smartphones is limited by a number of factors, the future is promising, as the adoption of digital technology among farmers is steadily increasing. Meanwhile, Bakunda et al. (2023) reported that 18.5% of farmers in the Korogwe district obtained information via social media platforms.

While some farmers are already linked to social media platforms in accessing climate information, little is known about the climate events experienced by farmers in the past 10 years, their adaptation strategies and social media use pattern and potential in accelerating varietal and climate information to farmers. Although conventional surveys have long been employed to capture public opinion, recent progress in natural language processing (NLP) provides innovative ways to examine user-generated content from digital media platforms and weblogs (Gokcimen and Das, 2024).

This study contributes to the intersection of agricultural climate impact assessment, climate change adaptation, ICT4Ag, and rural development studies by examining common bean production in sub-Saharan Africa. Drawing on household surveys, long-term climate data, and farmers' social media behavior in Tanzania, it advances understanding of how digital communication and climate information interact to shape adaptation strategies in farming communities. Triangulating farmer perceptions, climate records, and social media interactions offers complementary insights into how these platforms can support climate information delivery.

This study undertook a comparative study by leveraging household survey data collected from four districts of major common bean production zones in Tanzania's Northern and Southern zone. The survey findings on climate events were compared with 30 years climate data, aggregated into three ten-year periods sourced from NASA POWER. Finally, farmers' social media usage reported in the survey is also compared with data from an independent WhatsApp group called "*Kilimo Bora Cha Maharage*" (Swahili for "*Better Bean Farming*").

2 Materials and methods

2.1 Primary data

2.1.1 The study location

This study utilizes household survey data gathered in July 2024, comprising a total of 315 households across four districts in Tanzania: Siha, Karatu (Northern zone), Mbozi, and Sumbawanga (Southern zone).

2.1.2 Household survey

Primary data was collected through a household survey conducted in four districts and two major common bean production zones: Siha, Karatu (Northern zone), Mbozi, and Sumbawanga (Southern zone). These regions and districts collectively provide a representative overview of the climate conditions experienced by bean farming communities throughout the country. The survey was carried out via face-to-face interviews between July 8 and July 24, 2024.

2.1.2.1 Survey design and data collection

This study employed a cross-sectional design to assess climate events experienced by farmers, their communication patterns, and the potential of social media to deliver information. Data were drawn from three sources: household surveys, WhatsApp group discussions, and NASA climate data. Quantitative data from the household surveys were analyzed using descriptive and inferential statistics to identify patterns, prevalence, and associations. Qualitative data from open-ended survey responses and WhatsApp communication analysis provided deeper insights into farmers' experiences and social dynamics. The three datasets were analyzed independently and then compared to identify convergent or divergent insights. This triangulation was used to enhance contextual validity and capture multiple perspectives, providing both statistical generalization and contextual interpretation, without establishing correlation or causality across data sources.

2.2 Secondary data

2.2.1 Climate and WhatsApp data source

Secondary data included country-wide temperature and rainfall, which we downloaded from the National Aeronautics and Space Administration (NASA) Prediction of Worldwide Energy Resource (POWER) Project's Hourly 1.0 version on 2023/11/26. The thirty-year rainfall and temperature data (covering 1991 to 2020) was divided into 10-year intervals. The temperature and rainfall offer several significant advantages, primarily due to the quality, coverage, accessibility, and comprehensiveness of the datasets provided by NASA's satellites. The data was used to assess temperature and rainfall climate variability and climate change, estimate the short- and long-term effects of climate on agricultural production. This aligns with a similar approach used by Ochieng et al. (2016) and Sarker et al. (2012). Also, the data was compared with survey responses on events experienced by farmers.

Another secondary data was the 2 years (2022–2024) WhatsApp discussions from *Kilimo Bora Cha Maharage*, a WhatsApp group dedicated to bean production. The WhatsApp user group platform has 198 members. The platform was established in May 2016, and it connects multiple actors including farmers 62%, non-governmental organizations (NGOs) 12%, researchers 12%, grain traders 8%, processors 2%, agri-input suppliers 8% (e.g., seed producers) from Tanzania and beyond. It serves as a valuable space for seeking expert advisory, knowledge sharing and providing updates on bean production and commercialization. The platform was selected for its exclusive focus on common bean production and its broad farmer representation across the major bean-producing zones of Northern, Southern, and Lake. For data security reasons the study focused on key platform discussions without linking them to any individual participants. Since none of the survey respondents were members of this WhatsApp group, it served as an ideal platform for independent validation of information. Prior to downloading the WhatsApp data, verbal and signed consent was obtained from the group administrator.

Additionally, this study was reviewed and approved by The Institutional Review Board (IRB) for International Center for Tropical Agriculture (CIAT) with approval number IRB32 to ensure that the rights, welfare, and privacy of participants are protected.

2.3 Survey data collection and sampling procedure

2.3.1 Sample size determination

In each of the four target regions, one district was selected, followed by the selection of two wards per district, and two villages per ward, guided by the district office. Approximately 20 households were randomly chosen from each village, focusing on areas prominent in common bean production and covering different agro-ecological zones to ensure representativeness. The farmers interviewed were reached through random sampling. The study focused on household head members responsible for decision-making. If the household head was unavailable, another representative with decision-making authority was interviewed. Therefore, the total sample size consisted of 315 bean farming households. To determine the sample size, the formula by Yamane (1967) was applied using below Equation 1.

$$n = \frac{N}{1 + N\,x\,e^2}$$

Where:

- N = 1,482 (Population size)
- *e = 0.05* (margin of error for a 95% confidence level)

Therefore, the required sample size for a population of 1,482 with a 5% margin of error is approximately 315.

2.3.2 Semi-structured interview

Semi-structured interview questionnaires were designed and configured using the Survey CTO tool and featured both closed and open-ended questions. The closed-ended questions generated quantifiable data, while the open-ended questions provided deeper insights and detailed explanations. Before commencing the questionnaire survey, respondents were briefed on its purpose and informed that the collected data would be used solely for academic research. Assurances were given to protect the privacy of the respondents and their households, and all data was gathered with their voluntary participation and verbal consent.

2.4 Data analysis

This study used three different types of data sets to assess and compare the feedback which were received from the survey participants on climate events and social media communications. Since the study is an exploratory assessment of potential rather than a definitive test of correlation or causation, the three datasets were analyzed independently.

Climate Data: Historical temperature and rainfall (X and Y) location point data were analyzed using spatial analysis techniques in ESRI ArcGIS 10.8. Specifically using Inverse Distance Weighting (IDW) was employed to interpolate and analyze spatial climate patterns using below Equation 2.

The Inverse Distance Weighting (IDW) calculation is expressed as:

$$\mathrm{IDW}(Zi) = \Sigma\left(Zj / dij\hat{\ }p\right) / \Sigma\left(1 / dij\hat{\ }p\right)$$

Where:

$$Zi = \text{Estimated value at location i}$$

$$Zj = \text{Known value at location j}$$

$$dij = \text{Distance between point i and j}$$

$$p = \text{Power parameter (set to 2)}$$

Household Survey Data: Data collected from the household surveys was analyzed using descriptive statistics and Logistic Regression. A Generalized Linear Model (GLM) was incorporated within the Logistic Regression analysis, with all analysis performed using R, using below Equation 3.

The Binary Logistic Regression model is expressed as:

$$\mathrm{Logitp}(x) = \log\left[p(x)1 - p(x)\right] = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta nXn + \varepsilon \quad (1)$$

where *Logitp*(*x*) = Natural log of the odds of using social media to access climate information.

$$p(x) = \text{Probability of using social media}$$

$$1 - p(x) = \text{Probability of not using social media}$$

$$1 - p(x) = \text{Probability of not using social media}$$

$$\alpha = \text{Constant of the equation}$$

$$\beta_1 - \beta_n = \text{Coefficients of predictor variables}$$

$$X_1, X_2 \ldots X_n \text{ are predictor variables entered in the model}$$

$$e = \text{The precision error, which is 0.05}$$

$$\text{The predictor variables are: } X1 = \text{Performance expectancy}$$
$$X2 = \text{Effort expectance}$$
$$X3 = \text{Social influence } X4 = \text{Facilitating conditions}\}$$

WhatsApp Data: The text data from the *Kilimo Bora Cha Maharage* WhatsApp Platform Communications was analyzed using R. This involved creating WordCloud model to identify key themes and sentiments. The WordCloud was performed using Equation 4.

Where the WordCloud is expressed as:

$$\mathrm{WordCloud}(\mathrm{Text}) = \mathrm{wordcloud}(\mathrm{Freq}(\mathrm{TDM}(\mathrm{Clean}(\mathrm{Text}))))$$

Where:

$$\mathrm{Clean}(\mathrm{Text}) = \text{lowercase} + \text{punctuation removal} + \text{stop words removal} + \text{whitespace stripping}$$

$$\mathrm{TDM}(.) = \text{Term–Document Matrix generation}$$

$$\mathrm{Freq}(.) = \text{Word frequency computation}$$

$$\mathrm{wordcloud}(.) = \text{Word cloud visualization using frequency data}$$

3 Results

3.1 Socio-demographic characteristics

In total, 315 households (33% women) respondents were interviewed, the majority of respondents were male household heads (67%), followed by female spouses (17%), female household heads (4%), and adult children (4%). The study targeted household members who were in a position to make decisions. In cases where the head of the household was absent, a representative capable of making decisions was interviewed instead. By location, the highest proportion of respondents came from Mbozi district (26%), followed by Karatu and Siha (24.8%), and Sumbawanga district (24.4%). The respondents ages ranged widely, with an average age of 45 years (Table 1). The majority (41.60%) were between 36 and 50 years, 26.7% were aged 18–35 years' old, 51–65 years were 25.4%, while only 6.3% were aged above 66 years (Table 1).

Most (74.6%) of the respondents had only received primary school education (0–7 years in school), followed by 17.83% who had spent 8–11 years in formal education, while only 4.4% had reached Diploma-level (12–13 years' schooling) and 3.2% had spent the most time in formal education, reaching College/University level (14–16 years' education) making them the least represented group. Regarding experience in agriculture, the highest proportion (50.5%) of farmers worked in the agriculture field 0–10 years, while only 11.1% of farmers had worked for 31 years or more (Table 1).

3.1.1 Climate events and adaptation experience

This study not only intended to explore the critical role of social media in delivering climate information to farmers, but also to examine the climate challenges farmers have faced over the past decade, and the strategies they have adopted to adapt to these challenges. Farmers were asked to recall climate events experienced over a 10-year period, providing a manageable timeframe to enhance reliability in their responses. Our results indicate that 97% of farmers feel there have been changes in weather patterns during the past 10 years. Regardless of sex and location, results indicated that 168 (53%) farmers have noted significant climate variability in the past 10 years, with increased rainfall (100%) being the highest climate variability observed (Figure 1).

The Southern zone districts of Sumbawanga (35%) and Mbozi (26%) had highest number of farmers who recalled experiencing increased rainfall, followed by the Northern zone districts of Karatu (23%) and Siha with the lowest score of (19%). The farmer responses and survey results were also compared with a spatial analysis map generated using NASA POWER climate data (Figure 2). The map represents a 30-year period, divided into three 10-year intervals to help observe long-term trends. Results show a steady increase in the average precipitation trends over the past 30 years. The analysis seems to align with farmer views, especially in the Southern zone compared to the Northern zone of Tanzania.

These increased precipitation events have caused severe impacts on common bean production, the most significant being a decline in yield (57%). Other challenges include increased disease incidence (17%), pests (15%), weeds (12%), and difficulty in timing seasons (12%). Decreased land quality (8%), emergency of new diseases (2%), and issues like waterlogging and rising production costs (4%) each, have further amplified the situation (Table 2).

TABLE 1 Household demographic characteristics.

Variables	Observations	Percentage (%)
Sex	Women	33
	Men	67
	Male household head	67
	Female spouse	17
	Female household head	4
	Female adult child	12
District	Mbozi	26
	Karatu	24.8
	Siha	24.8
	Sumbawanga	24.4
Age	18–35 years: Youth	26.7
	36–50 years: Middle aged	41.6
	51–65 years: Older adult	25.4
	66 + years	6.3
Education	0–7 years (Primary school)	74.6
	8–11 years (Secondary school)	17.83
	12–13 years (Advanced/ Diploma)	4.4
	14–16 years (University/ College)	3.17
Experience in agriculture	0–10	50.5
	11–20	22.9
	21–30	15.6
	31+	11.1
	N = 315	100

Regarding adapting to these events, 57% of farmers reported taking no measures, of which 59% cited the main reason being a lack of knowledge on what actions to take. Among the 43% taking action, the top seven most cited strategies included early planting (25%), spraying pesticides (20%), changing crop varieties (18%), crop diversification (14%), Soil & water conservation measures (13%), Changing crop types (13%), and Changing planting location (11%), while only 1% mentioned conducting water harvesting (Table 3).

3.1.2 Mobile and smartphone ownership

Mobile phone ownership was noted to be higher (84%) among interviewed farmers, with 38.2% being women. By contrast, only 70 (22%) farmers (25.7% women) owned smartphones. Karatu District in the Northern zone had the highest smartphone ownership (36%), while the Southern zone district of Sumbawanga had the lowest (13%) (Table 4).

Smartphone ownership based on age showed that middle-aged adults (36–50 years) had the highest representation at 44%, while the 66 + aged had the lowest at 5% (Table 3). Smartphone ownership is shown to increase with higher education levels where majority owners have an average of 7–10 years of schooling, while ownership is low among individuals with lower education (5 years of education; Table 4).

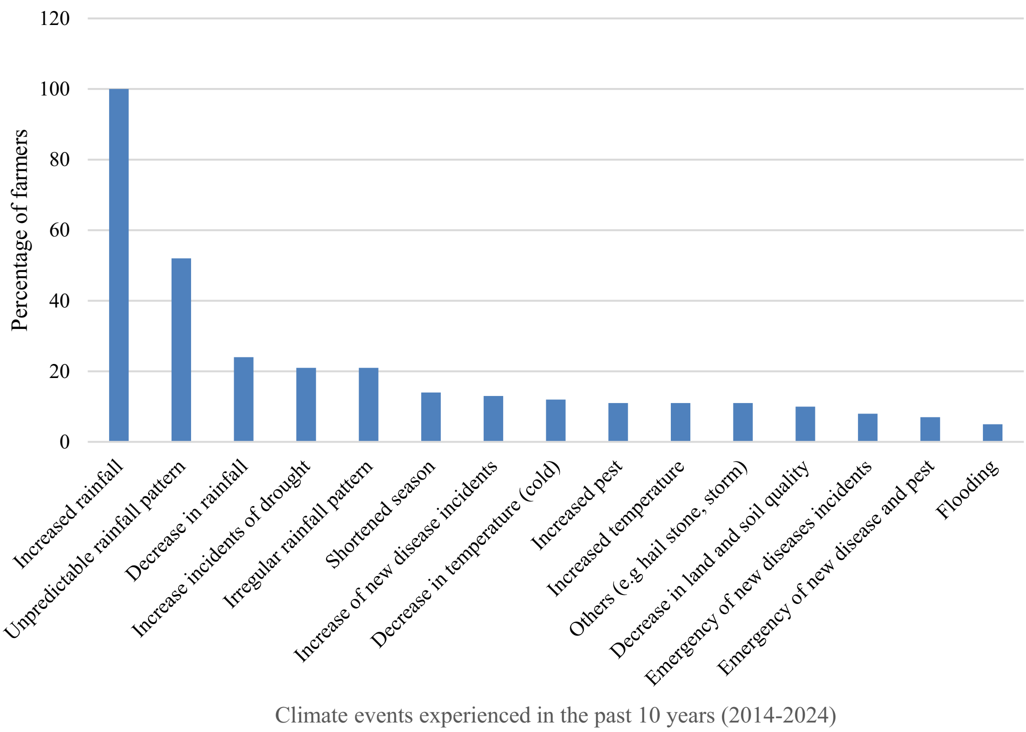

FIGURE 1
Climate events experienced by the surveyed farmers in the past 10 years (2014–2024).

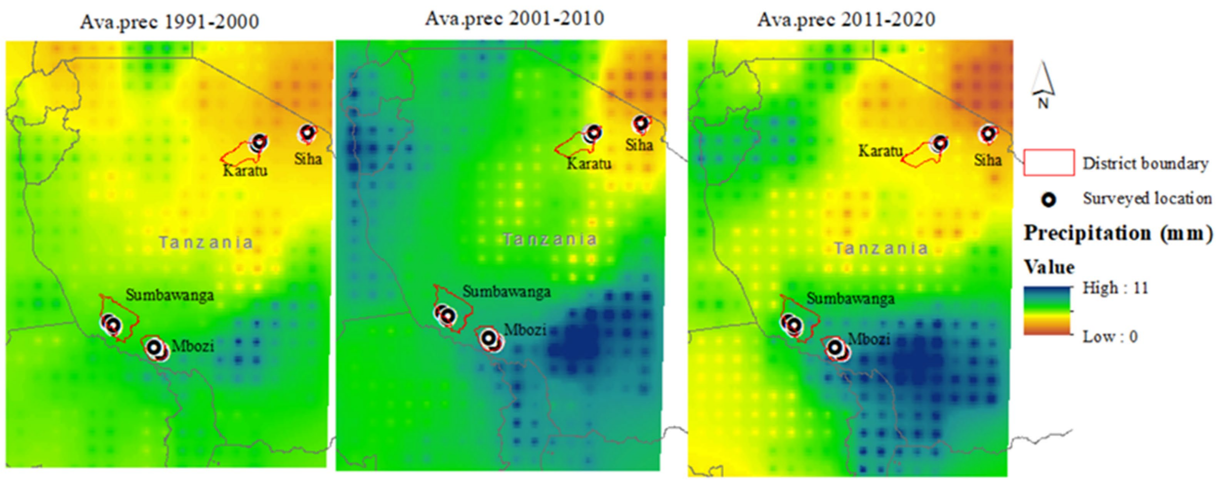

FIGURE 2
Spatial average precipitation variability from 1991 to 2020 (Data source: NASA POWER Project server).

3.1.3 Social media access, usage patterns and engagement among farmers

Farmers reported varying starting years for social media use, with adoption steadily increasing from 2% in 2009 to 26% in 2023. However, there was a notable decline in subscriptions from 9% in 2016 to 2% in 2018, attributed to the introduction of several regulations in the country (Figure 3).

Among the 70 smartphone owners, 58 equivalent to (18.4%) farmers (70.7% men and 29.3% women) were already connected to social media. If the farmer was using more than one social media platform, they were asked which one they use the most. WhatsApp emerged the most used App (67%), Followed by Facebook (28%), while the least used were YouTube, TikTok, and Opera (2% each) (Table 5). Most of the farmers (60%) use social media for networking and engagement with the community.

On frequency of social media use: nearly half (48%) of the participants reported using social media daily and only a small fraction (2%) used it on a monthly basis (Table 5). Most respondents (36%) spent 2–4 h per day on social media, while only 5% spent 4–6 h, making them the least represented group. The most popular browsing

TABLE 2 Impact caused by climate events.

Impacts caused with climate events	%
Decline in yield	57%
Increased disease incidence	17
Pests	15
Weeds	12
Difficulty in timing season	12
Decrease land quality	8
Water logging	4
Rising of production cost	4

TABLE 3 Adaptation measures taken by the surveyed farmers.

Adaptation strategies reported	Percentage (%)
Early planting	25
Spray of pesticides	20
Changing crop varieties	18
Crop diversification	14
Soil and water conservation measures	13
Changing crop types	13
Changing planting location	11
Change of fertilizer application rates	6
Irrigation	4
Mixed varieties	4
Moving to high elevation areas	3
Tree planting	2
Change to organic manure	2
Water harvesting	1
Total (*N* = 168)	136

TABLE 4 Mobile phone ownership among survey respondents.

Definition and degree	Variable	Percentage (%)
Farmers owning mobile phones	Women	38.20
	Men	61.80
	N = 266 (84%)	
Farmers owning smartphones	Sex	
	Female	25.70
	Male	74.30
	N = 70 (22%)	
	Age category	
Smartphone ownership by age category	18–35	31.60
	36–50	44.30
	51–65	19.10
	66+	5.00
Smartphone ownership per district	Karatu	36
	Mbozi	26
	Siha	26
	Sumbawanga	13

time was early evening (19:00–20:00), preferred by 53.4% of respondents, whereas early morning hours (04:00–08:00) were the least preferred, with only 3.4% browsing during this period (Table 5).

The browsing time and discussed topic was also compared with data obtained from the *Kilimo Bora Cha Maharage* WhatsApp platform. The findings aligned perfectly with farmers' stated preferences, demonstrating consistency between their reported habits and actual platform usage patterns (Table 5; Figure 4). Using the same platform data, we analyzed the platform's activity trends throughout the year, to understand the best months to share the climate information. The results indicate that the platform is most active in January before experiencing a slight decline in February, March, and April. Activity begins to increase again in May and remains high through June, July, and August. Activity decreases again in September and November, followed by another peak in December (Figure 5).

In addition to assessing general social media use, the study aimed to gain deeper insights from farmers specifically connected to agriculture-focused platforms. Of the 58 farmers who reported using social media, only 7 (12%) were members of such platforms representing just 0.2% of the total sample. Among these platform members, women accounted for 28.5%. With the exception of Sumbawanga, seven WhatsApp groups were identified across three districts: Siha (*Kilimo cha Viazi Mviringo*), Karatu (*Kilimo Endelevu RECODA*, *Kilimo Market*, and *SNV Farmers Platform*), and Mbozi (*Mauzo ya Kahawa*, *VBA Mkoa wa Sogwe*, and *Kilimo Bora cha Mbogamboga na Matunda – KIBOWAVI*). The majority of these groups (71%) were managed by NGOs such as Helvetas, RECODA, and SNV, while traders and local government each administered 14% of the platforms (Table 6).

3.1.4 Climate information through social media, behavioral change and trust

Among of surveyed farmers, only 30 (9.5%) farmers accessed climate information through social media, 33.3% each from Karatu and Mbozi districts reported receiving climate information through social media, followed by 20.0% in Sumbawanga and 13.3% in Siha. The data reveals a gender disparity in access: only total of 16.7% of women received information via social media compared to 83.3% of men. Notably, Karatu had no women accessing social media for climate information, while Mbozi showed the highest female access at 10%, followed by Siha and Sumbawanga with 3.3% each (Table 7).

Among the 30 farmers who accessed climate information, the majority (90%) received weather predictions, while smaller proportions received guidance on the type of variety to plant (10%), planting time (7%), and pest and disease management (3%). When asked about practices adopted from social media, 82% of 28 respondents reported using climate information frequently before and during planting. Half of the farmers adopted climate-smart varieties, while 25% applied water harvesting techniques. A few (4%) mentioned other adaptations, such as saving capital for farm production (Table 8).

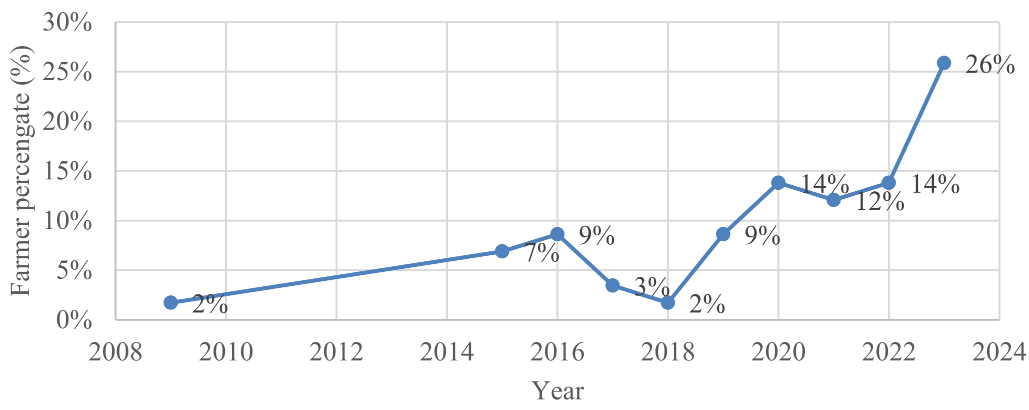

FIGURE 3
Year in which the surveyed farmers started using social media.

TABLE 5 Patterns of social media use among farmers.

Parameters	Observations	Percentage (%)
Farmers connected to social media	Women	29.3
	Men	70.7
		100
Most-used social media channel	WhatsApp	67
	Facebook	28
	YouTube	2
	Opera	2
	TikTok	2
		100
Frequency of social media platform use	Daily	48
	Weekly	40
	Monthly	2
	Rarely	10
		100
Length of time spent on social media platform per day	1–2 h	28
	2–4 h	36
	4–6 h	5
	< 1 h	24
	6 > hours	7
		100
Best time of day/night to browse through social media	Afternoon (14:00–18:00)	12.1
	Early Night (19:00–20:00)	53.4
	Night (21:00–00:00)	19
	Early morning (04:00–08:00)	3.4
	Morning (09:00–12:00)	5.2
	Midday (12:00–14:00)	6.9
	N = 58	100

3.1.4.1 Information sharing

Further analysis of farmers' behavior shows that 93% of those who receive climate information via social media actively re-share the information within their villages, highlighting the importance of peer-to-peer communication at the local level. Nearly half (48%) extend this sharing to others within the ward, while a much smaller proportion disseminates information more broadly at 14% at the district level, and only 3% each at the regional and national levels. These findings suggest that while social media serves as a valuable source of climate information, its redistribution remains largely localized, emphasizing the strong role of community networks in informal knowledge sharing among common bean farmers. This localized sharing can be leveraged to strengthen last-mile communication strategies in climate services (Table 9).

3.1.4.2 Information utilization and trust

When asked about the credibility of climate information received through social media, 67.7% of farmers rated it as highly credible, while 46.7% considered it moderately credible. A small fraction of respondents either did not know (7%) and the rest found the information not credible (3%). Farmers' perception of credibility was influenced by two main factors: 60% cited the reputation of the platform as a key reason for trusting the information, and 63% based their trust on the context in which the information was presented (Table 10).

3.1.4.3 Challenges limiting social media adoption

The study also identified key challenges limiting the adoption of climate information shared via social media among common bean farmers. The most prominent barrier was misinformation or lack of trust in information sources (40%), followed closely by both language and cultural barriers and limited technical expertise in using social media information each reported by 37% of respondents. Privacy concerns were minimal, affecting only 2%, while 7% cited other challenges such as limited digital literacy, internet costs, and difficulty retrieving previously viewed messages (Table 11).

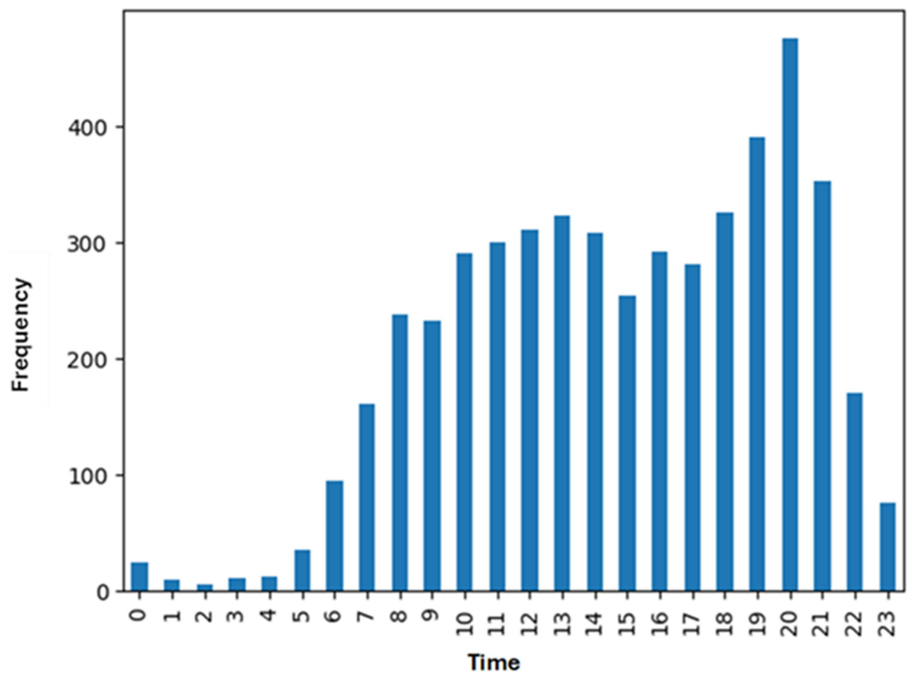

FIGURE 4
Surveyed farmers' preferred time for browsing social media platforms.

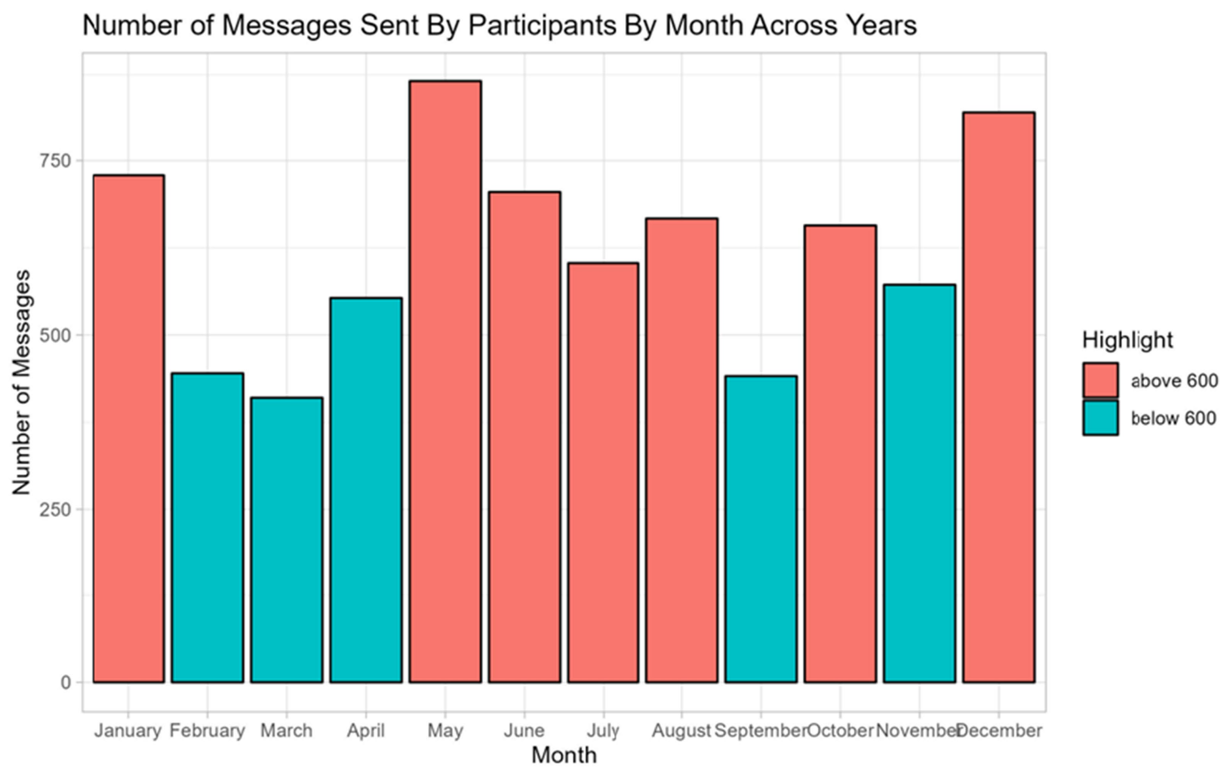

FIGURE 5
Number and monthly frequency of messages sent on the WhatsApp bean group platform.

TABLE 6 Leading information platforms and popular topics discussed/available on the platform.

Platform lead	Percentage %	Popular topic in the platform	Percentage %
NGO	71	Seed	71
Trader	14	Pesticide	14
Local government	14	Market information	14
N = 7	100	*N* = 7	100

TABLE 7 Farmers receiving climate information through social media.

Category	Number	Women (%)	Men (%)	Total Percentage of farmers (%)
Farmers receiving climate information through social media.	30	16.7	83.3	100
				9.5 (*N* = 315)
Farmers receiving climate information through social media among farmers connected to social media.	58	8.6	43.1	51.7
Farmers receiving climate information through social media among farmers owning smart phones.	70	7.1	35.7	42.9
District				
Karatu	10	0	33.3	33.3
Mbozi	10	10	23.3	33.3
Siha	4	3.3	10	13.3
Sumbawanga	6	3.3	16.7	20
	N = 30			100

TABLE 8 Type of climate information received by farmers through social media and behavioral change.

Type of climate information received	Percentage (%)	Adopted practices from social media	Percentage (%)
Weather prediction	90	Frequent use of climate information prior and during planting	82
Planting time	7	Use of climate smart varieties	50
Type of variety to plant	10	Use of water harvest management techniques	25
Disease and pest management	3	Others (saving capital for farm production)	4
N = 30		*N* = 28	

TABLE 9 Information sharing.

	Location	Percentage (%)
	Within village	93
	Within Ward	48
Do you reshare the information you receive?	District	14
	Region	3
	Country	3
	N = 29	

3.1.4.4 Solution for enhancing social media use

To overcome these barriers and enhance uptake, farmers suggested several strategies. The most recommended was the sharing of success stories and innovative solutions (63%), followed by customizing climate-related content to fit diverse cultural and local contexts (53%), and the use of simple, easy-to-understand language (47%). These responses indicate that beyond access, trust, relevance, and clarity of information are crucial for effective adoption. Therefore, improving digital literacy, promoting relatable farmer experiences, and tailoring messages to local contexts are essential strategies for strengthening climate communication through social media (Table 11).

3.1.5 Evaluating the factors influencing social media usage for climate information access

The Logistic regression was used to analyze socio-economic and demographic factors associated with farmers' use of social media. Results indicate that education level is the most significant predictor (Estimate = 0.038, $p < 0.01$). This suggests that farmers with higher levels of education are substantially more likely to adopt and use social media platforms, highlighting the importance of education in enhancing access to digital information. Similar results were reported by Almasi et al. (2023) in Tanzania and by Abuta et al. (2021) in Nigeria, respectively (Table 12).

TABLE 10 Trust on the information shared.

Do you consider the information credible?	Percentage (%)	Why do you perceive the way you perceive it?	Percentage (%)
Highly credible	67.7	Reputation of the platform	60
Moderate	46.7	Context in which the information is presented in	63
I do not know	7		
Not credible	3		
N = 30		*N* = 29	

TABLE 11 Farmers' reported challenges for social media adoption and their proposed strategies to improve uptake.

Challenges to adoption (%)		Strategies to improve uptake (%)	
Misinformation (not trusting information sources)	40	Use of simple language	47
Lack of technical expertise in using social media information	37	Success stories, innovative solutions	63
Language and cultural barrier	37	Customizing climate-related content to resonate with diverse audience	53
Privacy concerns	2	Other (e.g., education on climate change and advocate on smartphone use)	7
Other (e.g., Internet cost and having difficulty locating a message I previously viewed)	7		
	N = 30		*N* = 30

TABLE 12 Marginal effects of factors influencing social media usage.

Coefficients	Estimate	Std. Error	*Z* value	*p*-value
Age	−0.0042	0.0043	−0.98	0.329
Sex	−0.0132	0.0716	−0.18	0.854
Education	0.038	0.0116	3.28	0.001 ***
Income	2.07e-07	1.16e-07	1.79	0.073 *
DistrictMbozi	−0.1384	0.101	−1.37	0.171
DistrictSiha	0.0054	0.1281	0.04	0.966
DistrictSumbawanga	−0.1570	0.112	−1.41	0.159
Experience in farming	0.0016	0.00486	0.34	0.730
Land size	0.0198	0.01873	1.06	0.290
Household size	−0.0079	0.01634	−0.49	0.627
Extension service	−0.1021	0.07187	−1.42	0.155
Membership to farmer group	0.13684	0.07293	1.88	0.061*

N = 315 social media users, *,**,*** significant at 10, 5 and 1%, respectively.

4 Discussion

4.1 Climate events and adaptation

Majority (93%) of farmers have felt that climate has changed for the past 10 years. The most common climate event has been increased rainfall (100%), particularly in southern zone districts of Tanzania. This statement is also supported by the climate data spatial analysis of NASA POWER for 1991–2020 (Figure 1). The findings align with prediction of Borhara et al. (2020) and Jha et al. (2023), who predicted increased precipitation in Southern zone and drier Central and Northern zone. Excessive moisture in soils is known to create anoxic conditions that hinder nitrogen fixation, nitrogen uptake, root growth, and nodulation in common beans (Beebe et al., 2013). Notably, 57% of the farmers interviewed are not taking any measures to adapt to these challenges due to lack of knowledge of what is required. Farmers who do act commonly use strategies such as early planting, applying pesticides, diversifying crops and varieties, soil and water conservation, changing crop types, and changing planting location (Table 3). Similar strategies have also been observed in Kenya (Gebre et al., 2023) and in South Africa (Maka, 2025). Logistic regression analysis indicates that adoption to mitigation measures is more influenced by location (district differences) and, to a lesser extent, age and extension services (Table 13). Therefore, location-specific mitigation programs, age sensitive training to different categories, and enhancing quality and relevance of extension services to improve farmers' adoption of climate change mitigation measures is vital. Interestingly, access to extension services was negatively associated with adoption to climate adaptation measures ($p < 0.10$), suggesting that farmers receiving extension support were less likely to implement mitigation practices. Similar findings were reported by Maka (2025) in South Africa, highlighting that the mere availability of extension services does not guarantee positive adaptation

TABLE 13 Marginal effects of the factors influencing farmers' adoption of climate-change mitigation measures.

Coefficients	Estimate	Std. Error	*z* value	*p*-value
Age	−0.0057	0.00327	−1.74	0.082*
SexMale	−0.0428	−0.0600	−0.71	0.475
Education	−0.0115	0.0114	−1.00	0.317
Experience	0.00402	0.00333	1.21	0.228
DistrictMbozi	−0.1872	0.0768	−2.44	0.015**
DistrictSiha	0.0638	0.0785	0.81	0.416
DistrictSumbawanga	−0.154	0.0826	−1.86	0.062*
Total Land size	0.0138	0.0140	0.98	0.325
Household size	−0.0027	0.0128	−0.21	0.836
Extension services	−0.0940	0.0573	−1.64	0.100*

$N = 315$, *, **, *** significant at 10, 5 and 1%, respectively.

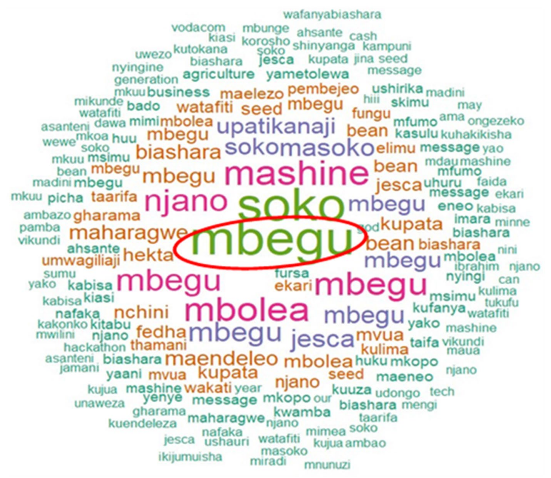

FIGURE 6
Among the topics discussed on the *Kilimo Bora Cha Maharage* WhatsApp group, *mbegu* [seed] is the most popular.

outcomes, possibly reflecting challenges in the quality or delivery of advisory support.

4.2 Role of social media usage pattern and its potential for climate information delivery

Both smartphone ownership (22%; 25.7% women) and social media usage (18.4%; 29.3% women) among farmers remain low particularly women, older farmers and Sumbawanga farmers (Tables 4, 5). Indicating information access disparity among social groups and location. In the meantime, social media subscriptions are increasing yearly, indicating its future widely usage potential. WhatsApp is the most widely used platform by farmers (67%) in Tanzania, also noted by Almasi et al. (2023) and Adejo and Opeyemi (2019) in Nigeria. Best engagement times is between 1900-200hrs daily and off planting months. This means farmers are more likely to engage with and access climate information on social media around this period. Among social media users, 42.9% access climate information via these platforms (Table 7), with women accounting for only 16.7%. By district, notably, in Karatu no female respondents reported accessing climate information through social media (Table 7), underscoring persistent gender and location inequalities in digital access.

Out of the total population only 9.5% (16.7% women). are accessing climate information through the platforms Figure 6. The type of information received is dominated by weather prediction (90%), while guidance on variety type to plant is limited (10%), yet seeds 'mbegu' remain a dominant topic on agricultural platforms (Table 6; Figure 6). This suggests that farmers need clearer guidance on seed of particular variety to plant bundled with weather prediction data. Meanwhile, farmers are utilizing this climate information before and during planting (82%) and adopt climate-resilient varieties (50%) promoted on the platforms (Table 8). The information utilization reflects behavioral change, showing that when relevant information is accessible, farmers readily integrate it into their practices. Nevertheless, about 93% of farmers receive climate information via social media re-share it within village networks (Table 9). Such peer-to-peer exchange positions social media as both a learning tool and a mechanism to accelerate adaptation. Farmers (67.7%) perceive the climate information they receive as highly credible (Table 10), with trust anchored in platform reputation (60%) and message relevance (63%). Meaning the source of the information holds a strong potential for delivering and adoption of climate information in Tanzania. Logistic regression further shows education as a critical driver of social media use. Similar observations were made by Sebotsa et al. (2020a,b). With 74% of farmers reporting low education, their ability to access and use climate information via social media may be limited. While social media can effectively disseminate such information, structural barriers will necessitate complementary channels to reach women and other underserved farmers categories.

Among the barriers, misinformation and lack of trust (40%) top the list (Table 11), hindering effective use of social media for climate communication, as also noted by Gokcimen and Das (2024), stressing that accessibility alone is not enough without trust.

4.3 Limitation of the study

A key limitation of this study is its reliance on social media to disseminate climate and varietal information. While promising, risks like education, location, sex and age differences may reduce effectiveness representing these groups. Additionally, the study's cross-sectional design limits generalizability, as survey and qualitative data may not represent broader populations or capture the full diversity of experiences. Nonetheless, triangulating quantitative and qualitative evidence enhanced credibility and depth, supporting transferability to similar contexts. Future research should further explore causal links across diverse data sources.

4.4 Policy

Policy should focus to enhance farmers' climate adaptation capacity through access to digital tools such as smartphones especially among women, strengthen digital literacy, and ensure climate information is shared in farmer-preferred formats. The policy should also work to build a credible, culturally, and geographically relevant content for information utilization. District-level collaboration among extension services (both public and private), meteorological agencies, and research institutions is necessary to delivering verified information.

5 Conclusion and recommendations

Although the social media usage is still low, there is growing potential in the near future as the subscription keeps increasing yearly and farmers utilize and trust the information shared. Information on specific seed varieties, their suitable growing conditions, and access points should be delivered to farmers in a timely manner. A needs assessment should be conducted across farmer categories (age, sex, education, gender, and adaptation knowledge) in each location to identify the most effective ways of supporting climate adaptation for different groups. Meanwhile, agricultural stakeholders should adopt integrated, multi-channel strategies combining social media, radio, SMS, local dramas, and in-person advisory services to reach diverse farmer category.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by The Institutional Review Board (IRB) of the Alliance of Bioversity International and CIAT. Verbal consent was obtained from the respondents for the publication. Verbal consent was obtained from the WhatsApp group administrator, with assurances that the data would be used solely for academic research and that members identities would remain confidential and no personal identifiable information was included in the analysis.

Author contributions

SK: Conceptualization, Validation, Writing – review & editing, Investigation, Formal analysis, Software, Resources, Methodology, Data curation, Visualization, Writing – original draft. PV: Formal analysis, Visualization, Methodology, Supervision, Conceptualization, Writing – review & editing, Data curation, Investigation, Validation. EM: Writing – review & editing, Supervision, Methodology, Validation, Formal analysis, Visualization, Conceptualization, Investigation. TA: Project administration, Formal analysis, Writing – review & editing, Methodology, Funding acquisition, Supervision, Investigation, Resources, Conceptualization. JI: Methodology, Formal analysis, Data curation, Visualization, Writing – review & editing, Investigation, Conceptualization, Supervision. JO: Formal analysis, Resources, Visualization, Data curation, Investigation, Validation, Supervision, Project administration, Writing – review & editing, Funding acquisition, Methodology. JR: Writing – review & editing, Supervision, Methodology, Conceptualization, Investigation, Visualization, Funding acquisition, Resources, Project administration, Data curation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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