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New Information and Communication Technologies for climate services: Evidence from farmers in Ada East District, Ghana

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A R T I C L E I N F O

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A B S T R A C T

How people respond to climate information service (CIS) depends on how information is designed and communicated. While the introduction of new information and communication technologies (ICTs) has improved the delivery of CIS, there are persistent usability challenges, especially among smallholder farmers. This study examined the usability of new ICTs in delivering CIS for farming in Ada East District, Ghana. The research addressed the question, how do smallholder farmers respond to CIS delivered through new ICTs, and what are the usability challenges of these technologies. Using data from document reviews, interviews, and focus group discussions, findings show that farmers predominantly rely on local or indigenous knowledge and traditional ICTs like radio and television for CIS, 7 New ICTs including: Website on weather information, Bulletin on social media: Facebook, WhatsApp weather forecast presented as a flyer, YouTube video on weather information, Short message service (SMS), Audio WhatsApp weather forecast and Weather apps were identified, providing daily, weekly and seasonal forecasts outlooks. However, the utilisation of these new ICTs is relatively limited. Only a few farmers were aware of the delivery of CIS through these new ICTs. Farmers with smartphones are mainly those who access daily and seasonal forecast outlooks using new ICTs, while face-to-face interactions remain the common mode for disseminating information among farmers. Although new ICTs offer forecasts, usability is influenced by the relevance and comprehension of the content, location success and time, typography, symbols and graphics, language clarity, feedback and interactivity and ability to use the new ICT tools. The findings of the study have implications for CIS developers and providers to incorporate design principles such as revision of text structure, font style and size, symbols, wording pattern and word counts. It shed light on the evolving landscape of CIS delivery in farming communities, where traditional methods coexist with emerging digital platforms and provided knowledge on the need to raise awareness on the use of new ICTs with CIS among farmers.

Practical Implications of the research for policy makers and practitioners: The use of Information and Communication Technologies (ICTs) in Climate Information Services (CIS) offers a transformative approach to agricultural decision-making for farmers. This research identifies various new ICT platforms including Websites, Bulletin on social media: Facebook, WhatsApp weather forecast presented as a flyer, YouTube video on weather information, Short message service (SMS, Audio WhatsApp weather forecast and Weather apps, as key tools for delivering weather and climate forecasts to farmers. The findings have crucial implications for policymakers, businesses, and agricultural extension services, emphasising the role of ICTs in enhancing access to vital climate information for improved farming practices.

Implications for Policy Makers: Policymakers should work towards standardising content and delivery methods of CIS across various ICT platforms to ensure consistency and reliability. This includes setting guidelines for accuracy, clarity, and comprehensibility of weather information. Furthermore, regulatory frameworks should be established to monitor and evaluate the performance of new ICT-based CIS providers, ensuring they meet the required standards and addressing issues of misinformation.

Policies should encourage the development of user-friendly ICT platforms that cater to the diverse needs of farmers. This involves promoting the design of intuitive interfaces that are easy to navigate and available in local

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languages. Policy support for user-centred design can enhance the effectiveness of ICT-based CIS by making them more accessible and practical for end-users.

Enabling feedback mechanisms within new ICT-based CIS can enhance their relevance and usability. Policy initiatives should support integrating interactive features in CIS platforms that allow farmers to provide feedback, ask questions, and seek clarifications. This could involve the development of mobile apps or platforms where farmers can communicate directly with meteorologists or agricultural experts.

The varied use of platforms such as websites, social media, and mobile apps allows for tailored dissemination of CIS to different segments of the farming population. Policy interventions should ensure equitable access to these technologies across all regions, especially targeting under-served and rural areas. This could involve subsidising data costs or providing ICT training to farmers to bridge the digital divide.

Investment in ICT infrastructure is essential to support the effective delivery of CIS. This includes enhancing internet connectivity in rural areas, promoting the adoption of smartphones, and improving mobile network coverage. Such infrastructural developments will facilitate farmers' access to real-time weather updates and ensure the sustainability of new ICT-based CIS.

Implications for Businesses: The emergence of new ICT-based CIS presents significant business opportunities for ICT, telecommunications, and software development companies. Businesses can innovate by developing and marketing new applications, platforms, and services tailored to the needs of farmers. For instance, creating localised weather apps or integrating CIS with agricultural management systems can provide value-added services to the farming community. Businesses can explore partnerships with CIS providers to sponsor or subsidise the delivery of weather information services to farmers. This can enhance brand visibility and corporate social responsibility (CSR) while supporting the agricultural sector. For instance, telecommunications companies can offer discounted data plans for accessing CIS or collaborate with the Ghana Meteorological Agency to disseminate free weather updates via short message service (SMS).

The adoption of new ICTs in agriculture opens up new markets for businesses. Companies can target rural and farming communities with customised products and services such as affordable smartphones, data plans, or specialised apps for agricultural purposes. Market research and segmentation strategies can help businesses identify and cater to the specific needs of different farming segments.

Implications for Agricultural Extension Services: Agricultural extension services should focus on training and capacity building to help farmers effectively use new ICTs to access CIS. This includes training sessions, workshops, and tutorials on using smartphones, navigating websites, subscribing to SMS services, and understanding weather forecasts. Building farmers' digital literacy is crucial for maximising the benefits of ICT-based CIS.

Agricultural extension services can modernise their practices by integrating new ICT-based CIS into their outreach programs. Extension agents can use mobile apps, social media, and other digital platforms to disseminate weather information, offer real-time advice, and engage with farmers more effectively. This approach can enhance the reach and impact of extension services, making them more responsive to the needs of farmers.

To enhance the usability of CIS, agricultural extension services should ensure that weather information is localised and presented in a context relevant to farmers. This involves translating weather updates into local languages, using culturally appropriate symbols, and providing practical advice that farmers can apply directly to their agricultural activities.

Agriculture extension services can facilitate the formation of community networks or groups that share weather information and CIS updates via ICT platforms like WhatsApp or Facebook. These networks can serve as support systems where farmers exchange information, share experiences, and discuss the implications of weather forecasts on their farming practices.

Establishing a feedback loop is essential for the continuous improvement of new ICT-based CIS. Extension agents can collect feedback from farmers on the usability, accuracy, and relevance of the information provided through various ICT platforms. This feedback can be used to refine and enhance CIS, ensuring that it meets the evolving needs of the farming community.

Conclusion: By recognising and addressing the unique challenges and opportunities presented in our research findings, stakeholders can enhance the accessibility, usability, and impact of weather information on farming practices. Together, these efforts can contribute to a more resilient and informed agricultural sector that is better equipped to navigate the complexities of climate variability and change.

Introduction

In recent years, the integration of new Information and Communication Technologies (ICTs) has significantly transformed the landscape of climate information services (CIS) delivery, holding considerable promise for enhancing agricultural practices. The intersection of technological innovation and climate services presents a unique opportunity to address the challenges faced by farmers in adapting to changing environmental conditions (Sarku et al., 2021; Gouroubera et al., 2023). How people respond to climate information service (CIS) crucially depends on how information is designed and communicated. The research and innovation roadmap for climate services emphasises the importance of user-centric approaches, and interdisciplinary innovation focused on co-production, capacity building, and regional modeling capabilities (Street, 2016).

CIS involves the production, translation, and transfer of climate research into actionable information for decision-making (Vaughan et al. 2018). Scholarly discourse on the subject has been that CIS should be relevant, satisfying user needs, and include a procedural dimension engaging users in its development (Tall and Njinga, 2013; Vaughan and Dessai, 2014). Despite empowering farmers to tackle climate risks, low uptake persists due to gaps between information providers and farmers, influenced by communication modes (Nyadzi, 2020; Sarku et al 2021).

Stakeholders are responding to the challenges in various ways, including the delivery of CIS with new ICTs. New ICT in this context refers to online-mobile based messaging applications (e.g., WhatsApp), Short Message Service (SMS), mobile automated messaged and mobile data collection and digital storage applications (e.g., open data kit) that enable the exchange of textual, audio, video and pictorial information between two or more actors (Barber et al., 2016; Bell, 2015). The emergence of multimodal mobile applications as components of smartphones helps to combine voice and touch, pre-recorded, audio, video, music features and so forth to enhance the usability of CIS. The availability of new ICTs helps provide market prices, forecasts, insurance products, and agricultural advisory services among other benefits (Munthali et al., 2018). The tools present new opportunities for information sharing and alternative forms of connectivity (Karpouzoglou et al., 2016; Bennett and Segerberg, 2012). In this context, there are high expectations that new ICTs can enhance interaction and CIS exchange in farming communities.

The development of new ICTs and their adoption is also supported by the provision of, and expansion in infrastructures like the internet, electricity, broadband, submarine cables, telecommunication networks and data centers. Other factors include improvement in connectivity in rural areas and the availability of funding to explore the potential of Big Data as a strategic resource to reconcile productivity and sustainability (FAO, 2022). Also, the youthful population create opportunities for the use of new ICTs in Ghana's agricultural sector. The digitalisation agenda of the government of Ghana has also paved way to attract investors and venture capital inflows (Nyamekye et al., 2022).

Despite expectations, the growth of new ICTs faces challenges that agripreneurs, governments and donors are yet to grasp. Most new ICT initiatives for agriculture including CIS have struggled to scale up, requiring a rethinking of initial strategies and approaches. The ability to upscale innovations and achieve enhanced usability of CIS is attributed to interconnecting socio-economic, cultural, policy and technical issues which create entry barriers for service providers to scale the adoption of new ICT.

Although CIS is still growing, research has been carried out on the institutions, politics, national policies, and gender (Naab et al., 2019; Nyantakyi-Frimpong, 2019, Partey et al., 2019,2020; Nyamekye et al, 2019, 2021; Antwi-Agyei, et al., 2021a,b; Sarku et al., 2024). A few studies have illustrated how co-production has potentials to enhance the usability of CIS for farming (Gbangou et al., 2020; Sarku et al., 2022; Nyadzi et al., 2022). To some extent, research has also involved users (farmers) in the design of service platforms to enhance the usability of climate services (Clarkson et al., 2019; Agyekumhene et al. 2020, Sarku et al, 2020; Caine et al., 2018). Although we recognise the strength of the rich literature in elucidating different aspects of the usability of CIS in Ghana, we opine that there is relatively less attention towards the servicescape aspect (i.e., the behavioural intention of farmers, value creation and perceived service quality). This is particularly relevant in the context of the provision of CIS with new ICTs for farming. The key question is whether new ICTs enable farmers to find, comprehend and apply relevant CIS for decision-making.

With the emergence of the use of new ICTs to provide CIS, little is known about how they are used in practice for farming and whether or not they meet the 'service' needs of farmers. This research area is noticeably lacking from the climate service literature but is arguably implicit in research focused on the design of user-interfaces (e.g. Christel et al. 2018), citizen science research and users' experiences of climate information (Hewitson et al. 2017). Our study aims to examine the usability of new Information and Communication Technologies (ICTs) in delivering Climate Information Services (CIS) for farming in Ghana, specifically in the Ada East District. To attain the objective, we answer the following research questions:

- What type of new ICT-based CIS exists in the Ada East District, Ghana?
- What is the extent and perception of the use of CIS delivered through new ICTs?
- Which factors affect the usability of the new ICTs used for the delivery of CIS for farming in the Ada East District?

Answers to the research questions will contribute to the existing literature by addressing a critical gap on the "servicescape" dimension in the delivery of CIS through new ICTs. While there is substantial research on CIS design, co-production, and user engagement, relatively little attention has been given to the service environment in which these technologies are implemented. Our study is not an attempt to challenge or find fault with CIS delivered with new ICTs; instead, we seek to contribute to knowledge on the use of new ICTs for the delivery of CIS. We identify farmers' experiences and the extent of the use of new ICTs and the factors that affect the usability of information, focusing on the farming communities in the Ada East District, Ghana. We opined that if the usability of new ICTs for CIS delivery is to be enhanced, then it requires knowledge of farmers' opinions on whether such services are designed with servicescape features.

In the next section, we conduct a literature review on concepts such as usable CIS, co-production, servicescapes and new ICTs to summarise what we already know and what more remains to be known. In Section 2.2, we explained the analytical framework guiding the study as well as the description of the study area. the methodology employed for the research are outlined in section 3. The findings are presented in Section 4, followed by a discussion and conclusion in sections 5 and 6 respectively.

Literature review

Usable climate information services

Usable Climate Information Services (CIS) are those that are intuitive, accessible to diverse audiences, and applicable based on their content. In the agricultural domain, a usable CIS for farmers emphasises effective communication and visual presentation of information (Lemos et al., 2012). The delivery and acceptance of CIS can be viewed as a pull–push process, where various conditions and institutions influence usability, with CIS providers on the push side and farmers on the pull side. Information providers perceive they supply valuable information, whereas farmers seek practical knowledge (Sarku et al., 2022). This is akin to a marketplace where information can be likened to good which holds potential usefulness but transforms into usability only when it is applied into decision-making (Dilling and Lemos, 2011).

Several factors, such as conservatism, perceived risk, institutional influences, and cultural aspects, affect the usability of CIS in the farming context (Kirchhoff et al., 2013; Sarku et al., 2022). Additionally, challenges from information providers, like inadequate down-scaling, poor scale-up of innovations, and limited farmer engagement, impact usability (Antwi-Adjei et al., 2021). The Global Framework for Climate Services aims to integrate climate information into decision-making globally, nationally, and locally to manage climate risks effectively (Hewitt et al., 2020). This shift recognises CIS as a tool supporting decision-making through co-production, aligning supply and demand sides (Vincent et al., 2020). Despite efforts to address user context challenges, there's a concern that information providers may neglect the service environment aspect in the guise of co-production in CIS provision.

Co-production

Co-production is a prominent theme in the literature and practice concerning CIS for agriculture, aiming for iterative interaction between service providers and farmers to align objectives (Vincent et al., 2018; Meadow et al., 2015). However, the involvement of users in CIS development does not always eliminate the usability gap due to assumed user profiles and needs by providers. Farmers' limited experience or exposure to CIS further hinders the articulation of their needs (Antwi-Adjei et al., 2021). The service component in CIS delivery is often absent, as models like donor funding or experimental stages dominate, lacking user-driven perspectives and service focus (Antwi-Adjei et al., 2021; Sarku et al., 2024).

In the public sector, farmer involvement in CIS production is considered voluntary, and treated as an 'add-on' controlled by professionals, excluding users from service design and planning. This mode challenges the public service delivery logic, potentially treating users as passive consumers rather than co-producers (Lugen, 2020). Shifting towards a service-dominant culture in CIS production and delivery emphasises user experiences, making them co-producers to enhance service value (Nilsson and Ballantyne, 2014). Drawing knowledge from the service management and marketing sector and various service-based research fields regarding operationalisation of 'servicescape' can offer insights to improve climate services (Osbourne et al., 2012).

Servicescapes

In the CIS context, servicescapes encapsulate the tangible, spatial dimensions, functionality, as well as signs, symbols, and artefacts (tools) that convey information and its quality (Nilsson and Ballantyne, 2014). The servicescape also elicit cognitive, emotional, and physiological responses that significantly impact the behaviour of both service providers and users, shaping the quality of their interaction and influencing customer experiences, expectations, and satisfaction (An et al., 2023). For users to engage with CIS, the service environment serves as their initial point of perception, play a crucial role in shaping impressions regarding the anticipated level of service quality (Amer and Rakha, 2022). Additionally, the servicescape has the potential to affect the nature and quality of interactions between CIS providers and users, allowing providers to intentionally design their services to create an atmosphere that enhances users' overall experience. Regardless of whether the setting is physical or virtual, it is arguable that servicescapes exert influence over users' interpretations of value propositions, expectations, and satisfaction (Nilsson and Ballantyne, 2014).

The application of CIS varies depending on the organisational activities of service providers, such as communication methods and training initiatives aimed at familiarising users with the values, norms, and practices of the organisation (van Beuningen et al., 2011; Bovaird et al., 2015). A further dimension explored in the literature pertains to the motivations driving users to engage with services. Motivations can span from finding services interesting, worthwhile, or enjoyable to seeking material rewards, social rewards, a sense of goal attainment, self-efficacy enhancement, or complying with legal obligations (Sarku et al., 2020). Given the significance of these service features in the context of CIS, it is imperative for CIS research to scrutinise the extent to which these factors motivate the usability of information and to identify pathways through which these motivations can be strengthened.

With the involvement of numerous CIS providers in Ghana (Sarku et al., 2021,2022), there is a growing trajectory toward marketisation of information (Randalls 2010; Webber and Donner 2017). Thus, the language of business and corporate services are permeating the CIS sector in Ghana. We argued that though CIS may have exclusive features in terms of products provided, it is not unique from other public services especially in information dissemination processes, since it aims to meet the demands of users who should be able to extract the highest value from it (Troccoli 2018). Every service is associated with providers, users, goods/products and service delivery mechanisms. Whether a service such as CIS is delivered through the public policy process as a public good, or initiated through private investment or market regulation, the core definition remains the same (Troccoli, 2018). If CIS is a service rendered to farmers, then, this research asks whether service-based characteristics which are evident in other public goods and services are operationalised for the sector. This study seeks to suggest that the idea of servicescape (Mari and Poggesi, 2013) is relevant to the delivery of CIS. Servicescapes hold the potential to impact behavioural intention, value creation, and perceived service quality. However, the incorporation of this concept into the CIS domain remains a relatively unexplored area. Initially funded, CIS has gradually integrated business models, with users making direct and indirect payments (Paparrizos et al., 2023). This evolution necessitates a more focused consideration of the service environment for CIS, especially as new ICTs are increasingly utilised to meet the evolving service requirements in CIS.

New information and communication technologies for CIS delivery

New ICTs are positioned as mechanisms to enhance service delivery and innovation in the agricultural sector (Chakravarty et al., 2018). These technologies provide opportunities for information sharing and connectivity, transforming users into information co-producers and fostering online networks (Stevens et al., 2016). Expectations are high for new ICTs to facilitate interaction and information exchange between CIS providers and users, creating virtual communities for learning, joint problem-solving, and improving farmers' linkages to services (Leeuwis et al., 2018). Data associated with these technologies are linked to databases, allowing for accessible presentation and tailoring of advice and service delivery (McCole et al., 2014; Buytaert et al., 2014). Moreover, new ICTs enhance farmers' access to various information, such as market updates, weather data, production advice, and financial services through SMS mobile applications (Barber et al., 2016; Qiang et al., 2012).

Challenges arise from a technology-centered perspective that overlooks the social context shaping technology use, including human abilities, socio-political influences, and the wider institutional environment (Cieslik et al., 2017; Leeuwis, 2013). New ICTs are expected to bring positive outcomes, but the mutual shaping between technology and society may lead to unintended consequences and amplify existing inequalities (Cieslik et al., 2017; Stilgoe et al., 2013). The implementation of new forms of CIS delivery may introduce new forms of exclusion and deviate from the intentions of CIS providers (Stilgoe et al., 2013).

Research on new ICTs for CIS provision in farming is limited, necessitating a focus on the service environment embedded in the delivery of information with technologies. Drawing from the literature, we proposed an analytical framework with eight criteria to assess the usability of new ICT for the delivery of CIS for farming.

Analytical framework

Usable new ICTs are about the integration of information and ICTs for the delivery of climate or weather forecasts which could be essential for decision-making in farming. We proposed that the usability of new ICTs and CIS is intertwined, as an ICT that delivers information must be usable for the information to be accessed and applied effectively. Conversely, even if the climate or weather forecast is potentially usable, but the medium of information delivery lacks servicescape criteria (design features), the usability gap will persist. Therefore, the usability of ICT and CIS should be considered together, recognising their interdependence. Tailoring new ICTs for optimal usability of weather or climate forecast necessitate the design that fulfills servicescape features and align with farmers' expectations. The premise is that usability guarantees value, emphasising the importance of aligning with users' definitions of a good experience. Eight (8) key criteria drawn from the literature was used to assess the usability of new ICTs for the delivery of CIS. These criteria include the relevance of the content, location success, location time, comprehension, typography, symbols and graphics, use of clear language, feedback and interactivity and ability to use the new ICT tools explained as follows:

- **Relevance of the content** of the ICT platform for decision-making considers how climate or weather information provided with a new ICT platform is relevant or applicable to farming practices, culture, and other socio-economic characteristics of farmers (Sarku et al., 2022). It also evaluates integration with management strategies like input distribution, acreage estimation, and crop yield (Baffour-Ata et al., 2021).
- **Location success** considers whether or not users are able to find or identify the relevant information with an ICT platform (Maat and Lentz, 2010).
- **Location time** refers to the time participants needed to find the relevant information with the new ICT (e.g. less than 5 min). It also

includes considering cognitive load, learnability, and memorability. It takes into account literacy issues and the use of relevant language (Maat and Lentz, 2010).

- **Comprehension** takes into account the understandability of the information displayed by a platform. It also considers the number of keywords conveyed either in text or audio-visual with a new ICT (Pettersson, 2010). Strategies for enhancing comprehension of information could also include simplifying complex terms, avoiding jargon, and ensuring that content is concise and logically organised (Nandakumar et al., 2020).
- **Typography, symbols and graphics** essentially means the application of elements such as the style and appearance of words in a functional and meaningful way. For example, operationalising typography would involve selecting and applying specific fonts, sizes, and styles to convey a particular tone or message. Symbols may be integrated to represent concepts or ideas, and graphics could be employed to enhance visual appeal and convey information effectively (Pettersson, 2010).
- **Use of clear language** involves employing a language that is understandable to wider audiences. Strategies for enhancing clear language include translating information in the local languages (Özkan and Ulutas, 2014).
- **Feedback and interactivity** consider implementing user feedback mechanisms that encourages users to provide comments, suggestions, and report issues (Sarku et al., 2022). It also about incorporating interactive elements such as clickable infographics. The tools could also provide options for users to subscribe to specific topics of interest and foster a sense of community around the information platform (Nyadzi et al., 2018).
- **Ability to use the new ICT tools** consider choosing ICT tools with intuitive interfaces and user-friendly features to facilitate easy adoption. It also concerns the selected tools aligning with the users' needs and technical competencies (Gbangou et al., 2020). It may also foster a culture of continuous learning and adaptation to technological advancements (Sarku et al., 2020b).

The analytical criteria aided in identifying the empirical factors that affect the usability of new ICTs for CIS from farmers' perspectives. Against this conceptual background, this study examines the usability of new ICTs used for the provision of CIS in Ghana.

Research methods

Study area

Ada East District (Fig. 1), situated in the Greater Accra Region of Ghana, encompasses latitudes 5°45′ to 6°00′ (North) and longitudes 0°20′ to 0°35′ (East). Its geographical boundaries include North Tongu District to the north and east (Volta Region), the Gulf of Guinea to the south, and Ada West District to the west (Sarku et al., 2020a). Covering a total area of 289.783 square kilometers, positioned in the coastal savannah agroecological zones, the district experiences annual rainfall of approximately 800 mm (Teye and Owusu, 2015). This climatic condition, coupled with savannah vegetation, supports the cultivation of various crops such as vegetables, cassava (Manihot esculenta), maize

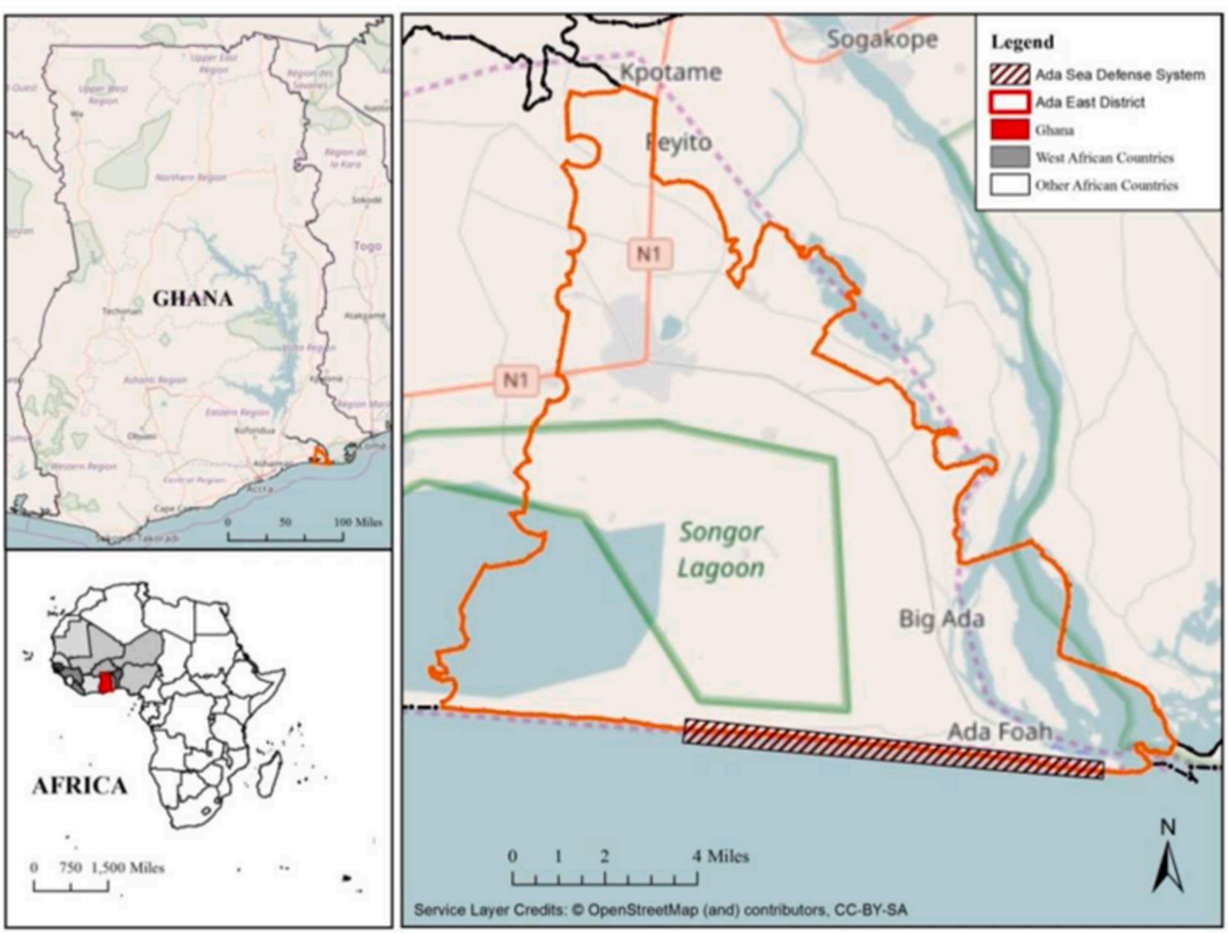

Fig. 1. Ada East district Map with its location in Ghana and Africa ().
Source: Owusu-Daaku, 2017

(Zea mays), sorghum (Sorghum), and rice (Oryza sativa) (Gbangou et al., 2019). However, vegetable farming takes precedence, meeting the demands of urban markets in the Greater Accra Region (Jumpah et al., 2020; Sarku, 2023). The selection of Ada East District as the field research site is rooted in the prevalence of *peri*-urban farming and the intensive cultivation of vegetables for urban markets in the Greater Accra Region. Consequently, CIS gains significance in guiding farmers' decision-making processes. A research on the perception of farmers regarding the usability of ICTs for CIS is relevant in the context of farming in the district.

Research methodology

Research design

The research was conducted as an exploratory study (Jebb et al., 2017) to derive an answer to the main research question on how smallholder farmers use CIS delivered through new ICTs, and what usability challenges do they face in adopting these technologies within their farming practices in southern Ghana. The exploratory qualitative research was therefore designed as an interactive interview with few participantsand focused on what and why questions rather than the development of theories and other variable. Our aim was to engage deeply with key informants who could provide insights into this emerging area, rather than to conduct a comprehensive survey. Therefore, our approach was focused on depth rather than breadth, making it a starting point for further research in other regions.

Data collection

Data collection for the study was conducted in three phases: (1) desktop review of CIS and ICT use, (2) interviews and (3) focus group discussions (FGDs) with farmers(Fig. 2).

Phase1: Desktop review

The first phase involved a desktop review toto identify CIS in Ghana in general and the type of ICTs that were used for the delivery of information. This was carried out by searching the websites of organisations that were providing CIS. Some published literature on CIS for farming were also reviewed. Subsequently, we narrowed the search to identify the delivery of CIS with new ICTs which has coverage extending to the Ada East District. This led to the collection of text, video, images and audio materials on the new ICTs (video recording, flyers, interface of audio recordings, websites, and WhatsApp).

Phase 2: Semi-structured interviews

In the second phase, we conducted 35 semi-structured interviews with farmers from different communities in the Ada East District, including Angorsekope (8 interviews), Kasseh-Kpodokope (5 interviews), Ada Foah (11 interviews), Kajanya (4 interviews), Toje (4 interviews), and Manaikpo (3 interviews). Though seemingly limited in geographic scope, narrowing the study to the Ada East District allows for context-specific insights into the socio-economic and environmental challenges smallholder farmers face. This localised approach provides rich qualitative data, informs future research, enhances understanding of ICT platform implementation, and refines methodology for broader studies on CIS delivery. The unit of analysis for this study was a farming household with selected household head being either male or female or a younger member with much knowledge of the subject.

The interviewees were identified with the help of agricultural extension agents in charge of each of the communities. Interviewees were selected based on the availability and willingness, duration of stay in the community, age, gender, education, years of farming experience, and farming type (Appendix 1). Interviews were conducted using a semi-structured guide that covered demographic details, knowledge of Climate Information Services (CIS), and ICT usage for delivering forecast information. Farmers shared preferences, experiences, and usability challenges of new ICTs for CIS, with suggestions for improvement. ICT identification was based on prior research, literature, and informal discussions with agricultural extension agents, revealing various information sources, including WhatsApp groups, GMet flyers, and YouTube videos. The interviews were conversational, allowing flexibility in question order and promoting open dialogue between participants and researchers.

The second aspect of the interviews focused on evaluating the usability of selected new ICTs for Climate CIS. Participants described various criteria, including the relevance of content for decision-making, location success and time, comprehension, and the clarity of typography, symbols, graphics, language, feedback and interactivity and ability to use new ICT (see section 2 for explanations on each usability criteria). Example, farmers identified weather symbols printed in colour during discussions about typography and graphics. This approach extended to examining downloaded weather forecast videos, smartphone weather apps, and website interfaces. Probing questions stimulated dialogue on the need for refined content and features. The usability test involved interviewees answering questions orally while using

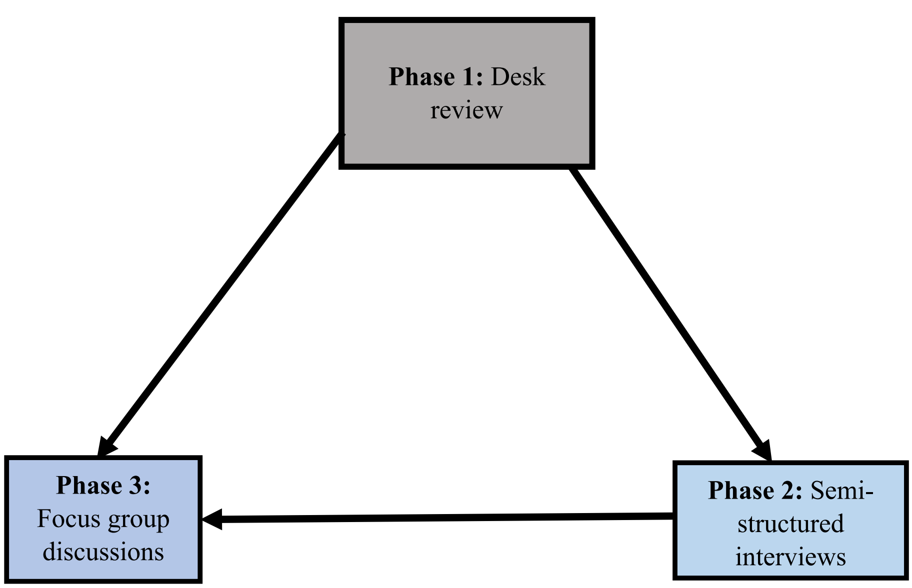

Fig. 2. Approach to data collection ().
Source: Authors' own construct

printed interfaces of selected ICTs. Participants needed to find relevant information and respond to questions to assess location success and time. A stopwatch was used to measure usability i.e how long participants took to locate information, allowing a maximum of 5 min to ensure ample time for individuals with varying literacy levels. Unsuccessful attempts to locate information led to stopping the stopwatch before the 5 min had elapsed. Observations of participant interactions with the ICTs informed insights on usability. The interviews lasted 30–45 min and were audio recorded, with data triangulated against a desktop review to enhance validity.

Phase 3: Focus Group Discussions Following the semi-structured interviews two focus group discussions (FGDs) were conducted i Angorsekope and Ada Foah with mixed group of male and female farmers of varying ages. The focus group discussants in Ansorsekope community comprised 9 participants, that is 5 women and 4 men while the group discussion at the Ada Foah comprised 8 participants (3 women and 4 men). Both men and women were equally engaged in expressing their opinion on each question that was raised during the group meetings. These discussions further explored the usability of ICT-based CIS, with participants reviewing printed interfaces of weather apps, symbols, and forecasts. (see appendix 2). Farmers were encouraged to share their experiences with CIS and provide suggestions for improvement.

Data analysis

The usability assessment of new ICTs for CIS involved analysing audio recordings from interviews, observation notes, and screenshots of selected interfaces, all into Atlas.ti. The analytical criteria were used to categorise and code the data. The video recording, flyers, interface of audio recordings, and snapshots of website interfaces were also coded to identify content, language, and symbols comprehension. To understand new ICTs' (potential) role in supporting the provision of CIS to farmers, we reviewed the content and functionality of the selected technologies, focused on major themes, including 'service provided' and 'service delivery method', 'platform use' and 'identification of platform features', as well as 'factors affecting usability'. Usability metrics such as location success were used to determine if participants could find relevant information within a five-minute timeframe. Each new ICT's location time was also computed, and comprehension was assessed using keywords associated with each technology. The approach was applied to other usability criteria such as relevance of the content, comprehension of the content of the ICT platform, typography, symbols and graphics and language issues. After the initial coding, data regarding extent and perception of the use of new ICTs were exported into Microsoft Excel Spreadsheet. The responses were categorised qualitatively based on the number of interviewees who reported using specific technologies. The categories were defined as follows: "most used" (30–35 interviewees), "often used" (20–29 interviewees), "moderately used" (10–19 interviewees), and "less used" (0–9 interviewees). Further interrelations between themes were analysed and explanatory factors for key findings were identified and supported with exemplary quotes from the transcripts and researcher's observations. The codes were compiled, summarised, mapped and interpreted to align with the research questions.

Findings

This section presents the results of the analyses, presented as into three sub-sections as follows:

Type of new ICT-based CIS for farming

Aside community radio and television which are traditional mode of information dissemination, we identified 7 new ICTs for delivering climate and weather forecast information in the form of text-based, imagery, video or audio based:

1. Website on weather information,
2. Bulletin on social media: Facebook,
3. WhatsApp weather forecast presented as a flyer.
4. YouTube video on weather information
5. Short message service (SMS).
6. audio WhatsApp weather forecast.
7. Weather apps.

Each of these new ICTs offers weather information tailored to specific regions in Ghana. For example, the Ghana Meteorological Agency (GMet) not only provides a nationwide forecast; it disaggregates data for all 16 regions in Ghana and highlights specific communities when the forecast indicates an impending condition. This localised approach is the reason we included these in our analysis. By providing detailed regional forecasts, farmers in Ada East can utilise this information effectively, ensuring it is relevant and applicable to their specific agricultural practice.

Website weather information

The website (https://www.meteo.gov.gh/gmet/) of the Ghana Meteorological Agency (GMet) was identified by farmers as one of the new platforms providing CIS. The website has eight main tabs labelled as 'Weather', 'Climate Change' 'Research', 'Services' 'About Us', 'Media Center', 'Maproom', and 'Resources' (see Fig. 3). The 'Weather' tab has other hyperlinks such as 'Regional Weather', 'International Weather', 'Aviation', Marine, and 'Events'. There were links to social media (Facebook, Twitter, YouTube) displaying weather and other meteorological news. The homepage also has news warning on expected weather conditions such as floods, rainstorms, and bushfires with accompanying advice for the public. For example, a warning indicating "*DUST STORM, GMet advises rise in sore throat, cough and sneezing and* that residents should stay indoors, use air purifiers if available, and wear masks when going outside to minimise health risks", a warning of "*Heavy floods expected – GMet* urges residents to prepare and advise communities stock essential supplies, and stay updated on local alerts to ensure safety." Also as seen in Fig. 3 "*2023 minor rainfall seasonal forecast– September, October, November inform the public of normal onset in inland places and early onset in coastal areas etc.*". The home page displayed a regional weather forecast, captioned as '*24- hour forecast for Ghana*' with symbols of different weather conditions for each region. There were other tabs and links such as '*Frequently Asked Questions*', '*News*' on the achievements and services (acquisition of data) from the agency. In addition, the website connects to the social platform channels of GMet.

Bulletin on social media: Facebook

We also found bulleting/flyers on seasonal and daily weather forecasts posted on the Facebook page of GMet (see Fig. 4). A flyer with information on a seasonal forecast indicates:

"KINDLY SHARE!!! 🌧 ⛈ 🌧 ⚠ 2020 SEASONAL FORECAST. Observed atmospheric conditions over land and oceans and outputs from major World forecast Centers like International Research Institute for Climate and Society (IRI), Climate Prediction Centre (NCEP-CPC), the European Centre for Medium Range Weather Forecast (ECMWF), UK Met Office, Meteo France, together with output of the Agency's model, do suggest that the rainy season over the country is expected to be as follows…."

The flyers provided descriptions of the seasonal forecast for all regions; albeit; flyers were also posted to alert the public about impending weather conditions for specific communities. A statement in this instance states: ⚠ *Weather Warning 30042020. Kindly observe the necessary precautions. Stay Safe ✓*". Subscribers could also use the 'share function' to disseminate the information as well.

WhatsApp: Forecast information on Bulletin/Flyers

Flyers on seasonal forecasts, daily weather forecasts for 12 hrs and weather outlooks were also delivered through WhatsApp (Fig. 2) but they were the same as the information disseminated on the Facebook

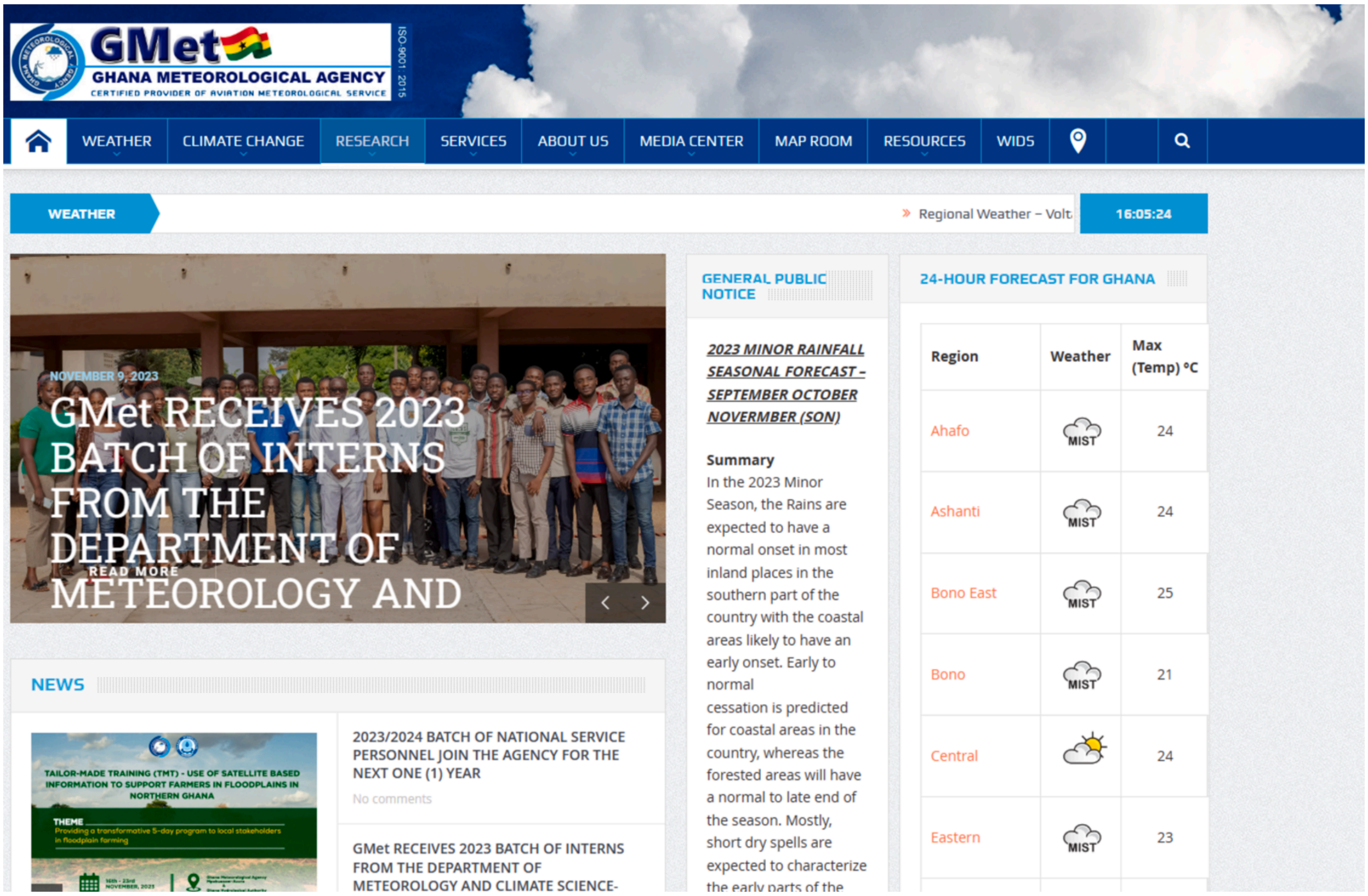

Fig. 3. Interface of GMet website showing weather forecast for the next 24 h ().
Source: GMet's website

page. The bulletins or flyers usually reach farmers by 'traveling' on several WhatsApp group pages or through individuals. Farmers indicated that they also received the bulletins or flyers from the Agricultural Extension Agents, friends within and outside the farming community or from WhatsApp group pages. Due to the way information is disseminated, farmers have little knowledge about the source of the information.

YouTube video on weather information

GMet has a YouTube channel with videos of daily (24–48 hrs) weather forecasts with presenters (Fig. 5). The YouTube video is produced as TV weather forecasts which can also be found on GMet's Facebook homepage. The program is dubbed, "Let's talk Weather" and it is segmented into episodes that delve into the outlook for the mid-week and coming weekend, for example, 10——15 October 2023.

Short message service (SMS)

The mobile SMS (Fig. 6) is another new ICT identified for CIS delivery to farmers. We found that the original providers SMS forecast delivered through MTN telecommunication channel were Ignitia. Although the organisation runs a business-to-business model or donor sponsorship of farmers in a project initiative, the farmers interviewed paid an amount of 0.30 Ghana Pesewas (equivalent to $0.02 as at 18th April 2024) per day as individual subscribers to access the weather forecasts. The customer's location is determined via mobile network technology; a text message containing a forecast for the next 48 hrs is sent out every morning. Farmers subscribe to receive SMS with the shortcode (*455#). It has inscriptions such as: "*Today, likely dry. Tomorrow, rain likely*".

Audio WhatsApp weather forecast

Audio recorded weather forecast **via whatsapp** (Fig. 7) is another important source of information provided by a private weather forecaster. The forecast includesdaily, weekly and seasonal forecasts and major weather alerts for unexpected conditions. The private weather forecaster (i.e. a retired GMet weather forecaster and resides in the district) provides tailored information for specific communities in the district. Each morning, the forecasts are delivered through audio recordings in both the local Dangbe language and English. These recordings were disseminated via WhatsApp group pages and individual contacts similar to the distribution methods of flyers. We identified that farmers with smartphones automatically received updates through the WhatsApp platform. Initial recipients often share this information with other community members. Since the forecasts are audio recorded, farmers were aware of the source. Importantly, the forecaster offers these services voluntarily,without payment or subscription.

The adoption of smartphones in rural communities in the district has also enhanced access to weather apps (Fig. 8) which are automatically available on phones. The Weather app identified in the study communities was the 'AccuWeather'. The AccuWeather app is typically preinstalled on some smartphones, requiring no additional effort for users to install it. The use of smartphones in the Ada East District is common among the younger generation, albeit, older persons also use it though they are limited to basic functions such as calling, receiving messages and accessing audio recordings on WhatsApp.

The experience and extent of use of the new ICT-based CIS in the Ada East District

We identified 5 different categories of responses regarding farmers'

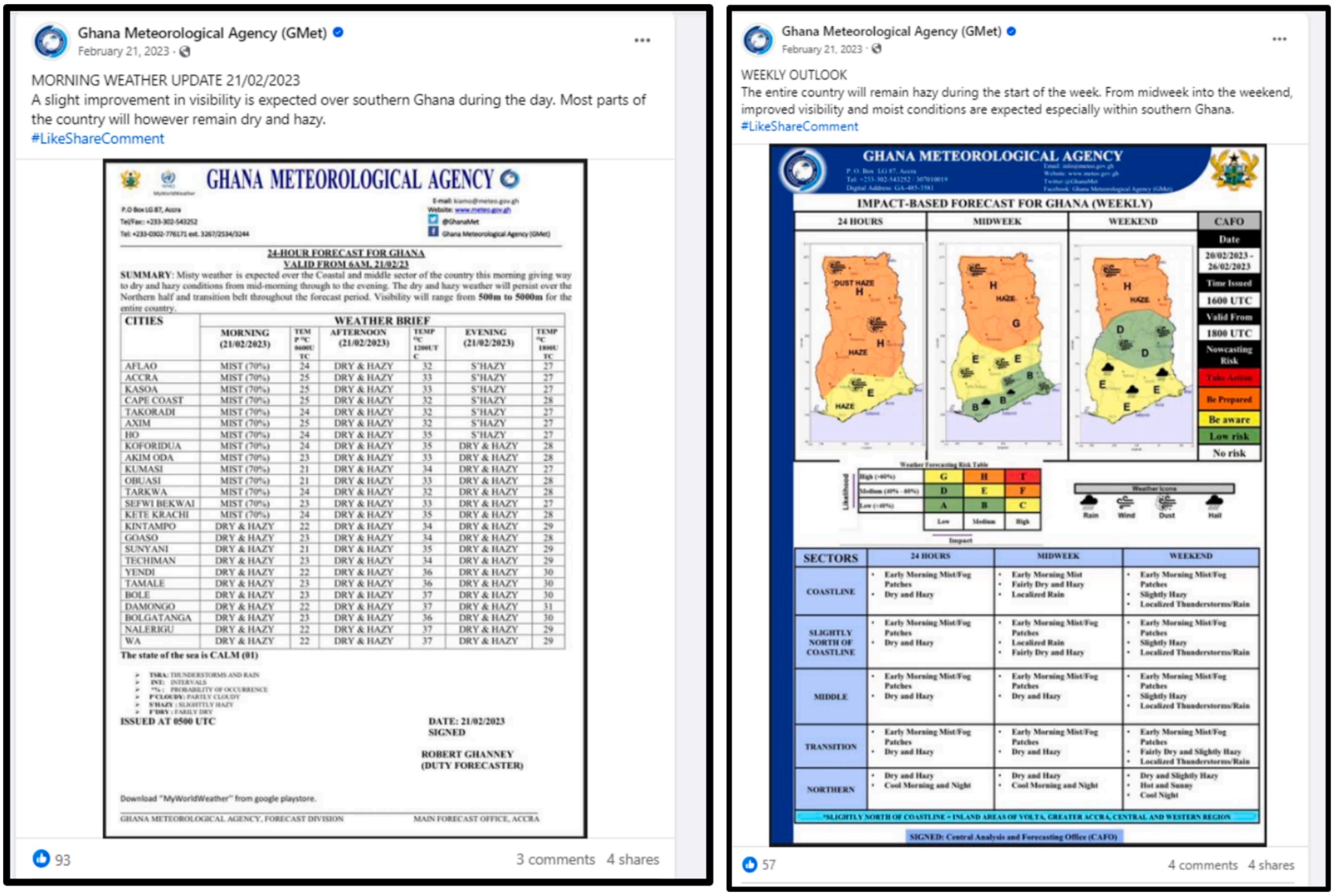

Fig. 4. GMet information on Facebook ().
Source: GMet's website/Facebook channel

experiences with new ICTs for the delivering CIS.

First, 3 farmers from the interview had never heard about any of the new ICTs and so relied solely on conventional means such as the community radio, private radio channels and television. They also relied on personal experiences and local or indigenous indicators to forecast the weather. Although they were aware of private weather forecasts, they did not receive this information as they lacked smartphones, relying instead on face-to-face interactions with contacts. Second, five (5) of the farmers interviewed acknowledged the existence of new ICTs for CIS but had never used them. Their main reasons included lack of access to smartphones, inability to use them, lack of interest, and a preference for older technologies like simple phones, televisions, and radios. They preferred information from the radio, which is accessible to everyone and often presented in local languages. For private weather forecasts, they relied on a community contact who communicated the information to them. While they had heard of SMS updates from MTN Ghana, they faced challenges with subscribing to the service and payment issues. One farmer mentioned accidentally discovering weather forecast videos on YouTube but had not used that source again.

Third, eleven farmers had previously used at least one new ICT for weather information but had stopped by the time of the study. The reasons for discontinuation included smartphones malfunctions, lack of interest and a return to relying on radio broadcasts or local knowledge.

Fourthly, we identified we identified eight intermittent users who occasionally check intermittent users who occasionally checked websites, AccuWeather and social media platforms like Facebook and WhatsApp for information. Their irregular usage was mainly due to limited internet access and the high cost of data. For example, a female farmer from the Ada Foah area mentioned during interview that checked WhatsApp messages only once a day and limited her internet use to less than 30 min to conserve data. Fifth and finally, nine farmers reported regularly accessing CIS through audio updates on WhatsApp, weather apps, and flyers on their smartphones. These interviewees frequently used their devices for various purposes, such as connecting with buyers and participating in multiple WhatsApp and Facebook groups. They often received updates without actively seeking them, as colleagues would post bulletins on WhatsApp, and mobile app notifications appeared automatically on their screens. The audio weather forecasts were accessible via WhatsApp, provided they were on the private weather forecaster's contact list.

Over all experiences of the 32 farmers out of 35 interviewees indicated a general awareness of new ICTs, especially, Bulletin on social media: WhatsApp, Bulletin on social media: Facebook, Mobile Apps and audio WhatsApp weather forecast were common.

The extent of use of information from new ICTs.

The findings on the extent of use of specific new ICTs among farmers, based on the frequency of use (i.e., daily to once a week) and the criteria outlined in the data analysis, reveal several key insights regarding the categorisation of usage (Table 1). The weather information website was classified as "less used," with only 2 farmers (5.7 %) reporting usage. Similarly, Bulletin/Flyers posted on Facebook were also "less used," as only 7 farmers (20 %) accessed GMet's Facebook account for weather forecasts, with 5 using it regularly and 2 visiting the page irregularly. In contrast, audio-recorded WhatsApp messages were categorised as "often used," with 21 out of 35 farmers (60 %) utilising this platform. YouTube videos for weather information were identified as "less used," with only 2 farmers (5.7 %) accessing them. Text-based information via SMS was also classified as "less used," with 5 farmers (14.2 %) utilising this

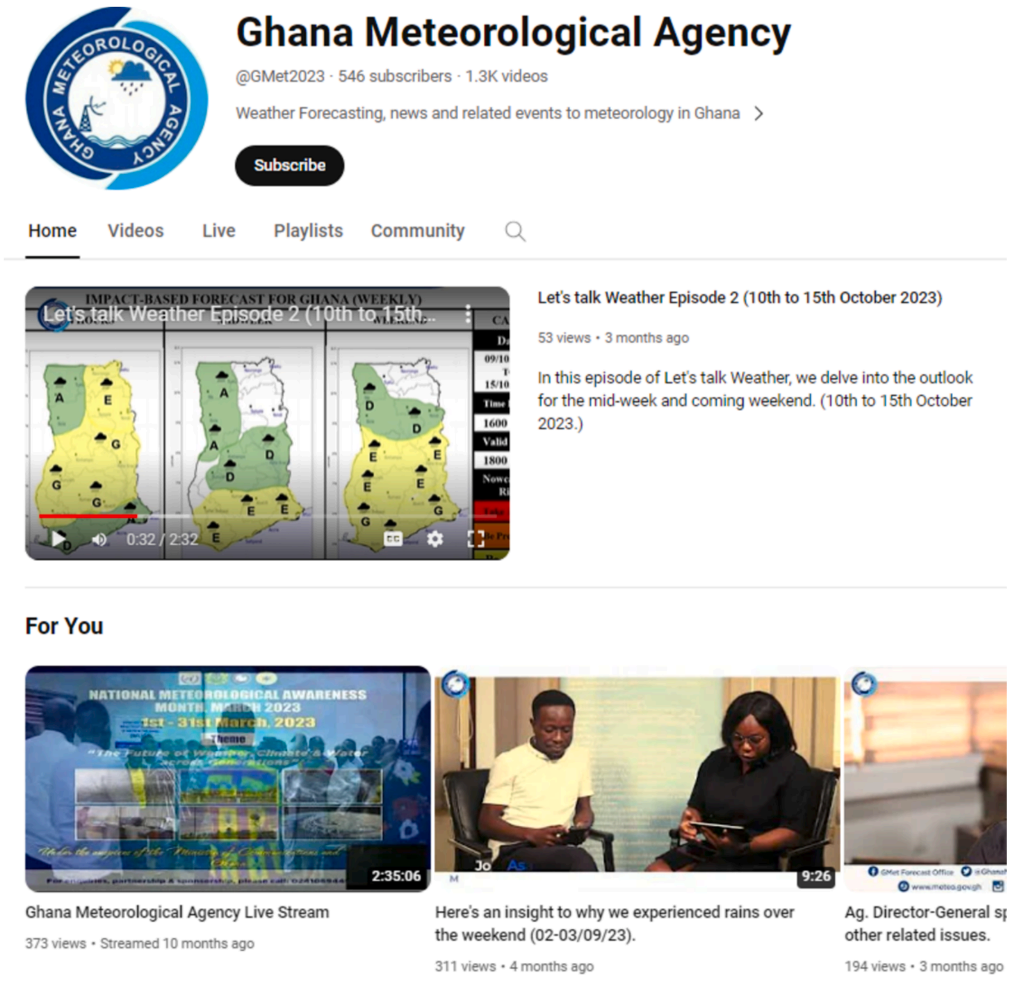

Fig. 5. A screenshot of the interface of the video recordings on weather conditions on YouTube ().
Source: GMet's website

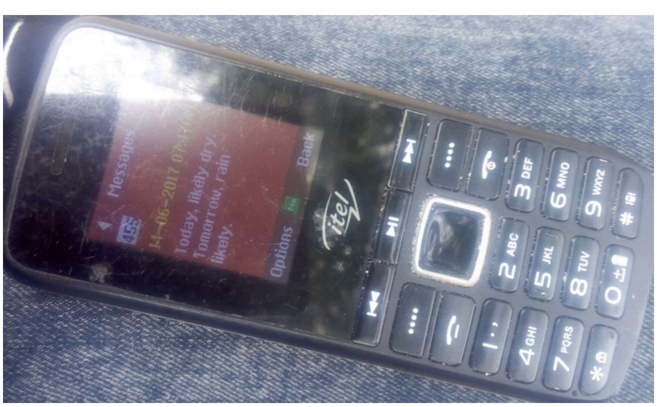

Fig. 6. A screenshot of SMS on weather conditions ().
Source: Authors' Fieldwork in the Ada East District

method. Weather apps, such as AccuWeather, fell into the "moderately used" category, with 19 farmers (54.2 %) relying on them to corroborate information from other sources.

Additionally, the findings highlight the influence of education on the extent of ICT platform use, although education is not the sole factor driving this behaviour. For example, Bulletin/Flyers via WhatsApp were frequently used by 23 farmers (65.7 %) across different educational levels, indicating a broad acceptance of this platform.

Authors' construct based on fieldwork

Factors affecting the usability of the new ICT used for CIS

We evaluated the usability of new ICTs for delivering CIS to farmers by examining their features through the lens of usability and servicescape, using the 8 analytical criteria. In this assessment, we engaged all farmers; frequent, intermittent and non-users to understand the usability and servicescape features of these new ICTs.

Relevant content

The website conveys ***relevant content*** on all expected weather conditions. It also provides information on weather outlook and relevant meteorological information to the public. For example, it offers information about the minor season as follows:

"In the 2023 Minor Season, the Rains are expected to have a normal onset in most inland places in the southern part of the country with the coastal areas likely to have an early onset. Early to normal cessation is predicted for coastal areas in the country, whereas the forested areas will have a normal to late end of the season. Mostly, short dry spells are expected to characterise the early parts of the season whilst getting to the end of the season there will be normal to longer dry spells for most places in the country. The SON season will be mostly above normal for the entire country. At the end of these forecasts, recommendations are

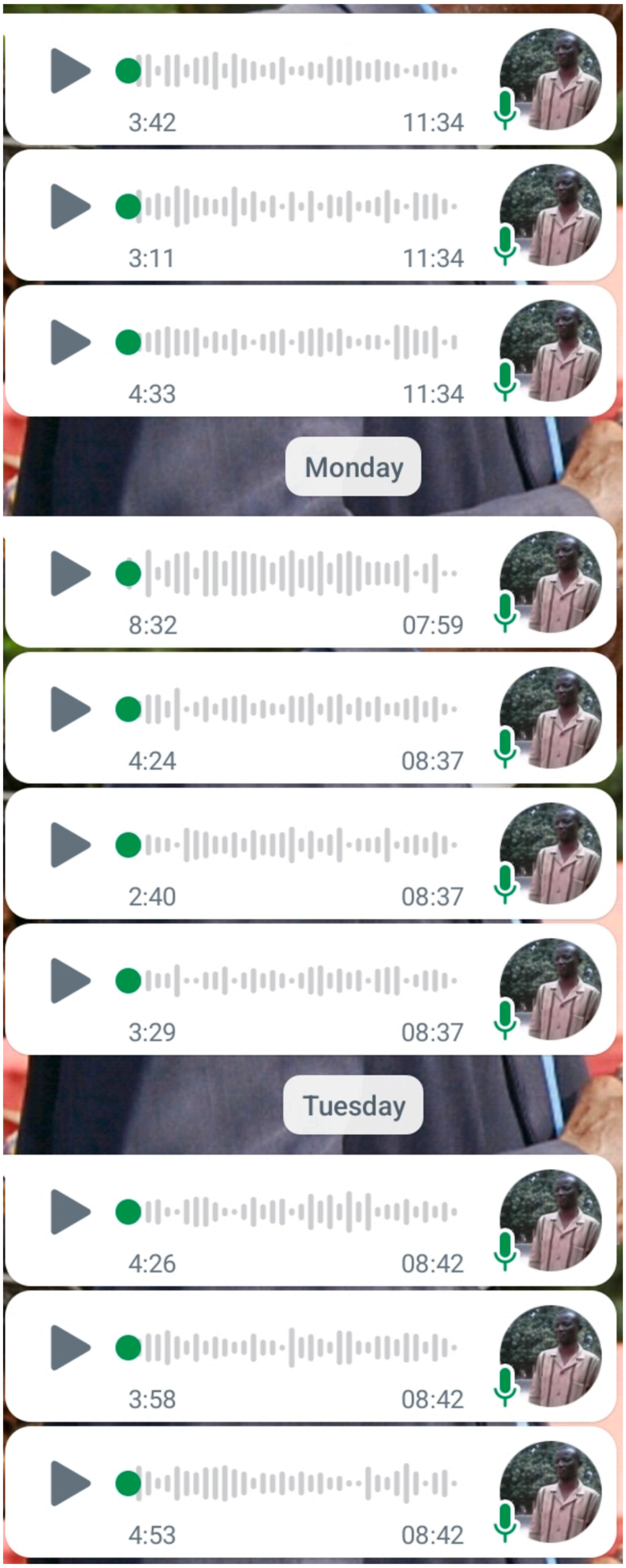

Fig. 7. A screenshot of audio WhatsApp recordings of the Private weather forecaster (.7 Weather Apps.
Source: Authors' Fieldwork in the Ada East District) 4.1

made to the various stakeholders to help manage risks and take advantage of the season".

The usability tests conducted during interviews and focus group discussions (FGDs) revealed that the content of climate information services (CIS) on various new ICT platforms was relevant for farming decision-making. The website content was especially useful, offering detailed information crucial for agricultural planning. Bulletins and flyers posted on Facebook and WhatsApp provided daily weather updates, focusing on rainfall, sunshine, hazy conditions, and other expected weather scenarios. Seasonal forecast bulletins also gave outlooks on impending weather, helping farmers anticipate future conditions. videos posted on YouTube covered a broader range of weather conditions, while mobile SMS forecasts primarily focused on expected rain or sunshine. These SMS updates also included practical advice, such as one text that read: "L*ight rain for the next 2 days, with periodic showers. Good time for weeding and planting.*" Such guidance helped farmers directly apply the weather information to their agricultural activities. One farmer, during an FGD in Angorsekope, mentioned that audio weather forecasts on WhatsApp provided similarly useful information on various weather conditions. These audio updates also included farming advice, guiding farmers on how to utilise the forecast effectively. FGDs revealed that weather apps offered information on rainy, sunny, and stormy conditions, further aiding decision-making. In summary (Table 2), across all ICT platforms, whether websites, social media, YouTube, SMS, or mobile apps, the CIS content was found to be relevant and valuable for farming. The FGDs highlighted an added benefit: these platforms communicated not just weather conditions but also the timing of expected events and the uncertainty surrounding forecasts, providing a temporal dimension to the information that further supported decision-making in agriculture.

Locaton success

Locaton Success was tested across the different platforms and results show that interviewees struggled to locate or identify weather information on GMet website due to cluttered homepage. Twenty-three (23) participants could not easily find the social media channels on the GMet website. However, once on the social media, identifying weather information on the Bulletin/Flyers on Facebook, WhatsApp and YouTube was straightforward. Interviewees were also able to successfully identify audio WhatsApp weather forecasts (see Table 2). Although weather apps were installed on their phones, 12 interviewees took over 5 min identifying the app icons. The findings on location success during FGDs highlighted the importance of symbols such as icons or logos in helping users to quickly access information with smartphones.

Location time

Our findings show that the ***location time*** was more than 5 min to identify relevant information using the new ICTs. Many interviewees struggled to find the information and perhaps, in real life situations, they might have given up sooner. Interviewees could not easily identify the social media channels on the GMet website in less than 5 min. Some (12) interviews exceeded this allocated time, especially for those unfamiliar with weather apps and audio WhatsApp forecasts, who took over 5 min to identify the icons before accessing the pages. However, weather information on bulletins or flyers posted on Facebook, WhatsApp, and YouTube was easily found within 1–2 min.

Comprehension of the content

Regarding ***comprehension of the content of the ICT platform*** for decision-making, we found that the new ICTs conveyed information with over 10 keywords, which hindered comprehension of information. Group discussants also indicated an overload of information on ICT pages. For example, the GMet's website had several hyperlinks, suggesting that its design was not solely focused on providing climate and weather forecasts.

Findings from interviews and FGDs reveal varied responses

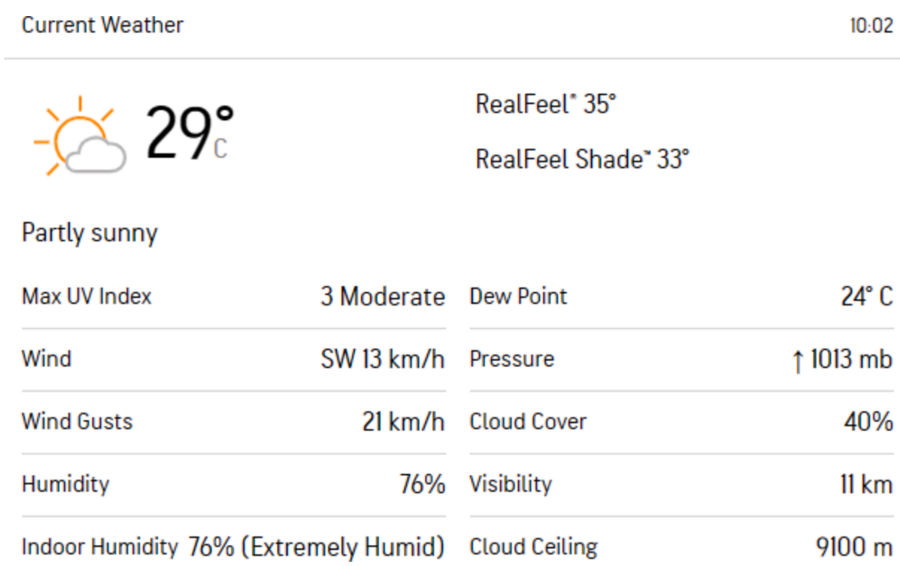

Fig. 8. A screenshot of the interface of the AccuWeather forecast on a farmers' phone ().
Source: Authors' Fieldwork in the Ada East District

Table 1
The extent of use of the new ICTs CIS.

Type of new ICT-based CIS	Level of education					Number of interviewees (n = 35)	Extent of use
	Non-formal education	Primary	Middel school/Junior High/Secondary	Senior High/ Secondary	Tertiary		
Website on weather information	–	–	–	1	1	2 (5.7 %)	'Less used'
Bulletin/Flyer via social media: Facebook	–	–	3	2	2	7 (20 %)	'Less used'
Bulletin/Flyer via social media: WhatsApp	–	3	14	4	2	23 (65.7 %)	'Often used'
YouTube video	–	–	–	–	2	2 (5.7 %)	'Less used'
The text based information (SMS) CIS	–	–	2	3	–	5 (14.2 %)	'Less used'
Audio WhatsApp weather forecast	1	2	13	3	2	21 (60 %)	'Often used'
Weather Apps	–	5	8	4	2	19 (54.2 %)	'Moderately used'

Table 2
Matching type of new ICT-based CIS with the servicescape criteria.

Type of new ICT-based CIS	**Usability criteria for accessing new ICTs (n = 35)**							
	Relevance of the content	**Location success**	**Location time**	**Comprehension**	**Typography, symbols and graphics**	**Use of clear language**	**Feedback and interactivity**	**Ability to use the new-ICT tools**
Website on weather information	12	12	8	17	26	10	0	5
Bulletin/Flyer via social media: Facebook	33	8	8	11	6	12	0	9
Bulletin/Flyer via social media: WhatsApp	35	25	29	11	6	12	0	28
YouTube video	25	5	24	12	29	21	0	12
The text based information (SMS) CIS	3	5	18	14	2	5	0	35
Audio WhatsApp weather forecast	28	28	22	21	15	35	18	28
Weather Apps	20	23	25	7	13	6	0	28

regarding the comprehension. For instance, discussants felt that the content of weather and seasonal forecast bulletin/flyers on Facebook and WhatsApp comprised more than 10 keywords, complicating the communication of weather information. In both interviews and FGDs, participants who could read indicated that the design of the organisation's heading and logo was clear, supporting the legitimacy of the information. The font size also ensured readability. However, the amount of information (referring to nationwide forecast exceeding 2000 words) required extra time to identify relevant sections for their communities, especially, when areas like Ada area is not specifically mentioned. For videos posted on the YouTube channel and the audio WhatsApp weather forecast, comprehension was measured based on the length of the content, which, ranged between 1–5 min. YouTube weather videos lasts between 1 min or 25–30 sec. Although farmers interviewed would have preferred YouTube weather videos, a farmer who had used it indicated: "*The weather forecaster presents the information within some short minutes*". During FGDs farmers discussed the trade-offs associated with video length, expressing concerns that longer videos recordings could limit access to information due to high internet data cost.

The audio WhatsApp weather forecast lasted between 5–6 min, occasionally extending to 10 min, depending on the depth of the explanation. Mobile SMS messages, on the other hand were brief with examples such as: "*Today, rain likely, afternoon. Tomorrow, rain likely*". However, both interviewees and focus group discussants opined complained that the messages were too short. Findings from the interviews showed that 14 farmers understood SMS when displayed. Focus group discussants also mentioned that while the SMS provided general awareness of the expected weather conditions, it lacked details about timing and duration of events such as how long the expected rainfall will last (i.e. whether there would be rain all day or not).

Typography, symbols and graphics

Typography, symbols and graphics were found relevant to both interviewees and the focus group discussants. These elements were used across weather information on the websites, Bulletin/Flyers on Facebook and WhatsApp and YouTube videos. Our findings from interviews shows that symbols like sunshine, cloud and rain were easily identified by all farmers (Fig. 9). However, symbols for thunderstorms, windy conditions, and partly cloudy conditions were not easily identified. Similarly, symbols such as fog, hot, cold and windy conditions were not identified during the FGDs. The interviewees and focus group discussants could not differentiate between sunny, partly sunny, mostly sunny, hazy sunshine, and intermittent clouds. We identified similar responses

Fig. 9. Symbols of weather conditions **Authors' construct based on fieldwork**.

to the differentials among precipitation conditions such as showers, rainfall, partly cloudy, and thunderstorms.

Interviewees indicated that some weather forecasts shared via bulletins/Flyers on Facebook and WhatsApp and YouTube were displayed on the map of Ghana delineated into regions with different shades of colours (see Fig. 10). The graphic representation was useful for interviewees who were literate or familiar with the location of their villages on the map. Sometimes, the forecasts were conveyed in tabular form. Focus group participants added that mobile SMS CIS and the audio WhatsApp weather updates used words that mimic the symbolic display of weather conditions making it easier to conceptualise and understand the information provided.

Use of clear language

Findings from the FGDs indicate that, using ***of clear language*** promotes clarity of information. This criterion was identified by discussant in the audio WhatsApp weather forecast and mobile SMS CIS. Interview results further reveal that only the audio WhatsApp weather forecasts were presented in the local language. All other new ICT based CIS were delivered in English. Eleven (11) interviewees and four (4) FGD discussants mentioned difficulties in reading and interpreting the information in English by themselves because of limited literacy skills.

Feedback and interactivity

With regards to ***feedback and interactivity***, none of the new ICT-based CIS platforms allowed users (farmers) to interact with information providers to ask questions and seek clarifications. During the FGDs, farmers expressed a desire for opportunities to ask questions or provide feedback; however, no mechanisms were available for interaction. For audio WhatsApp weather forecast, farmers indicated that they usually call the retired private weather forecaster to seek clarifications when necessary.

Although Table 2 shows high number of farmers who reported being capable of using the new ICTs, findings from FGDs provided further insight into their, ***ability to use the new ICT tools.*** Aside from mobile SMS and applications that, were automatically delivered upon subscription, other new ICT platforms required more effort from farmers, from logging to access content. For instance, they had to log into platforms like Facebook platform, GMet homepage or YouTube page, or recognise icons for WhatsApp and AccuWeather, making accessibility more complex.

Authors' construct based on fieldwork

Discussions

This study set out to identify the usability of new Information and Communication Technologies (ICTs) used for the delivery of Climate Information Services (CIS) for farming decision-making. The findings of the study reveal 7 new ICTs including Websites, Bulletin on social media: Facebook, WhatsApp weather forecast presented as a flyer, YouTube video on weather information, Short message service (SMS, audio WhatsApp weather forecast and Weather apps Each of these ICT platforms employs various communication format such as text, imagery, video, or audio to disseminate weather-related information. The growing use of these new ICTs align with other studies exploring the applications of various technologies for delivering agricultural information (see for instance, Muthali et al. 2018; Slavova and Karanasios, 2018; Sarku et al., 2021; Coggins et al., 2022). Although not purposely designed for farmers, the new ICTSs identified in this study played critical role in disseminating valuable information. These results underscore how new technologies can help bridge the information and technology usability gap especially for smallholder farmers.

The results also show that factors such as relevance, location success and time, comprehension, typography, symbols, graphics, language, feedback, interactivity, and ease of use were relevant service features

Cumulative and Probability Forecast Maps for 2023 SON Season

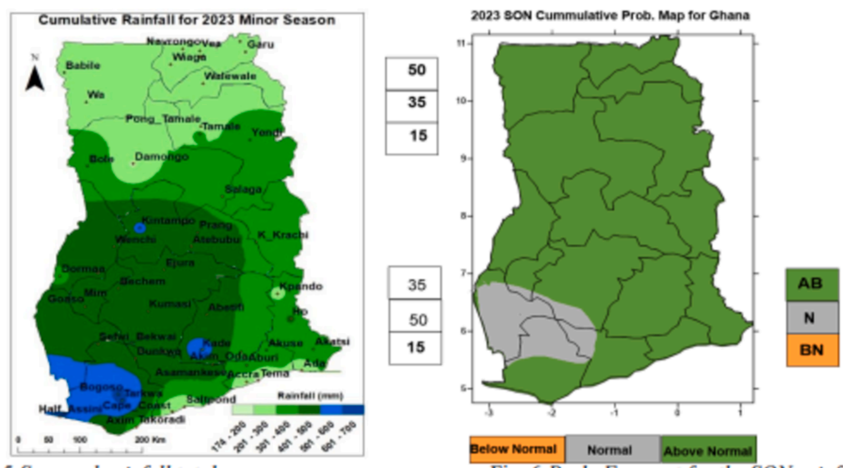

Fig. 5 *Seasonal rainfall total for the 2023 minor season*

Fig. 6 *Prob. Forecast for the SON rainfall total for the 2023 minor season*

Table 3. Forecast of Total Rainfall Amount for September – November (SON) Season

ZONE	LTM (mm)	SON (mm)
East Coast	125 – 210	180 – 350
West Coast	270 – 450	350 -- 600
Forest	280 – 470	300 – 650
Transition	300 – 500	360 – 520

Onset Dates and Probability Forecast Maps for 2023 SON Season

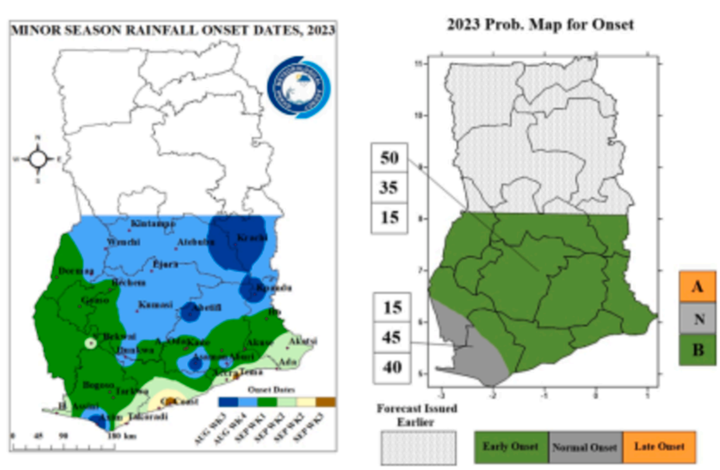

Fig. 1 *Onset dates for the 2023 minor season*

Fig. 2 Prob. forecast for *Onset dates for the 2023 minor season*

Fig. 10. A display of expected weather conditions for minor season, 2023 across Ghana ().
Source: GMet's website/Facebook channel

that significantly influenced usability of the new ICTs and the effectiveness of information delivered through the platforms. For example, we identified that comprehension issues were linked to information overload on certain platforms, hindering farmers' ability to interpret forecasts effectively. While symbols and graphics were generally helpful, some symbols such as those indicating varying precipitation conditions, were challenging for farmers to understand. Feedback and interactivity were limited across all the ICT platform, with farmers expressing the desire for more opportunities to engage and ask question. Additionally, the effort required to use some ICTs, such as logging into Facebook or accessing specific websites, was seen as a barrier to consistent usage. Sarku et al (2020) noted that the usability of smartphones was hindered by literacy and numeracy issues and farmers' lack of time and fatigue associated with sourcing information with smartphone applications. While several factors account for the usability gap in the use of new ICTs, Sarku et al further highlighted that the "smartphone phobias" among some farmers, referring to a general fear or reluctance to use the technology. The authors emphasised the importance of clear language as demonstrated by the accessible format of the audio WhatsApp forecast.

Another finding from the study reveals that farmers' use of ICTs varied significantly, with some adopting multiple platforms while others eschew new technologies altogether. Factors influencing ICTusage range from smartphone accessibility and technological literacy to individual interest and reliance on traditional media like radio and television, as well as local or indigenous knowledge. Additionally, intermittent use of ICTs was common due to challenges such as limited internet access and high cost of data plans. The findings are consistent with the GSMA (2022) report, which highlighted that despite increasing adoption of ICTs in developing and middle-income countries, usability challenges remain persistent. The GSMA report found that daily mobile internet and phone use was mainly centered on instant messaging, online calls video calls, watching free videos and reading the news. However, 44 % of adults in less-middle-income countries still do not use mobile internet and related technologies due to barriers such as knowledge and skills gaps, affordability, safety and security concerns, and a lack of relevant content and services. Our study support these findings, as farmers participating in the study had access to basic or smartphones; yet, they were limited in fully utilising the technology due to lack of supportive 'servicescape' features.

Farmers had limited awareness of certain new ICTs and the information providers, which impacted their willingness to adopt these technologies due to trust issues. In essence, trust is widely recognised as a crucial factor in navigating uncertainties such as climate change and variability, prompting action in situations where risks are perceived, especially in interactions with others (Agyekumhene et al., 2018). Trust signifies confidence in the reliability of individuals or systems to achieve specific desired outcomes (Giddens, 2013), and plays a role in the reliability both in interpersonal relationships and in trust in systems, such as new ICTs (Agyekumhene et al., 2018). The use of weather forecasting in farming decisions can have adverse consequences, especially when the forecast fails. According Sarku et al., (2022) farmers are more likely to trust CIS when they are aware of the source of the information. In this study, it was evident that the only information provider farmers considered directly accountable was the retired private weather forecaster. To ensure that CIS providers meet the required standard servicescape features for the delivery of information, there is a need for the development of a customer relationship management system to oversee the delivery of technologies and services across geographical areas. This could be achieved through the establishment of community-based service centers or by leveraging trusted intermediaries like extension workers, early adopters, community leaders and co-operatives, who have established trust with farmers.

Unlike standard information design and usability tests where the interface is tightly controlled, the interfaces of seven new ICTs varied considerably. These platforms incorporate a range of features such as infographics, varying text lengths, and template size. A major challenge identified was usability, especially with technologies featuring extensive text structures which could lead to important information being 'buried' within lengthy text sections. This underscores the importance of determining the specific information needs of farmers regarding CIS and to ensure that theseinformation are both accurate and aligned with the characteristics of the service environment. Taking a usability-focused approach requires a reevaluation of the information design and servicescape specific to these new ICTs. This reassessment should be informed by data on users' (farmers) information needs. While additional research is necessary, we anticipate that the insights from this study have broader applicability across agriculture, CIS, and smallholder sectors where the application of new ICTs are gaining prominence.

The integration of the various new ICTs for disseminating weather and seasonal climate forecasts outlooks present both benefits and challenges, as highlighted by the findings of the study. On the positive side, GMet's website effectively conveys comprehensive information about weather and seasonal climate forecasts and meteorological insights across multiple platforms including social media, videos, mobile apps, and SMS, proving invaluable for farming decisions. However, the usability testing revealed significant trade-offs. The complexity of navigating the website can be challenging for farmers, hampering their ability to locate relevant information. Additionally, information overload on certain platforms further complicate matters, making quick comprehension and decision-making difficult. Lengthy content in bulletin/flyers and videos, presents accessibility challenges, especially for users with limited data access and literacy skills, while the use of symbols, graphics, and clear language generally enhances the accessibility and clarity of information, some symbols may be ambiguous or hard to interpret. Moreover, lack of interactivity across all ICT platforms limits user engagement and feedback mechanisms, impeding the opportunity for clarification and tailored support. In terms of user effort, some platforms offer seamless delivery of information, while others require active participation, such as logging in or recognising icons, potentially deterring consistent usage among farmers. Although the integration of diverse ICT platforms enriches the dissemination of weather information, addressing usability challenges, simplifying content, enhancing interactivity, and reducing user effort are essential for maximising their effectiveness in supporting decision-making in agriculture. Balancing the richness of information with ease of access and comprehension remains crucial for optimising the usability of ICTs for decision-making in farming.

We recognize that our study has some limitations. One is the imbalance between male and female participants. While ensuring a more balanced gender representation in the sample would provide deeper insights into gender-specific preferences and issues related to technology use, the focus of this paper was primarily on the general usability of the technologies across the community, rather than on gender differentiation. Moreover, in the study area, men typically own farms and are household heads, and women are more involved in agricultural trading. Nonetheless, despite that efforts were made to include women through purposive sampling, we recommend further research on gender differentiation of new ICT use in CIS in the study area involving a balance of women and men respondents. Another limitation is the study's exploratory nature which limits our ability to provide detailed explanations in some cases, as it primarily serves as a foundational step in identifying the emergence of new digital platforms and their methods of delivering climate information. Therefore, we call for further research to elaborate on these findings.

Finally, this study makes several significant contributions to research. First it introduces the concept of "servicescape" into the CIS context, an area that has not been adequately explored. Servicescapes encompass both the tangible and intangible elements of service delivery environments that influence user perceptions, behavioural intentions, and satisfaction. This research highlights the importance of integrating servicescape features such as user interface design, ease of use, interactivity, and responsiveness into ICT platforms to enhance CIS usability. Second, the evaluation of how farmers perceive and use of ICT tools like mobile applications, SMS services, and digital data platforms for receiving CIS provides insights into the real-world application of these technologies, addressing a gap in current research that primarily focuses on technology design rather than how these systems function in practice for end-users. Third, by applying an analytical framework based on eight usability criteria (relevance, location success, location time, comprehension, typography, symbols, language clarity, feedback, and tool usability), this research provides practical insights into how ICT platforms can be optimised to meet farmers' needs. It connects the technical side of ICTs with the human dimensions of service design, thus offering a more holistic view of CIS delivery. Fourth, while much of the current literature on CIS focuses on broader institutional, political, and gender dynamics, this study narrows its focus to the practical implementation of CIS through new ICTs in Ghana. It provides context-specific insights into the challenges and opportunities presented by ICT adoption in rural farming communities, particularly in the coastal savanna agroecological zone. Fifth, what makes this study unique is its focus on how farmers experience the delivery of CIS through ICT platforms. It goes beyond the theoretical and technical aspects of CIS design to explore the practical usability of these tools in everyday agricultural decision-making. The research acknowledges that even the most advanced ICT solutions can fail to deliver value if they do not align with users' expectations and service needs. By incorporating user feedback and emphasising servicescape features, this study proposes practical solutions for enhancing the effectiveness and usability of CIS in the farming sector. In addressing these objectives, the study not only fills a critical research gap but also offers actionable insights that can help policymakers, CIS providers, and ICT developers better tailor their services to meet the specific needs of farmers. This contributes to the broader goal of enhancing agricultural resilience and productivity in the face of climate change.

Conclusion

The study examined new ICTs utilised for delivering CIS in the farming communities in the Ada East District. Using a desktop review, interviews and focus group discussions, we identified seven distinct ICT platforms, including, Websites, Bulletin on social media: Facebook, WhatsApp weather forecast presented as a flyer, YouTube video on weather information, Short message service (SMS, audio WhatsApp weather forecast and Weather apps. Each platform offered a unique way to disseminate weather forecasts, accommodating various preferences and levels of technological accessibility. The research highlighted the varied experiences of farmers with these ICTs, from unawareness to frequent usage. Factors influencing usage included smartphones accessibility, literacy levels, interest, and ease of accessing information. While some farmers preferred traditional methods like radio and TV broadcasts, and local or indigenous knowledge, others appreciated the convenience and timeliness of new ICTs. Despite differences in usage, the study underscored the importance of relevant content and usability in supporting farmers decision-making. The examined platforms provided detailed weather forecasts, often accompanied by advice tailored to agricultural activities. However, challenges such as cluttered interfaces on websites and comprehension issues with lengthy text content were identified, suggesting areas for improvement in usability. Furthermore, the study emphasised the need for clear language and interactive features to enhance user engagement. While some platforms lacked interactivity for user feedback, others, like the audio WhatsApp forecasts, allowed for direct communication with information providers, enabling clarification and deeper understanding. Finally, the findings indicated:

1 A variety of CIS are available to users in the selected study area, which incorporate new ICTs location success, location time, comprehension, typography, symbols and graphics, language clarity, feedback and interactivity and the ability to use the new-ICT tools This study therefore sheds light on the evolving landscape of CIS delivery in farming communities, where traditional methods coexist with emerging digital platforms. To improve the servicescape of new ICT-based CIS, efforts should focus on enhancing accessibility, usability, and interactivity. This can empower farmers with timely and relevant information, ultimately fostering more informed decision-making and resilience in agriculture. Simplifying and clarifying messages, along with increasing interactivity, will enhance understanding among users, including farmers.

CRediT authorship contribution statement

Rebecca Sarku: Writing – original draft, Visualization, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Famous Addi:** Field data curation, Methodology and Validation. **Emmanuel M.N.A.N. Attoh:** Writing – review & editing, Validation, Methodology, Data curation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. . Socioeconomic characteristics of interviewees

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District	Socioeconomic Characteristics																			
	Total number of interviewees	Sex		Age					Education					Years of experience farming				Type of farming practices		
		Male	Females	18-29yrs	30-40yrs	41-50yrs	51-60yrs	60yrs>	Non-formal education	Primary	Junior high level	Senior high level	Tertiary	5<	5–10 yrs	10–20 yrs	20 yrs >	Irrigation	Rainfed	Both
Ada East District	35	26	9	5	16	8	3	3	1	10	18	4	2	2	9	9	15	–	13	22

Authors' construct based on fieldwork.

Appendix 2

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Weather Icons

Icon Number	Icon	Day	Night	Text
1		Yes	No	Sunny
2		Yes	No	Mostly Sunny
3		Yes	No	Partly Sunny
4		Yes	No	Intermittent Clouds
5		Yes	No	Hazy Sunshine
6		Yes	No	Mostly Cloudy
7		Yes	Yes	Cloudy
8		Yes	Yes	Dreary (Overcast)
11		Yes	Yes	Fog
12		Yes	Yes	Showers
13		Yes	No	Mostly Cloudy w/ Showers
14		Yes	No	Partly Sunny w/ Showers
15		Yes	Yes	T-Storms
16		Yes	No	Mostly Cloudy w/ T-Storms
17		Yes	No	Partly Sunny w/ T-Storms
18		Yes	Yes	Rain
19		Yes	Yes	Flurries
20		Yes	No	Mostly Cloudy w/ Flurries
21		Yes	No	Partly Sunny w/ Flurries
22		Yes	Yes	Snow
23		Yes	No	Mostly Cloudy w/ Snow
24		Yes	Yes	Ice
25		Yes	Yes	Sleet
26		Yes	Yes	Freezing Rain
29		Yes	Yes	Rain and Snow
30		Yes	Yes	Hot
31		Yes	Yes	Cold
32		Yes	Yes	Windy

(Source: Authors' Fieldwork in the Ada East District)

(Source: Authors' Fieldwork in the Ada East District).

Data availability

Data will be made available on request.

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