UNIVERSITY OF MEDIA, ARTS AND COMMUNICATION
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COMMUNICATION STRATEGIES ON THE ADOPTION OF WEATHER APPLICATIONS BY FARMERS IN GHANA: STUDY OF FARMERS IN ADA DISTRICT

BY

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MADC24016

A DISSERTATION SUBMITTED TO THE UNIVERSITY OF MEDIA, ARTS AND COMMUNICATION UNIMAC IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MA IN DEVELOPMENT COMMUNICATION

DECEMBER 2025

DECLARATION

DECLARATION BY STUDENT

I hereby declare that this research is a result of my/our own original research and that, no part of it has been presented for another degree in this university or any other higher education institute. I further declare that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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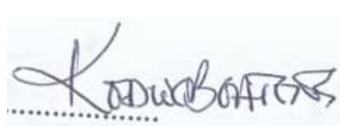
CERTIFICATION BY SUPERVISOR

This Dissertation/Thesis has been prepared and presented under my supervision according to the guidelines for supervision and formatting of Dissertation/Thesis laid down by the University of Media, Arts and Communication, UniMAC.

Dr Kodwo Jonas Anson Boateng		12th December, 2025
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ABSTRACT

This qualitative exploratory study investigates communication strategies for promoting weather forecasting application adoption among smallholder farmers in Ada District, Ghana. Despite sophisticated weather apps designed to support agricultural decision-making, adoption rates remain disappointingly low. Through in-depth interviews with 28 farmers, 5 agricultural extension officers, and 3 app developers, the research examines how language barriers, cultural contexts, and communication channels influence technology adoption.

Grounded in Rogers' Diffusion of Innovations Theory and the Integrated Communication Effectiveness Model, findings reveal that low adoption stems from multilevel communication failures operating across linguistic, semantic, cognitive, and cultural dimensions. The study identifies five interconnected themes: (1) language barriers extending beyond simple translation to encompass technical terminology and semantic gaps; (2) a profound trust deficit between scientific forecasts and deeply-rooted indigenous weather knowledge systems; (3) digital literacy challenges that transcend basic phone operation to include interface navigation and information interpretation difficulties; (4) the critical role of trusted intermediaries, particularly agricultural extension officers, in facilitating adoption through face-to-face demonstrations; and (5) systemic structural constraints including unreliable internet connectivity, high data costs, and institutional fragmentation.

The research demonstrates that effective technology diffusion requires culturally responsive, participatory communication strategies that bridge scientific and indigenous knowledge systems while addressing systemic structural constraints. The study provides actionable recommendations for multiple stakeholder groups: app developers should prioritize participatory co-design, implement multilingual voice-first interfaces, and integrate traditional weather indicators; extension services must formally position officers as digital agriculture intermediaries with adequate training and resources; policymakers should invest in rural digital infrastructure, subsidize data costs, and establish coordination mechanisms between meteorological agencies, developers, and extension services; and development organizations should adopt comprehensive ecosystem approaches that recognize technology adoption as a socially-embedded, relationship-driven process rather than a purely technical intervention.

This research contributes theoretically by extending Rogers' framework to account for structural prerequisites and cultural knowledge systems in resource-constrained contexts, empirically by providing rich multi-stakeholder perspectives on agricultural technology adoption in West Africa, and practically by offering specific, implementable strategies for enhancing communication effectiveness in digital agricultural development.

Keywords: communication strategies; digital agriculture; Ghana; indigenous knowledge integration;

smallholder farmers; technology adoption; weather forecasting applications

DEDICATION

This study is dedicated to the memory of my late father, my mother Mary Otto, my wife Alice Koomson, and my brothers, Felix Nkumsah, Jude Nkumsah and Seth Nkumsah.

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to God Almighty, who has been my guiding light and source of strength throughout this journey.

My special appreciation also goes to my supervisor, Dr. Kodwo Jonas Anson Boateng, whose intellectual guidance, constructive feedback, and unwavering support throughout this research process have been invaluable. Your mentorship has profoundly shaped both this work and my development as a researcher.

My immense appreciation goes to the farmers in Ada District who generously shared their time, experiences, and insights despite demanding agricultural schedules. I extend sincere thanks to the agricultural extension officers, and to the weather application developers who candidly shared their experiences and visions for digital agricultural transformation.

My heartfelt thanks to my mothers, Mary Otoo and Auntie Jane, and also my brother, Jude Nkumsah and my friend Philemon Kwasi Edwards for the emotional support, understanding, and encouragement throughout this academic journey. Your support sustained me through challenging moments.

Finally, I acknowledge the resilient farmers of Ghana whose dedication to feeding the nation inspires this work. May this research contribute to improving communication strategies that support your agricultural livelihoods and climate adaptation efforts.

Thank you all for your contributions to this research. I am grateful and humbled by your support.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

With about 44% of Ghana's labor force working in farming and related activities, agriculture forms the cornerstone of the nation's economy and plays a major role in generating gross domestic product (Ghana Statistical Service, 2021). The agricultural sector is largely made up of smallholder farmers practicing rain-dependent farming, rendering them particularly at risk from climate instability and unpredictable weather conditions that have intensified throughout sub-Saharan Africa (Amikuzuno & Donkoh, 2024).

The growing threat of climate change has intensified the challenges facing Ghana's agricultural sector. Smallholder farmers, who constitute over 70% of Ghana's agricultural workforce, face mounting pressures from erratic rainfall patterns, prolonged droughts, unexpected flooding, and shifting seasonal cycles that disrupt traditional farming calendars (Akuriba et al., 2022).

Onyeaka et al. (2024) argue that climate variability and unpredictable weather patterns have increasingly threatened agricultural productivity and food security across sub-Saharan Africa, with Ghana being particularly vulnerable to these challenges.

As a result of these challenges, more people now understand the vital role that weather and climate information services (WCIS) play in guiding agricultural choices. Having access to dependable, current weather forecasts allows farmers to make educated decisions concerning planting schedules, crop types, irrigation timing, pest management strategies, and when to harvest their crops (Nyamekye et al., 2022).

The rapid proliferation of mobile technology across Ghana has created unprecedented opportunities for transforming agricultural information delivery. With mobile phone penetration rates exceeding 80% in rural areas, digital platforms present a promising avenue for bridging the information gap between meteorological services and smallholder farmers (Asante-Addo et al., 2023). This technological revolution has sparked the development of various weather forecasting applications specifically designed for agricultural use, including the notable FarmerSupport app (FSapp), which represents a collaborative effort to address the weather and climate information needs of Ghanaian farmers.

FarmerSupport app (FSapp) is a weather and climate information platform created collaboratively to meet farmers' specific needs for hydro-climatic data (Paparrizos et al., 2023). Despite the technical sophistication and scientific accuracy of these digital weather platforms, their adoption and sustained usage among smallholder farmers remain disappointingly low. This paradox highlights a critical disconnect between the availability of weather information and its effective utilization for agricultural development.

This study will adopt an exploratory research design to investigate the effectiveness of communication strategies in promoting weather forecasting app adoption among smallholder farmers in Ghana. The exploratory approach will be operationalized through a qualitative methodology, utilizing in-depth interviews with farmers, extension agents, and app developers in Ada, a farming community in Greater Accra Region, Ghana. The research will employ non-probability sampling with purposive sampling to ensure geographic and demographic diversity, complemented by stratified sampling to maintain gender balance (50% women farmers) and target participants aged 18-65. Data collection will involve multiple qualitative methods to capture diverse perspectives and experiences, while data analysis will utilize thematic analysis, narrative analysis, and discourse analysis to explore how language constructs meanings, identities, and social relationships within the context of weather app adoption.

The exploratory design provides the flexibility and depth needed to address the study's comprehensive objectives while generating actionable insights for enhancing communication strategies and facilitating more accessible adoption of digital weather tools among Ghanaian smallholder farmers.

Psychological barriers stem from internal attitudes, perceptions, and cognitive limitations; trust, fear, and confidence, while structural barriers arise from external systemic and infrastructural inadequacies; language, technology access, and institutional support.

Psychological barriers refer to the internal, cognitive, emotional, and perceptual factors that hinder smallholder farmers from adopting and effectively using weather forecasting applications. Psychological barriers in the study includes:

Lack of Trust in Digital Forecasts: Many farmers have deep-rooted trust in traditional or indigenous weather prediction systems. Skepticism toward scientific weather data, particularly when predictions conflict with traditional knowledge, discourages adoption and regular use of weather apps.

Fear of Technological Complexity: Farmers often perceive weather apps as complicated or “meant for the educated.” This perceived difficulty creates anxiety and resistance toward engaging with mobile-based technologies, especially among older farmers.

Low Self-Efficacy and Confidence: Due to limited digital literacy, many farmers doubt their own ability to use mobile applications correctly. This self-doubt reduces willingness to learn or experiment with weather apps, even when the tools are accessible.

Cognitive Overload and Misinterpretation: Weather data are often presented using technical terms and symbols that are difficult for low-literacy users to interpret. Misunderstanding or misinterpretation of this information can lead to frustration and eventual disengagement.

Cultural and Social Perceptions: Some communities perceive digital tools as foreign or elitist innovations, creating a psychological distance between local farmers and technology developers. This perception can make digital weather platforms seem irrelevant or culturally incompatible.

Structural barriers encompass systemic, institutional, and infrastructural challenges that limit farmers' ability to access, adopt, and sustain the use of weather applications. In the context of this study, some structural barriers include:

Limited Digital Infrastructure: Inadequate internet connectivity, unreliable power supply, and poor network coverage in rural farming communities constrain consistent access to weather apps.

Low Digital Literacy and Education Levels: The majority of smallholder farmers have limited formal education, reducing their ability to navigate mobile interfaces or interpret digital weather data, especially when presented in English.

Language Barriers: Most weather apps operate in English or a few dominant local languages, excluding many farmers who speak minority dialects. This linguistic mismatch restricts comprehension and usability.

Economic Constraints: High costs of smartphones, data bundles, and app subscriptions discourage low-income farmers from adopting digital platforms, even when they recognize their potential benefits.

Institutional Weaknesses: Poor coordination between meteorological agencies, app developers, and agricultural extension services leads to fragmented communication and inconsistent dissemination of weather information.

Limited Support and Training Structures: There is insufficient farmer education, demonstration, or continuous technical support to build capacity and confidence in using digital weather tools. The absence of extension officers trained in digital agriculture compounds the problem.

Policy and Regulatory Gaps: Weak policy frameworks for integrating weather information systems into national agricultural extension programs hinder the institutionalization and sustainability of digital weather platforms.

Addressing both dimensions through inclusive, culturally sensitive communication strategies and strong policy support is essential for improving adoption of weather applications among Ghanaian farmers.

1.1 Problem Statement

Ghana's agricultural sector faces a fundamental communication challenge in the digital age. While weather forecasting applications have been developed with sophisticated meteorological capabilities and scientific accuracy. Existing weather forecasting apps in Ghana, including the widely promoted FarmerSupport app (FSapp), provide scientifically accurate meteorological data derived from advanced forecasting models and satellite imagery. However, uptake and sustained usage among the target population of smallholder farmers remain consistently low, creating a significant gap between technological capability and agricultural development impact (Limantol et al., 2022).

The core problem lies not in the technical accuracy of forecasts, but in the communication gap between scientific information and actionable agricultural decisions (Dennis et al., 2024), identifies challenges such as language barriers and low digital literacy hinder widespread adoption among farming communities. This communication gap represents a missed opportunity for leveraging digital technology to enhance climate resilience and agricultural productivity among vulnerable farming populations.

This research addresses the critical question: How can communication strategies be designed to maximize the agricultural development impact of weather forecasting apps among Ghanaian smallholder farmers?

1.2 Aim

The purpose of this study is to assess the effectiveness of communication strategies aimed at promoting the adoption of weather forecasting applications among farmers. Additionally, it seeks to identify the various barriers that hinder smallholder farmers in Ghana from easily adopting these applications. Ultimately, the study will provide recommendations for enhancing the design and implementation of communication strategies to facilitate quicker and more accessible adoption of digital weather tools. This study seeks to systematically identify and categorize the technological, economic, social, and infrastructural barriers that prevent smallholder farmers in Ghana from adopting weather forecasting applications, and to evaluate the effectiveness of different communication strategies in overcoming these barriers to facilitate increased adoption of digital weather tools among the farming community.

Effective communication strategies are measured by their ability to reduce psychological barriers through trust-building, cultural sensitivity, and confidence enhancement, and also advocate for structural solutions through policy recommendations and stakeholder engagement. Communication strategies can transform language from been a barrier into an enabler by integrating local languages in the app with visuals, using symbols and imagery that transcend literacy barriers

1.3. Research Objective

1. To evaluate the effectiveness of current communication strategies used by weather forecasting apps in overcoming language and cultural barriers among smallholder farmers in Ghana.

2. To identify and analyze the key barriers that prevent smallholder farmers from adopting weather forecasting applications, with particular emphasis on communication-related obstacles and user characteristic influences.

3. To assess how the integration of indigenous weather knowledge with scientific forecasts in communication strategies affects farmer trust, adoption rates, and sustained usage of digital weather platforms.

1.4 Research Questions:

1. What language barriers exist in current weather forecasting apps, and how do these barriers affect information comprehension among smallholder farmers?

2. How do different communication channels, message formats, and farmer characteristics interact to influence app adoption and usage patterns?

3. To what extent does the integration of indigenous weather knowledge with scientific forecasts influence farmer trust and adoption of digital weather platforms?

1.5 Significance of the Study

This research contributes to the theoretical understanding of technology adoption in agricultural development contexts by examining the intersection of communication theory, digital innovation, and rural development. By applying established frameworks such as Rogers' (2003) Diffusion of Innovations Theory, the study advances theoretical knowledge about how communication design influences technology adoption among vulnerable populations. The research also contributes to the emerging field of digital agriculture by providing insights into the communication dimensions of agricultural technology transfer. The findings will reveal how cultural, linguistic, and socio-economic factors shape the impact of available technology on development outcomes.

From an applied standpoint, this study offers practical guidance for enhancing weather information service design and delivery in Ghana and throughout West Africa. The results will guide the creation of improved communication approaches that can strengthen how digital weather platforms contribute to agricultural progress.

The study provides valuable insights for various stakeholder categories. Technology companies and app creators will gain research-backed suggestions for enhancing multilingual capabilities (expanding beyond English to include local languages), improving user experience design, optimizing content distribution, and refining outreach methods. Meanwhile, agricultural extension programs can leverage these research outcomes to more effectively integrate digital weather data into their farmer education and assistance initiatives.

Government officials and decision-makers will gain insights into the communication requirements necessary for broader adoption of digital agricultural technologies. Aid and development agencies will learn to create effective communication frameworks that support their overarching objectives. This study employs development communication methods to link technological advances with tangible development outcomes.

Through examining communication mechanisms, the research addresses the disconnect between available weather-related technology and meaningful agricultural improvements. The results will inform the creation of information systems that genuinely benefit rural farming populations.

1.6 Scope of the Study

The research will take place in Ada, a farming community in Ghana's Greater Accra Region. This location because the main occupation of the indigenes is farming and was chosen to allow detailed study of how communication works in a specific farming area. The findings from Ada may also be useful for understanding similar farming communities throughout Ghana. The results could potentially apply to other farming areas across West Africa as well.

This qualitative study uses an inductive methodology to examine how Ghanaian smallholder farmers interact with and adopt weather forecasting applications. The research takes a phenomenological approach to explore participants' personal experiences, cultural interpretations, and communication challenges that might not be captured through quantitative research methods. The exploratory framework provides adaptability in gathering data, enabling researchers to follow emerging patterns and unexpected findings that could transform current knowledge about how farmers adopt digital agricultural technologies.

The study will conduct comprehensive interviews using 25-35 semi-structured questions with participants including 28 farmers, 5 agricultural extension workers, and 3 application developers, all located in the Greater Accra Region and surrounding areas. The data collection process is structured in three distinct phases spanning three weeks total. The initial week serves as preparation, focusing on building relationships with participants, refining interview protocols, and preparing research assistants. The second week concentrates on intensive data gathering through interviews with all participant groups. The final week is dedicated to conducting follow-up interviews to clarify any unclear information or fill gaps identified during analysis.

This study focuses on smallholder farmers in Ada's agricultural community within the Greater Accra Region as the main research subjects. Additional participants include agricultural extension officers working in Ada district and developers of weather applications. The sampling methodology uses a multi-layered purposive approach that divides Ada district into three geographical areas (coastal, inland, and transitional zones), ensures equal gender representation with 50% female participation and varied age groups, employs snowball techniques through community leadership networks to find information-rich subjects, and applies maximum variation methods to include diverse farming operations across crop varieties, land sizes, and technology familiarity levels.

This qualitative exploratory study uses a systematic methodology to examine how Ghanaian smallholder farmers adopt weather forecasting applications. The research targets 25-30 farmers to reach theoretical saturation, five extension agents from various sub-districts, and three representatives from leading weather app companies. Participant selection involves mapping communities with local agricultural officials, engaging traditional leaders and farmer organization heads, conducting preliminary community visits to establish trust, applying specific criteria (minimum three years farming experience, smartphone access, voluntary participation), and maintaining demographic balance for comprehensive perspectives.

The study employs multiple data gathering techniques including structured interview guides that investigate communication preferences and barriers to adoption, observation frameworks for documenting farmer-technology interactions, and monitoring of app usage patterns. Supporting tools include demographic surveys, visual materials, and audio recording devices. Two graduate research assistants with expertise in English, Twi, and Dangme languages and rural research backgrounds will be trained through an intensive week-long program covering research methods, interview skills, cultural awareness, and practical exercises, with continuous weekly review meetings.

Data capture involves high-quality digital audio recording with participant approval, comprehensive field notes using standardized formats, and digital documentation of app interfaces. Transcription occurs within 24 hours using a bilingual method that maintains original language before translation, capturing exact wording including pauses and non-verbal communication, with quality assurance through dual review processes supported by automated transcription tools and professional translators for culturally complex concepts.

The analytical approach combines predetermined categories based on Rogers' Innovation Diffusion theory with themes that emerge from the data itself. This involves systematic coding at three levels from basic description to theoretical framework construction, using NVivo 12 as the main analysis platform alongside supplementary tools for specialized analysis and collaborative work. Results presentation includes individual case studies and cross-demographic comparisons.

The findings analysis uses multiple layers including descriptive examination of current communication methods and farmer experiences, interpretive analysis of how farmers understand weather information and digital tools, critical examination of how social structures and cultural factors affect communication success, and theoretical analysis connecting results to established innovation and communication theories. Validation occurs through participant verification, expert review, and cross-referencing multiple data sources.

The study examines interconnected themes with communication strategies as the primary focus, analyzing recommended implementation approaches and evaluation methods for assessing effectiveness. Since climate information service success depends heavily on information design and delivery methods, communication design proves as vital as technical precision.

Key enhancement strategies include developing multilingual platforms incorporating local languages, combining traditional weather knowledge with scientific predictions to build trust, creating visual and audio communication methods for low-literacy contexts, establishing community training programs through extension services, and developing feedback systems allowing farmers to share local observations. The research emphasizes that trust, literacy, and feedback mechanisms are crucial adoption factors requiring comprehensive platforms connecting farmers to complete agricultural services.

The conceptual framework identifies relevant theory through logical progression from communication analysis to innovation adoption principles. The research's focus on weather app adoption directly indicates the Diffusion of Innovation Theory as the primary theoretical foundation. This framework acknowledges that communication and innovation diffusion strategies work together as complementary approaches for achieving social and behavioral transformation, suggesting an integrated methodology that combines communication theories explaining message design and delivery with innovation diffusion theories explaining technology spread through populations.

1.7 Organization of the Study

This study is structured across five sections that thoroughly explore how effectively weather forecasting applications communicate with small-scale farmers in Ghana.

The first section outlines the core research issue, explains why this study matters, and defines the specific goals and research questions driving the work.

The second section examines existing academic work, reviewing current understanding of digital farming technologies, weather information systems, communication theories, and how rural communities adopt new technologies.

The third section describes the research approach, covering the study design, methods for gathering information, how participants were selected, and the techniques used to analyze the data.

The fourth section shares the study's results, examining information collected through group discussions and individual interviews to answer the research questions and meet the study objectives.

The final section wraps up the research by discussing the main discoveries, offering practical suggestions for enhancing communication methods in weather apps, and proposing areas for additional research.

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

This chapter provides a comprehensive review of existing literature relevant to the communication effectiveness of weather forecasting apps among smallholder farmers in Ghana. The review is organized around key thematic areas that inform the research objectives, including the role of weather information in agricultural decision-making, digital agricultural technologies in Ghana and sub-Saharan Africa, communication theory applications in rural development, and factors influencing technology adoption among farming communities.

This comprehensive approach ensures that the study is grounded in existing theoretical knowledge while identifying gaps that justify the current research focus.

2.1 Background of Study

2.1.1 Climate Variability and Agricultural Vulnerability in Ghana

Ghana's agricultural sector operates within an increasingly challenging climate context characterized by rising temperatures, changing precipitation patterns, and extreme weather events. Scientific evidence indicates that climate variability has intensified across West Africa, with Ghana experiencing significant shifts in rainfall distribution, increased frequency of droughts and floods, and unpredictable seasonal transitions that disrupt traditional farming calendars (Antwi-Agyei et al., 2021).

The agricultural implications of climate variability extend beyond simple crop yield reductions to affect farmers' ability to plan agricultural activities, manage input investments, and coordinate marketing activities (Awotide et al., 2023). This uncertainty creates a cascade of challenges that undermine both immediate productivity and long-term sustainability of farming operations.

Temperature increases and rainfall variability have been documented across different agro-ecological zones in Ghana, with northern regions experiencing more severe impacts than southern areas (Derbile, 2021). These regional variations in climate impacts necessitate location-specific approaches to weather information communication that account for different levels of climate vulnerability and adaptive capacity.

Smallholder farmers represent the most vulnerable segment of Ghana's agricultural population due to their limited access to adaptive resources, dependence on rainfed production systems, and exposure to climate-related risks. Climate-related risks and variability pose significant challenges to the livelihoods and food security of smallholder farmers practicing rainfed agriculture (Gyampoh & Asante, 2024).

The vulnerability of smallholder farmers is compounded by their limited access to climate information services. Many farmers rely on traditional weather prediction methods based on indigenous knowledge systems, which, while valuable, may not provide sufficient accuracy or lead time for optimal agricultural decision-making in the context of changing climate patterns (Kemausuor et al., 2022).

Resource constraints further limit farmers' adaptive capacity. Smallholder farmers typically have limited financial resources to invest in climate-adaptive technologies, diversified cropping systems, or risk management strategies. This economic vulnerability creates a vicious cycle where climate impacts reduce agricultural productivity, further limiting farmers' capacity to invest in adaptive measures (Osei-Owusu et al., 2023).

Women farmers face additional vulnerabilities due to gender-based inequalities in resource access, decision-making authority, and technology adoption opportunities. These gender dimensions of vulnerability require specific attention in designing communication strategies for weather information services (Boateng et al., 2024).

2.1.2 Weather Information Services and Agricultural Decision-Making

Weather information serves as a critical input for agricultural decision-making across all stages of the farming cycle. From pre-season planning decisions about crop selection and land preparation to in-season management of irrigation, fertilization, and pest control, farmers rely on weather information to optimize their agricultural practices and minimize climate-related risks (Nyong et al., 2021).

Research demonstrates that access to accurate weather forecasts can significantly improve agricultural outcomes by enabling farmers to time their activities appropriately, select suitable crop varieties, optimize input usage, and implement risk management strategies. However, the effectiveness of weather information depends not only on its accuracy but also on its accessibility, relevance, and presentation in formats that support farmer decision-making (Fosu-Mensah et al., 2023).

Climate information services can build the resilience of African farmers to address the increasing threats associated with climate change (Nyamekye et al., 2022). The temporal dimensions of weather information needs vary considerably across different agricultural activities. While seasonal forecasts inform strategic decisions about crop selection and resource allocation, short-term forecasts support tactical decisions about planting, spraying, and harvesting activities.

Historically, Ghanaian farmers have relied on a combination of indigenous knowledge systems and formal weather information sources to guide their agricultural decisions. Traditional weather prediction methods include observation of natural phenomena such as wind patterns, cloud formations, animal behavior, and vegetation responses, as well as knowledge passed down through generations about seasonal patterns and climate cycles (Lykke et al., 2021).

Indigenous weather knowledge systems possess significant value due to their cultural relevance, local specificity, and integration with traditional farming practices. However, these traditional systems may be insufficient for addressing the challenges posed by changing climate patterns and the need for more precise timing of agricultural activities in modern farming systems (Codjoe et al., 2023).

Formal weather information sources, including radio broadcasts, television weather reports, and extension service communications, have provided additional channels for weather information delivery. However, these sources often present information in formats that may not be directly applicable to specific farming contexts or may not reach remote farming communities with adequate coverage and reliability (Atiah et al., 2022).

2.1.3 Digital Technologies in Ghanaian Agriculture

The advent of digital technologies has fundamentally transformed Ghana's agricultural landscape, creating new opportunities for information delivery, knowledge sharing, and agricultural innovation. Mobile technology penetration has reached unprecedented levels in rural Ghana, with smartphone adoption and internet connectivity expanding rapidly across farming communities (Adu-Gyamfi et al., 2023).

Smallholder farming in Ghana has undergone significant transformation with the advent of digital technologies, enabling numerous information providers to operate at different scales. This digital transformation has enabled the development of innovative agricultural applications that provide farmers with access to weather information, market prices, agricultural advice, and other critical information services.

The potential of digital agriculture extends beyond simple information delivery to encompass precision farming techniques, supply chain optimization, financial services integration, and market linkage facilitation. However, realizing this potential requires careful attention to the communication design principles that determine whether digital technologies effectively serve the needs of smallholder farmers (Wiredu et al., 2022).

Several weather forecasting applications have been developed specifically for the Ghanaian agricultural context, representing significant investments in digital agricultural innovation. The FarmerSupport app (FSapp) stands out as a notable example of collaborative development between research institutions, meteorological services, and farming communities.

The FSapp gathers weather forecast information from both local farmers and scientific sources, presenting this information to users through multiple communication modalities (Paparrizos et al., 2023). This hybrid approach represents an important evolution from purely scientific weather forecasting toward more participatory and locally grounded information services.

Other weather applications targeting Ghanaian farmers include both locally developed solutions and international platforms adapted for the Ghanaian context. These applications typically provide features such as weather forecasts, agricultural advisories, pest and disease alerts, and market information, utilizing various communication modalities including text messages, voice recordings, and visual displays (Asante & Amuakwa-Mensah, 2022).

Despite the availability of these digital weather information services, adoption rates and sustained usage patterns remain below expectations, highlighting the need for deeper understanding of the communication factors that influence technology acceptance and utilization among farming communities.

2.1.4 Language and Literacy Barriers

Language accessibility represents one of the most significant barriers to effective communication through digital agricultural technologies in Ghana. The country's linguistic diversity, with over 80 indigenous languages spoken across different regions, creates complex challenges for developing communication strategies that can reach diverse farming populations (Adongo et al., 2021).

Language barriers and low digital literacy significantly hinder widespread adoption of digital agricultural technologies in Ghana (Asante et al., 2024). Many weather forecasting apps are developed primarily in English and Twi, potentially excluding farmers who speak other indigenous languages or have limited literacy skills.

Digital literacy challenges compound language barriers by limiting farmers' ability to navigate mobile applications, interpret digital interfaces, and utilize advanced features of weather apps. Low levels of formal education among rural populations create additional obstacles for accessing and utilizing digital weather information services (Darkwah et al., 2023).

These communication barriers are particularly problematic because they disproportionately affect the most vulnerable farming populations, including women farmers, elderly farmers, and those in remote areas who may benefit most from improved access to weather information but face the greatest challenges in accessing digital technologies.

2.1.5 Cultural and Contextual Relevance

Effective communication of weather information requires careful attention to cultural contexts and local knowledge systems that shape farmers' understanding and interpretation of meteorological data. Weather forecasting apps must navigate the complex relationship between scientific weather prediction methods and indigenous knowledge systems that farmers have traditionally used to guide their agricultural decisions (Awokuse & Owusu, 2023).

The challenge of cultural relevance extends beyond simple translation of content to encompass deeper questions about how weather information is framed, presented, and integrated with existing knowledge systems. Farmers may be more likely to trust and utilize weather information that acknowledges and builds upon their traditional weather prediction methods rather than dismissing or ignoring indigenous knowledge (Naab et al., 2022).

Local context specificity represents another dimension of cultural relevance. Weather information must be tailored to specific agro-ecological zones, farming systems, and crop cycles to provide actionable guidance for agricultural decision-making. Generic weather forecasts may lack the specificity required to support farmers' complex decision-making processes about timing, resource allocation, and risk management (Ofosu-Asiedu et al., 2023).

2.2 Conceptual Analysis/Framework

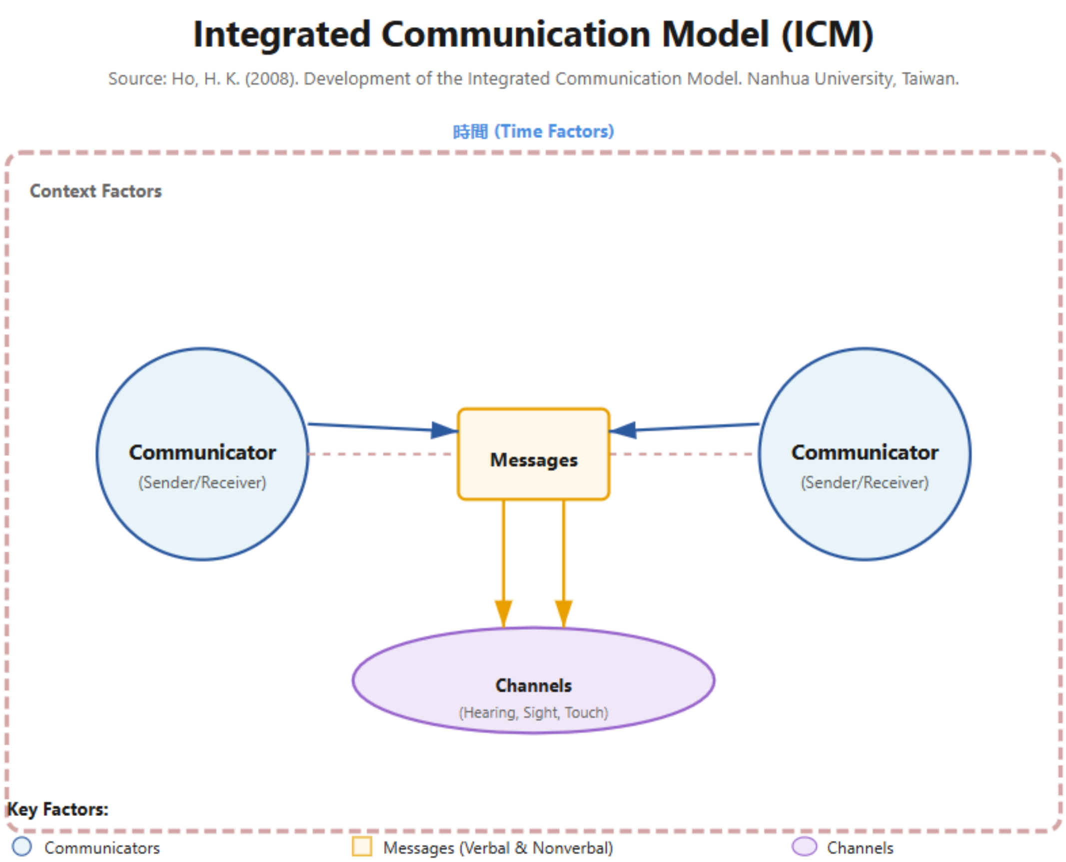

Figure 1:Integration Communication Model

The Integrated Communication Model consists of four interconnected elements that work together to create effective human communication. At the core are the communicators, who function as both senders and receivers and serve as the primary controllers of the communication process; they bring to interactions their self-concept, values, beliefs, knowledge, experiences, communication skills, and socio-cultural backgrounds, along with important perceptual processes involving attention, sensation, comprehension, and memory filtered through both biological limitations and cultural expectations. Messages represent the content being exchanged, encompassing both verbal stimuli (spoken words that can be intentional or unintentional) and nonverbal stimuli (facial expressions, posture, tone of voice, gestures, and appearance) that transmit meaning beyond words. Channels are the sensory pathways through which messages travel, primarily involving hearing, sight, and touch, with selection influenced by individual and cultural preferences.

The Integrated Communication Model provides a powerful lens for understanding why weather forecasting applications fail to achieve adoption among smallholder farmers in Ada, Greater Accra Region, despite their technical sophistication. Within Ada's farming communities, the four interconnected elements of this model operate simultaneously to either enable or constrain effective communication about weather information. The communicators (app developers) from urban technical backgrounds, agricultural extension agents working within Ada's communities, and farmers with varying levels of digital literacy and diverse linguistic backgrounds (Dangme, Twi, or English speakers) bring fundamentally different self-concepts, values, and experiences that shape how they interpret weather technology. The messages transmitted through weather apps often consist of technical meteorological terminology and numerical data presented in English language interfaces with complex visual displays, formats that many Ada farmers cannot readily comprehend due to low formal education and limited digital exposure. The channels through which these messages travel (smartphone screens, app notifications, visual weather icons) assume a level of technological familiarity that may not exist among elderly farmers or those in remote coastal and inland zones of Ada where network infrastructure remains unreliable. Effective communication strategies for weather app adoption in Ada must therefore address all four model elements simultaneously, strengthening relationships through trusted intermediaries like extension agents, encoding weather information into comprehensible local-language formats with visual aids appropriate for varying literacy levels, sequencing communication across the adoption timeline with sustained farmer support and training, selecting accessible channels that account for Ada's infrastructure limitations, building messages that integrate indigenous knowledge with scientific forecasts, and transforming the contextual and social environment to position weather apps as locally relevant tools that enhance rather than replace traditional farming knowledge.

2.3 Theoretical Framework

2.3.1 Diffusion of Innovation Theory

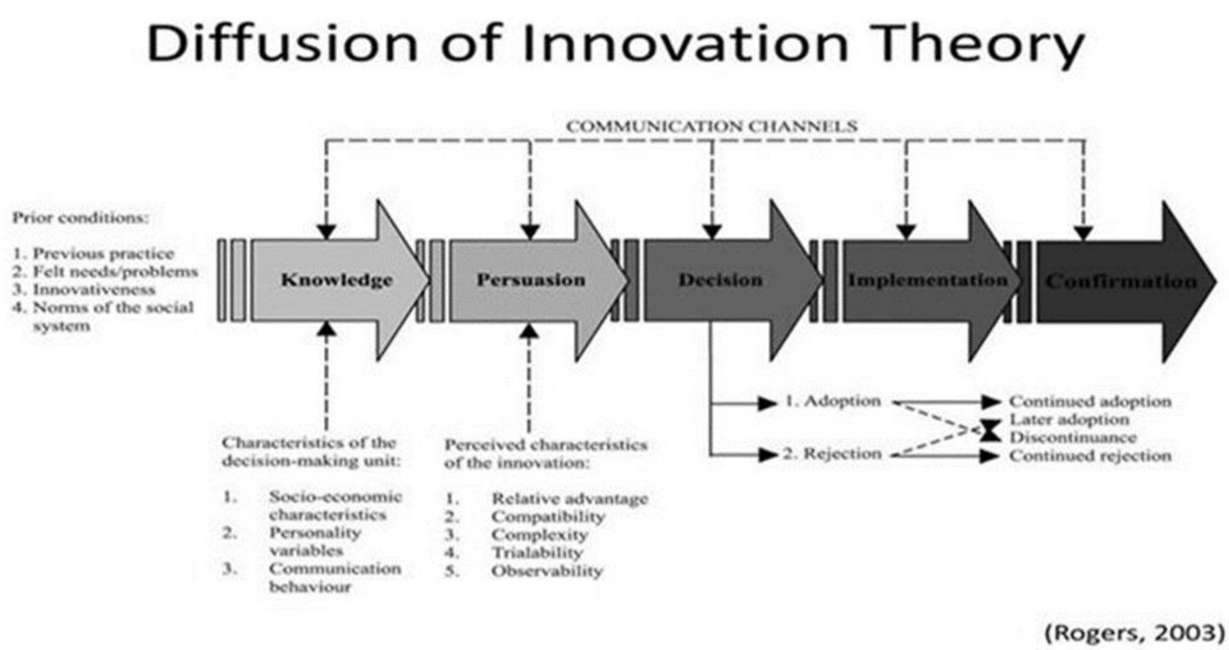

Figure 2: Diffusion of Innovation Theory

The diagram shows Rogers' (2003) model as communication channels flowing across all five stages of the innovation-decision process, indicated by the dashed lines with arrows pointing downward into each stage. These channels are critical because they transmit information about the innovation to potential adopters. Communication channels include both mass media (television, radio, newspapers) and interpersonal channels (face-to-face communication), with mass media being more significant at the knowledge stage for awareness-building, while interpersonal channels become more important at the persuasion stage for attitude formation. The continuous flow of communication channels across all stages emphasizes that information availability and source credibility remain relevant throughout the entire adoption journey.

The model identifies three key characteristics that influence how individuals or organizations make innovation decisions. Socio-economic characteristics include variables such as education level, income, social status, and occupational background; these factors typically correlate with innovativeness, with higher education and income often associated with earlier adoption. Personality variables encompass individual traits such as risk tolerance, openness to change, self-efficacy, and general attitude toward technology; individuals with higher risk tolerance and openness to new experiences tend to adopt innovations more readily. Communication behaviour refers to how individuals seek, process, and share information; those with higher engagement in communication networks, who actively seek information and maintain diverse communication channels, are more likely to adopt innovations earlier.

The five sequential stages form the core of the model, represented as a progression of arrows moving from left to right. These stages represent the temporal dimension of Rogers' theory, showing that adoption is not instantaneous but rather a process unfolding over time.

Knowledge Stage: This initial stage occurs when individuals become aware of the innovation's existence and begin seeking information about it. During this stage, potential adopters ask fundamental questions about what the innovation is, how it works, and why it exists. The knowledge stage is primarily cognitive, focused on information acquisition rather than emotional response. Communication channels, particularly mass media, are most effective here for creating initial awareness.

Persuasion Stage: Following knowledge acquisition, individuals form attitudes; either favorable or unfavorable toward the innovation. This stage is more affective or emotional than the knowledge stage, involving subjective evaluation and assessment of the innovation's relevance to personal or organizational needs. Individuals seek information about the innovation's advantages and disadvantages, often relying on trusted colleagues and peers rather than external experts. Social reinforcement from reference groups becomes particularly influential at this stage.

Decision Stage: At this critical juncture, individuals make a binary choice: to adopt (accept the innovation as the best course of action) or to reject (decide not to adopt). The diagram shows this as the branching point where the process diverges into two paths. Importantly, rejection at this stage can take either active form (consciously deciding against adoption after consideration) or passive form (simply not considering adoption). The decision may be influenced by the opportunity to trial the innovation first, as vicarious or limited trials often accelerate the adoption decision.

Implementation Stage: Once adoption is decided, individuals put the innovation into practice. This stage involves actual use of the innovation in real-world contexts. During implementation, users often engage in reinvention; modifying or adapting the innovation to fit their specific circumstances and needs. Technical assistance and support become crucial here to manage uncertainty about whether the innovation will produce expected outcomes and to troubleshoot problems.

Confirmation Stage: The final stage involves individuals seeking reinforcement for their adoption decision. Those who adopted continue to evaluate whether the innovation is meeting their needs and expectations. The confirmation stage can result in either continued adoption (if the innovation performs well) or later adoption (if additional time and experience strengthens commitment). However, discontinuance can also occur during this stage if the innovation fails to deliver expected benefits or if a better alternative emerges.

The model identifies five key attributes of innovations themselves that predict adoption likelihood. Relative advantage is the degree to which the innovation is perceived as superior to existing alternatives in terms of benefits, efficiency, or outcomes. Compatibility measures how well the innovation aligns with existing values, experiences, and needs of potential adopters. Complexity refers to the perceived difficulty of understanding and using the innovation; higher complexity slows adoption. Trialability represents the extent to which the innovation can be tested on a limited basis before full commitment. Observability is the degree to which results of using the innovation are visible to others, enabling peer learning and social proof.

The diagram shows the model converging into four possible outcomes following the decision stage. Adoption leads to continued adoption (the innovation becomes standard practice) or later adoption (gradual integration into routine). Rejection can result in continued rejection (permanent non-adoption) or discontinuance (initial adoption followed by abandonment due to dissatisfaction or discovery of better alternatives). These outcomes are not always final; the confirmation stage allows for outcome reversal, as individuals may shift from rejection to adoption or vice versa based on new information or changing circumstances.

The comprehensive nature of this model demonstrates that innovation adoption is not determined by any single factor but rather by the complex interaction of prior conditions, individual and organizational characteristics, the innovation's attributes, communication processes, and the sequential stages of decision-making. The feedback loops (shown by dashed lines) indicate that this is not a purely linear process; information from later stages can influence earlier perceptions, and outcomes can feed back into the system, affecting future innovation-decision processes within the social system.

In the context of weather forecasting apps, relative advantage refers to the perceived benefits of digital weather information compared to existing information sources. Compatibility encompasses the degree to which weather apps align with farmers' existing practices, values, and needs. Complexity relates to the perceived difficulty of understanding and using weather applications. Trialability refers to the extent to which farmers can experiment with weather apps before making adoption decisions. Observability concerns the visibility of benefits from using weather information services (Rogers, 2003).

The diffusion process occurs through communication channels that connect different categories of adopters, including innovators, early adopters, early majority, late majority, and laggards. Understanding these adoption categories and the communication preferences of different farmer groups is essential for designing effective strategies for scaling weather information services (Panzou et al., 2023).

The theory also emphasizes the importance of opinion leaders and social networks in influencing adoption decisions. In farming communities, respected farmers, agricultural extension agents, and community leaders often serve as influential sources of information about new technologies and practices (Wiredu et al., 2023).

2.4 Integrated Communication Effectiveness Model

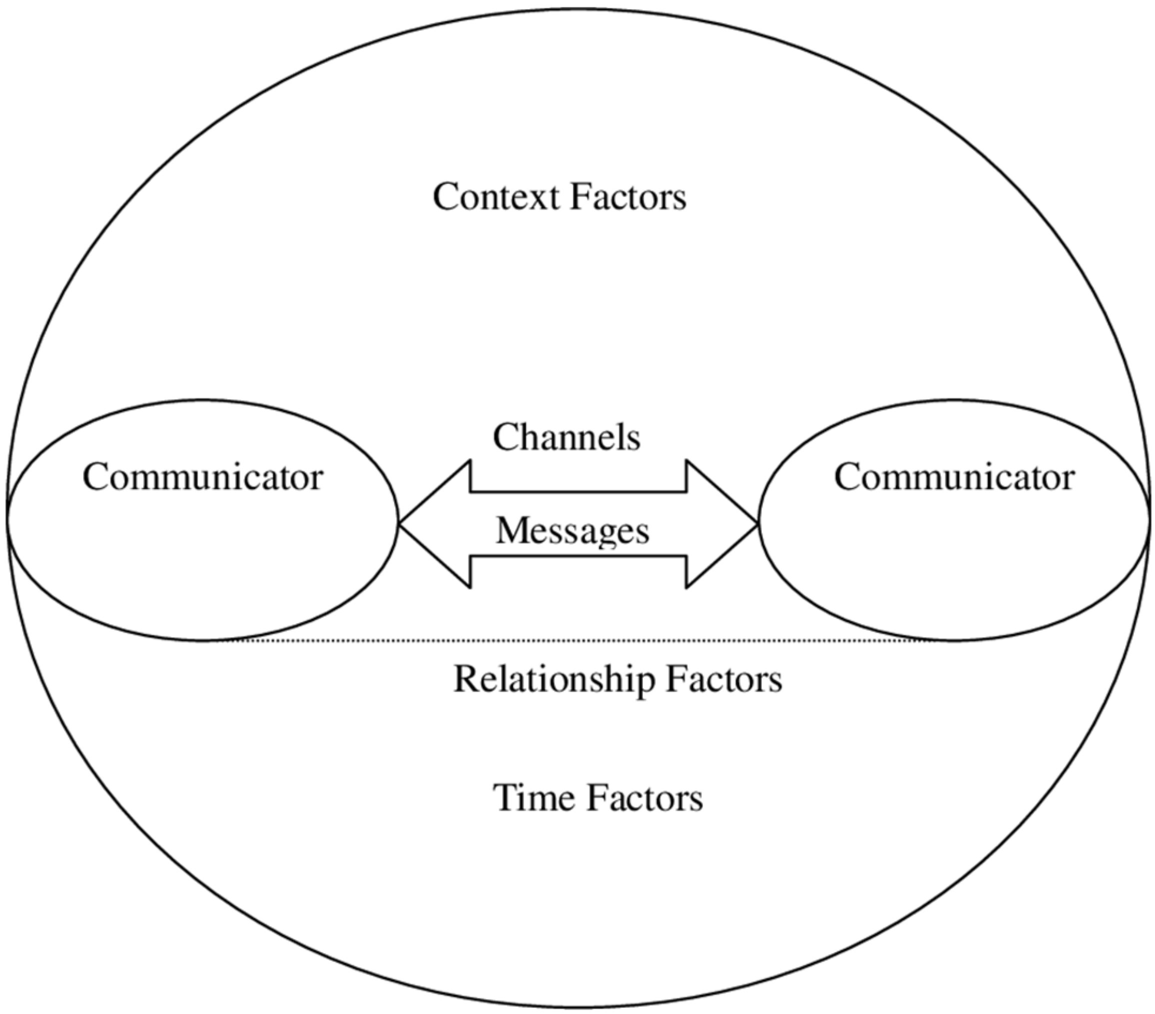

Figure 3: Integrated Communication Effectiveness Model

Source: Hua-Kuo Ho, 2008

The diagram illustrates the interpersonal communication process, highlighting the dynamic interaction between two communicators who exchange messages through various channels. The communicators represent the sender and receiver, both actively involved in encoding, transmitting, decoding, and interpreting messages. The messages are the core content being shared; ideas, emotions, or information, while the channels refer to the mediums through which these messages are conveyed, such as verbal speech, written text, or nonverbal cues. Surrounding these interactions are context factors, which include the social, cultural, and situational environments that influence how communication occurs and is interpreted. Relationship factors lie beneath the interaction, representing the nature of the relationship between communicators such as trust, power dynamics, or emotional closeness which affects meaning and tone. Lastly, time factors emphasize the temporal dimension of communication, including timing, duration, and the historical background of interactions, all of which shape understanding and effectiveness in communication.

The integration of Rogers' Diffusion of Innovations Theory with Communication for Development principles creates a powerful synergistic framework for understanding weather forecasting app adoption among farmers. Rogers' theory provides the structural foundation through its five innovation characteristics (relative advantage, compatibility, complexity, trialability, observability) and adopter categories (Rogers, 2003), while Communication for Development principles offer essential cultural sensitivity and participatory approaches that ensure technology diffusion is contextually appropriate and empowering (Ascroft & Masilela, 1994; Bessette, 2006; Servaes, 2008). This theoretical synergy emerges particularly in the innovation-communication nexus, where weather apps must demonstrate relative advantage through locally relevant benefits while maintaining compatibility with existing farming practices and cultural norms. The integration transforms Rogers' adopter categories from simple demographic classifications into culturally-mediated roles, where early adopters serve as cultural bridges requiring culturally appropriate messaging to reach different segments effectively. Language barriers are addressed through this synergistic lens as requiring semantic accessibility, cultural translation beyond literal linguistic conversion, and multi-modal communication approaches that match local literacy patterns and communication preferences. Cultural factors become innovation catalysts rather than barriers, with cultural compatibility ensuring weather apps align with existing weather prediction practices, social system integration recognizing how community hierarchies influence diffusion patterns, and trust-building mechanisms that validate information through cultural lenses of authority and community validation. The framework points toward communication strategies emphasizing participatory co-creation with farming communities, progressive disclosure that builds farmers' capacity to use sophisticated weather information, and community-centric feedback loops that continuously refine communication approaches based on user experiences. This synergistic integration ultimately directs research toward a culturally-responsive innovation diffusion model that recognizes farmers as active interpreters rather than passive recipients, emphasizes cultural bridge-building between meteorological and traditional knowledge systems, values participatory design emerging from community engagement, and accounts for systemic feedback requiring continuous refinement. The theoretical synthesis suggests that successful weather forecasting app adoption in agricultural contexts depends not on simple technology transfer but on culturally-grounded communication processes that respect existing knowledge systems while introducing innovative tools that enhance farmers' decision-making capabilities and climate resilience.

2.6 Study Framework for Weather App Adoption Among Farmers

(Author's Own Framework, 2025)

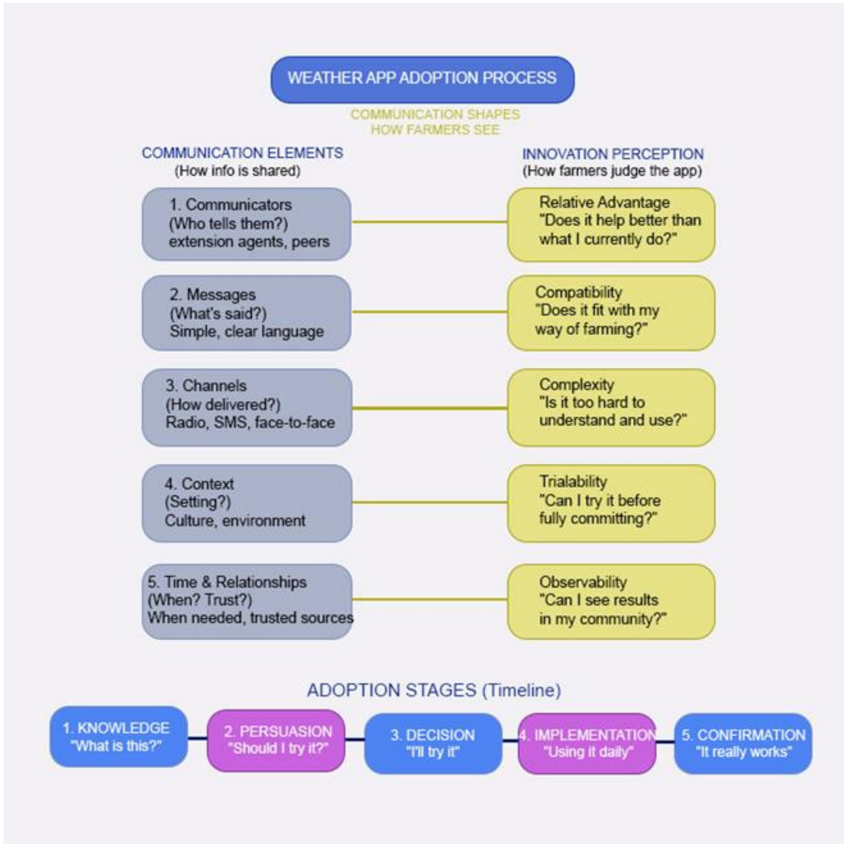

Figure 4: Weather App Adoption Among Farmers

The Core Idea: Technology adoption is fundamentally a communication process, not just a technology problem.

Step 1: Communication Elements (Left Side): Information about the weather app reaches farmers through specific people, using specific messages, through specific channels, in culturally specific contexts, at the right times, through trusted relationships.

Step 2: Communication Shapes Perception (Middle): How well this communication is done determines how farmers perceive the innovation. Good communication makes the app seem simple, relevant, and beneficial. Poor communication makes it seem complex and foreign.

Step 3: Perception Drives Adoption (Right Side): Farmers judge the app based on: Does it help? Is it compatible with my way of farming? Is it too hard? Can I try it? Will my neighbors see benefits?

Step 4: Decision Made Through Stages (Bottom): Adoption happens gradually through five stages. At each stage, communication must change. What works for awareness (radio) doesn't work for trust-building (peer conversation).

2.6 Review of Related Studies

Table 1: Synthesis of Literature Review

Study	**Theoretical Framework**	**Methodology**	**Key Findings**	**Conclusions**	**Strengths**	**Limitations**	**Relevance to Current Study**
Nyamekye et al. (2022) Climate Information Services and Farmer Decision-Making in	Knowledge-to-Action Framework; Elements of Decision-Making Theory	Longitudinal study (2017-2020); 180 farmers across 3 districts; mixed-methods with quarterly	78% had access to seasonal forecasts but only 43% used them for decisions. Three barriers: forecast-	Effectiveness depends on communication design, delivery channels, and integration	Strong longitudinal design; robust mixed-methods approach; tracked actual	Limited to northern Ghana; sample size relatively small for generalization; did not examine	Establishes that communication strategies determine impact more than technical

Northern Ghana		surveys, FGDs, in-depth interviews (n=30), participatory observation; statistical analysis and thematic coding	decision timeline mismatch, trust deficit vs indigenous knowledge, insufficient actionable guidance. Farmers receiving info via extension agents 2.3x more likely to act on forecasts vs radio alone	with local knowledge rather than forecast accuracy. Future services must prioritize participatory co-design with farmers' needs	behavior over time; identified specific communication barriers	digital apps specifically; limited analysis of literacy/language barriers	accuracy; validates focus on extension agents as key intermediaries
Fosu-Mensah et al. (2023) Farmers' Adaptation Strategies in Forest-	Sustainable Livelihoods Framework; Protection Motivation Theory	Cross-sectional survey; 450 households in Brong-Ahafo and Ashanti; structured	Weather information 3rd most significant factor for adaptation (β=0.287,	Language accessibility and cultural appropriateness are critical for climate	Large sample size; sophisticated statistical analysis;	Cross-sectional design limits causal inference; limited to two regions;	Provides empirical evidence for language/literacy barriers in weather

Savanna Transition Zone		interviews, 12 FGDs, key informant interviews; multinomial logit regression	p<0.01). Only 31% received info in understandable formats. 64% cited language barriers (English/technical terms). Local language info (Twi/Dagbani) showed 47% higher adoption of climate-smart practices	adaptation. Need multilingual platforms integrating scientific forecasts with indigenous terminology	explicit focus on language barriers; quantified relationship between language and behavior	did not examine digital technologies; self-reported data subject to bias	information; quantifies impact of local language on adoption rates
Wiredu et al. (2022) Digital Agriculture Transformat	TAM, UTAUT, Digital Divide Theory	Comprehensive survey; 850 farmers across 10 regions; stratified by	Ease of use (β=0.41, p<0.001) > usefulness (β=0.28, p<0.01). Basic	Digital transformation faces structural barriers requiring	Nationally representative sample; rigorous SEM	Cross-sectional design; potential response bias; limited	Validates focus on communication effectiveness over

ion in Ghana	(integrated framework)	farm size, gender, age, education; structural equation modeling; 40 in-depth interviews	smartphone skills increased adoption 5.2x. Infrastructure barriers: 73% unreliable electricity, 68% poor internet. Women 39% less likely to own smartphones, 52% less likely to use ag apps	ecosystem approaches: infrastructure, literacy training, gender equity, low-literacy UI design	analysis; explicit gender analysis; identified infrastructure constraints; challenged assumptions about utility primacy	focus on weather apps specifically; did not deeply examine cultural/linguistic factors	technical features; establishes ease of use as paramount; justifies 50% female sampling strategy
Asante et al. (2024) Language Barriers and Digital Literacy	Linguistic Relativity Theory; Information Processing Theory	Experimental design; 240 farmers in Greater Accra and Eastern regions; 3 treatment groups	Twi-multimedia: 63% higher comprehension vs English-only ($p<0.001$), 34% vs text-	Language barriers extend beyond translation to information design,	Experimental design enables causal inference; immediate and retention	Limited to 2 regions; relatively small sample; artificial experimental conditions	Demonstrates magnitude of communication barriers; validates research

		(English only, English+Twi, Twi+multimedia); comprehension tests (immediate and 7-day retention); qualitative interviews	only Twi (p<0.01). 7-day retention: 71% multimedia, 52% text Twi, 29% English. <20% comprehension for English-only among <primary education farmers (46% of sample). Strong preference for multimodal (text+visual+audio)	multimodal communication, cognitive accessibility. Need Universal Design principles for literacy/linguistic diversity	testing; multimodal treatment; included low-literacy farmers; quantified comprehension gaps	may not reflect real-world use; short retention period	question on language barriers; informs investigation of communication formats
Paparrizos et al. (2023) Co-	Participatory Design Theory; Co-	Action research (2018-2021);	Co-production led to: agricultural	Participatory design improves	Longitudinal participato	Limited geographic scope;	Provides evidence on FarmerSupp

Production of FarmerSupport App	Production Framework	iterative design workshops with 75 farmers, 12 extension officers, meteorological reps; Northern regions; needs assessment, prototype testing, usability studies, post-launch tracking	terminology (not meteorological), indigenous indicators integration, farming-relevant visual symbols, voice functionality. 34% adoption after 1 year. Persistent barriers: data bundles (67%), storage (41%), technical support (58%), extension integration (72%)	relevance/usability but insufficient without addressing infrastructure, economic constraints, institutional integration, sustained support. Apps are components of broader systems, not standalone solutions	ry approach; documented actual development process; tracked post-launch adoption; identified real-world implementation barriers	relatively small user base; unclear sustainability post-research; limited comparison with non-participatory apps	ort app; shows participatory design alone insufficient; validates examination of communication strategies, institutional support, structural barriers
	Value Chain Approach;	Mixed-methods; 520	Five channels with varied	Communication gap not	Large sample;	Northern regions	Establishes broader

Atiah et al. (2022) Climate Information Services Value Chain	Communication Effectiveness Framework	farmers in 3 northern regions; 45 stakeholder interviews (meteorological, media, extension, NGO); network analysis of info flows; content analysis of formats across channels	effectiveness: radio (68% reach, 22% actionability), SMS (45%, 31%), apps (23%, 41%), extension (34%, 67%), farmer-to-farmer (78%, 52%). Extension highest actionability despite lower reach. Apps highest actionability among users but limited reach. Generic forecasts rarely	meteorological gap. Technical forecast capacity exists but institutional fragmentation, poor communication design, inadequate last-mile delivery prevents effectiveness. Need coordinated multi-channel strategies with extension as	multi-stakeholder perspective; network analysis innovative; differentiated reach vs actionability; identified systemic communication failures	only; potential stakeholder interview bias; snapshot design; limited examination of specific communication barriers	context of systemic communication challenges; validates extension agents as high-actionability intermediaries; supports research objective on communication channel effectiveness

			crop/system-specific	contextualizing intermediary			
Kemausuor et al. (2022) Traditional Weather Prediction and Climate Adaptation	Indigenous Knowledge Systems Theory; Cultural Continuity Framework	Ethnographic (18 months); Volta, Northern, Ashanti regions; participant observation, life histories (32 traditional forecasters), FGDs (180 farmers); comparative accuracy analysis	200+ environmental indicators documented in indigenous systems. Traditional forecasts comparable accuracy for 1-7 days locally; scientific better for longer timeframes. Trust: traditional 87%, radio 34%, apps 19%. Trust	Indigenous knowledge is complementary not obsolete. Effective climate services must integrate traditional and scientific approaches, leveraging trust/relevance of indigenous	Deep ethnographic approach; documented sophisticated indigenous systems; comparative accuracy analysis; trust hierarchy analysis; multiple regions	Lengthy timeframe may limit replicability; potential observer effect; limited quantitative analysis; unclear how integration should occur practically	Provides context for indigenous knowledge integration question; explains adoption resistance to technically accurate apps; validates objective examining how indigenous integration affects trust

			from: social embeddedness/ accountability, culturally familiar terminology, historical utility track record	systems with temporal range/precision of scientific forecasts			and adoption

2.6.1 Identified Knowledge Gaps and Deficiencies

Current research falls short by not systematically analyzing specific communication elements such as language, visual design, terminology, and multimodality within weather apps through established communication theory frameworks. Furthermore, while studies recommend integrating indigenous and scientific knowledge, none explore the specific design, implementation, or communication mechanisms for this integration within digital platforms. A third gap is the failure to specifically investigate the perspectives of extension agents on app communication effectiveness or their role as crucial communication bridges, despite acknowledging their importance. The existing body of work also analyzes communication barriers in isolation (e.g., language or literacy) instead of comprehensively examining how multiple barriers interact and compound to prevent adoption. Theoretically, research largely applies agricultural adoption models (TAM, UTAUT) but lacks the application of communication-specific theories (e.g., Shannon-Weaver, Integrated Communication Model). The intersection of gender and communication is also neglected; while access disparities are noted, no study examines if communication barriers affect men and women differently or require gender-sensitive strategies. Finally, research focuses on adoption and use, but not the distinct concept of "actionability" a farmer's ability to translate weather information into specific agricultural decisions, regardless of technical accuracy.

2.6.2 Critical Observations and Study Justification

The current research landscape exhibits methodological patterns characterized by heavy reliance on northern Ghana, limiting generalizability, and a predominance of cross-sectional designs, limiting causal inference. There is an overemphasis on farmer perspectives, while the voices of extension agents and app developers are largely unrepresented. The theoretical foundation is weak, relying on rational decision-making models and neglecting the socio-cultural dimensions of communication effectiveness. Practically, existing studies identify problems but offer only general, non-actionable guidance ("improve communication") rather than specific design principles for app developers. The present study addresses these flaws by employing Theoretical Innovation (applying the Integrated Communication Effectiveness Model), ensuring Stakeholder Inclusivity (sampling farmers, agents, and developers), providing Geographic Expansion (researching coastal Greater Accra), performing a Communication-Centered Analysis of specific elements, focusing on Actionability, exploring specific Integration Mechanisms for indigenous knowledge, and conducting a detailed Gender-Communication Analysis. This comprehensive approach seeks to provide specific, actionable guidance rooted in communication theory.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodological approach employed to investigate the effectiveness of communication strategies in promoting weather forecasting app adoption among smallholder farmers in Ghana. The methodology is designed to address the research objectives and answer the research questions through a systematic and rigorous approach that ensures the reliability and validity of findings.

The chapter presents the research design, study population, sampling procedures, data collection methods, data analysis techniques, ethical considerations, and limitations of the study. This comprehensive methodological framework provides the foundation for generating meaningful insights into the communication dimensions of agricultural technology adoption.

3.2 Research Design

This study adopts a qualitative exploratory research design to investigate the complex communication dynamics surrounding weather forecasting app adoption among smallholder farmers in Ghana. The exploratory approach is particularly appropriate given the limited existing research on communication strategies for agricultural technology adoption in the Ghanaian context.

The qualitative methodology enables in-depth exploration of farmers' lived experiences, perceptions, and decision-making processes regarding weather app adoption. This approach allows for the examination of cultural, linguistic, and social factors. The exploratory design provides the flexibility needed to investigate emerging themes and unexpected findings that could inform future research and practice. This methodological choice aligns with the study's objective to understand the nuanced communication challenges and opportunities in agricultural technology adoption.

3.3 Research Philosophy

This study is grounded in an interpretivist research philosophy that recognizes the socially constructed nature of knowledge and the importance of understanding phenomena from participants' perspectives. The interpretivist approach acknowledges that farmers' adoption decisions are influenced by their cultural contexts, personal experiences, and social interactions.

The phenomenological orientation within the interpretivist framework emphasizes understanding the lived experiences of farmers as they encounter and evaluate weather forecasting applications. This philosophical stance recognizes that meaning-making is a dynamic process influenced by individual, cultural, and contextual factors.

3.4 Study Area

Figure 5: Satellite map of Ada Foah, Source: Google Earth Pro

Ada, Ghana, is a low-lying coastal town situated at the critical confluence of the Volta River and Atlantic Ocean, which creates complex microclimate zones highly vulnerable to extreme weather variations (Codjoe et al., 2020). The area experiences challenging conditions, including extreme temperature fluctuations and harmattan winds that reduce visibility to 1km (World Travel Guide, 2025). Local livelihoods, encompassing fishing, agriculture, and tourism, are critically weather-sensitive and require precise forecasting for safety and productivity (Codjoe et al., 2020). The unique intersection of river, ocean, and lagoon ecosystems results in highly localized weather patterns that standard regional forecasts cannot adequately capture. These geographical challenges, combined with ongoing climate change impacts such as the 2021 storm surge that displaced nearly 4,000 people (Mongabay, 2022), create an urgent need for innovative, hyper-local weather applications to support disaster risk reduction, economic activities, and community adaptation (Cudjoe & Alorvor, 2021).

This study is carried out in Ada Foah, the capital of the Ada East District, has a total population of 76,411, with females slightly outnumbering males at 51.5% (Ghana Statistical Service, 2021). The district is characterized by a predominantly young, working-age demographic, with 36.5% under 15 and 58.1% of working age; approximately 60.8% of residents are under 30 years old (Ghana Statistical Service, 2021). The population is largely Ga-Dangme (86.7%), with a literacy rate of 69.6% among those aged 11 and above, and the majority (64.9%) live in rural areas (Ghana Statistical Service, 2021). This young demographic, heavily reliant on weather-sensitive livelihoods, presents strong potential for weather app adoption. However, Ada Foah faces four critical, interconnected challenges: illegal sand mining that accelerates coastal degradation (Odjugo et al., 2024); severe coastal erosion claiming up to 4 meters annually and destroying 37% of Ghana's coastal land between 2005-2017 (Jayson-Quashigah et al., 2020; Mongabay, 2022); loss of agricultural lands to real estate development (Adarkwah et al., 2018); and encroachment on indigenous salt mining at Songor Lagoon by large-scale operations, displacing over 35,000 artisanal miners and sparking conflicts (Media Foundation for West Africa, 2022). These compounding threats make hyper-local weather information systems essential for community survival and economic justice (Issaka, 2023).

Ada Foah was selected as the study location due to its diverse agro-ecological contexts spanning coastal and inland farming zones, with agriculture being the primary economic activity supporting diverse crops including maize, cassava, vegetables, and rice (Ministry of Food and Agriculture, 2021; Adjei-Nsiah, 2012). The area's significance as the main source of staple foods with cassava as Ghana's most highly produced crop contributing 22% of agricultural GDP and maize being the most important cereal accounting for 55% of grain output makes it representative of Ghana's smallholder farming systems (Ministry of Business Development, n.d.; Berkeley Investors Club, 2019). Ada Foah faces high climate vulnerability characterized by irregular rainfall patterns, seasonal flooding, and drought conditions, with statistically significant positive trends observed for major wet season and mean annual rainfall, alongside day-to-day temperature variability that makes weather information particularly critical for agricultural planning (Ayamga et al., 2021; Tetteh-Ahinakwah et al., 2024). The area features adequate mobile network coverage with Ghana's 113% mobile penetration rate representing 38.95 million connections in 2024, though digital literacy challenges persist in rural areas, while Ada's multilingual population includes primarily Dangme speakers (part of the Ga-Dangme languages in Greater Accra Region), along with Twi and English, providing opportunities to examine language-related communication barriers in weather app adoption (GeoPoll, 2024; Wikipedia, 2025; Expatlife Ghana, 2024).

3.5 Target Population

The target population for this study consists of three distinct but interconnected groups:

Primary Population - Smallholder Farmers: Farmers operating on land sizes of 5 hectares or less, engaged in crop production, and residing in Ada district. This group represents the primary beneficiaries of weather information services.

Secondary Population - Agricultural Extension Agents: Extension officers working in Ada district who serve as intermediaries between formal agricultural services and farming communities. These professionals provide insights into communication challenges and opportunities from a service delivery perspective.

Tertiary Population - App Developers: Representatives from organizations involved in developing weather forecasting applications in Ghana, for agricultural use.

3.6 Sampling Strategy

Table 2: Geographic Sampling

Respondent Group	**Number (N)**	**Key Characteristics**
Smallholder Farmers	25 - 30	Gender: Maintained 50% female and 50% male balance. Geographic Zones: Coastal (32%), Inland (36%), and Transitional (32%). Education: 25% had no formal education; 75% had at least primary education. Experience/Technology: Average of 16.8 years farming experience; 75% owned smartphones. Age: 39% aged 18-35, 36% middle-aged, 25% older farmers.
Agricultural Extension Officers	5	Mean experience of 9.6 years. Represented various sub-districts and were fluent in multiple local languages.

Weather App Developers	3	Representatives from FSapp (a local platform).

This study employs a multi-stage purposive sampling approach to gather comprehensive qualitative data from three groups: smallholder farmers (Primary Population, 25-30 participants) who are the main beneficiaries; Agricultural Extension Agents (Secondary Population, 5 participants) who offer service delivery insights; and App Developers (Tertiary Population, 3 participants) providing design perspectives. Farmer selection uses geographic sampling across Coastal, Inland, and Transitional Zones, ensuring representation based on location, and demographic criteria including 50% female participation, a minimum of three years of experience, and age stratification (40% young, 35% middle-aged, 25% older). These smallholders, with an average of 16.8 years of experience and an average farm size of 2.3 hectares, primarily grew staple crops like maize, cassava, yam and vegetables. Maximum variation sampling is also employed to capture diversity in crop types, farm sizes, technology experience, and educational levels within each geographic zone.

Data will be collected through in-depth semi-structured Interviews (45-60 minutes for farmers, 30-45 minutes for agents and developers) covering topics from weather sources to technology perceptions, supplemented by structured observation sessions of farmer-technology interaction to document behaviors. The three-week data collection process involves pre-fieldwork community entry, intensive interviewing and observation, and a final data verification phase including member checking and preliminary analysis, all coordinated by a Principal Investigator and two trained Research Assistants fluent in local languages.

3.7 Data Management and Documentation

The study's data management and analysis procedures ensure rigor and ethical conduct. Data recording involves audio recording all interviews with consent, backed up by field notes capturing non-verbal cues and contextual information. For security, all digital files are stored on encrypted, password-protected drives with cloud backup, while physical documents are kept in locked cabinets, with access strictly limited to the research team. Data analysis begins with bilingual transcription (original language first) and quality assurance by two team members, followed by professional translation where needed. The primary analytical approach is thematic analysis, supplemented by narrative analysis of farmer stories and discourse analysis to examine language construction; all coding is guided by theoretical frameworks like Rogers' Diffusion of Innovation Theory, utilizing NVivo 12 as the main analysis tool. To ensure validity and reliability, the study employs triangulation across multiple sources and methods, member checking for participant verification, and peer debriefing to challenge interpretations. Transferability is established through thick description of the context, and dependability and confirmability are maintained via a comprehensive audit trail and regular reflexivity on researcher positionality.

3.8 Coding Mechanism

The research's coding mechanism is a comprehensive, multi-step process: data capture involves high-quality bilingual audio transcription of interviews (English, Twi, and Dangme) and field notes within 24 hours, alongside quality assurance via a dual review; analysis utilizes a combination of Thematic Analysis (for patterns), Narrative Analysis (for stories), and Discourse Analysis (for language construction); and coding is performed systematically at three levels using a hybrid approach (combining Rogers' Diffusion of Innovation Theory categories with emergent themes) on the NVivo 12 platform.

3.9 Ethical Considerations

The ethical conduct of this study is governed by strict adherence to institutional and universally accepted guidelines. The research received Institutional Approval from the University of Media Arts and Communications' Research Ethics Committee prior to any data collection. All participants provide informed consent through written consent with a witness for illiterate participants after receiving detailed information on the study's purpose, procedures, risks, benefits, and their right to withdraw at any time. Privacy and Confidentiality are maintained by assigning all participants pseudonyms, storing personal identifying information separately and securely, and ensuring that no reported data can lead to participant identification. The team is highly bent on professional conduct ensuring all research activities demonstrate cultural sensitivity by respecting local customs and traditions.

3.10 Limitations of the Study

The methodological limitations of the study must be acknowledged. The Geographic Scope, focused only on the Ada district, limits the generalizability of findings to other regions with different agro-ecological or cultural contexts. Despite using multilingual research assistants, language barriers pose a risk, as some linguistic nuances may be lost in translation, potentially affecting the depth of understanding. Furthermore, the selection criteria requiring smartphone access may introduce selection bias by excluding the most technologically marginalized farmers whose perspectives are highly valuable. Finally, the temporal constraints of a cross-sectional study design mean the data provides only a snapshot, failing to capture seasonal variations in technology use or the evolving adoption processes over time.

3.11 Chapter Summary

This chapter has outlined the comprehensive methodological framework guiding this qualitative exploratory study of communication strategies for weather forecasting app adoption among smallholder farmers in Ghana. The methodology combines rigorous sampling procedures, multiple data collection methods, and systematic analysis techniques to ensure reliable and valid findings.

The emphasis on cultural sensitivity, ethical considerations, and methodological transparency reflects the study's commitment to producing meaningful insights that can inform policy and practice while respecting the rights and dignity of research participants. The acknowledged limitations provide important context for interpreting study findings and identifying areas for future research.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the findings from the qualitative exploratory study investigating communication strategies on the adoption of weather forecasting applications by farmers in Ada District, Greater Accra Region, Ghana. The analysis is based on data collected through in-depth semi-structured interviews with 28 smallholder farmers, 5 agricultural extension officers, and 3 weather app developers, conducted over a three-week period within the month of October, 2025.

The chapter is organized thematically to address the three primary research objectives: (1) evaluating the effectiveness of current communication strategies used by weather forecasting apps in overcoming language and cultural barriers; (2) identifying and analyzing key barriers preventing smallholder farmers from adopting weather applications; and (3) assessing how the integration of indigenous weather knowledge with scientific forecasts affects farmer trust and adoption rates.

Data analysis employed thematic analysis, narrative analysis, and discourse analysis using NVivo 12 software. Theoretical saturation was achieved after interviewing 28 farmers, with consistent patterns emerging across all three geographic zones (coastal, inland, and transitional). The demographic characteristics of participants are first presented, followed by detailed thematic findings organized around the research questions. The research employs the use of fictitious names to ensure respondent's anonymity.

4.2 Demographic Characteristics of Participants

The following tables provide an overview of the anonymous profiles of the 36 respondents who were categorized into three groups i.e., smallholder farmers, extension officers and weather app developers.

Table 3: Anonymous Profile of Smallholder Farmers

Respondent ID	Farm Produce	Age Range (Years)	Gender	Years of Experience	Educational Background	Geographical Location	Smart-Phone Exposure
SHF1	Vegetables and Maize	36-49	Farmer	21-35	No Education	Coastal Zone	Yes
SHF2	Maize	18-35	Female	10-20	Junior High School	Coastal Zone	Yes
SHF3	Yam	50-65	Female	21-35	Primary Education	Coastal Zone	No
SHF4	Vegetables	36-49	Female	21-35	Primary Education	Transitional Zone	Yes
SHF5	Vegetables and Maize	36-49	Female	10-20	Junior High School	Inland Zone	Yes
SHF6	Maize	50-65	Female	21-35	No Education	Inland Zone	Yes
SHF7	Vegetables and Maize	18-35	Female	10-20	Junior High School	Transitional Zone	Yes

SHF8	Vegetables	18-35	Female	10-20	Senior High School	Inland Zone	Yes
SHF9	Maize	36-49	Female	10-20	Tertiary	Coastal Zone	No
SHF10	Maize	36-49	Female	10-20	Primary Education	Inland Zone	Yes
SHF11	Maize	18-35	Female	10-20	No Education	Transitional Zone	Yes
SHF12	Yam	50-65	Female	21-35	No Education	Transitional Zone	No
SHF13	Potatoes & Yam	36-49	Female	10-20	Junior High School	Inland Zone	No
SHF14	Maize	50-65	Female	21-35	Primary Education	Coastal Zone	Yes
SHF15	Vegetables & Maize	36-49	Male	10-20	Junior High School	Transitional Zone	Yes
SHF16	Vegetables	18-35	Male	10-20	Senior High School	Coastal zone	Yes
SHF17	Vegetables and Maize	18-35	Male	10-20	Senior High School	Coastal zone	Yes
SHF18	Maize, Potatoes & Yam	18-35	Male	10-20	Tertiary	Inland Zone	Yes
SHF19	Vegetables	36-49	Male	21-35	Tertiary	Inland Zone	No

SHF20	Maize	18-35	Male	10-20	Junior High School	Transitional Zone	Yes
SHF21	Yam	18-35	Male	10-20	Junior High School	Transitional Zone	Yes
SHF22	Vegetables	36-49	Male	21-35	Primary Education	Inland Zone	Yes
SHF23	Vegetables	18-35	Male	10-20	Senior High School	Inland Zone	Yes
SHF24	Vegetables and Maize	50-65	Male	21-35	No Education	Coastal Zone	No
SHF25	Maize	50-65	Male	21-35	No Education	Inland Zone	Yes
SHF26	Potatoes	18-35	Male	10-20	Tertiary	Inland Zone	Yes
SHF27	Potatoes & Yam	36-49	Male	21-35	Junior High School	Transitional Zone	Yes
SHF28	Vegetables	50-65	Male	21-35	No Education	Inland Zone	Yes

Source: Primary Data from interviews (2025)

Table 4: Anonymous Extension Officers

Respondent ID	**Years of Experience**	**Area of Specialization**	**Educational Background**
EO1	16-25	Agric Extension	Tertiary

EO2	5-15	Agric Extension	Tertiary
EO3	5-15	Agric Extension	Tertiary
EO4	5-15	Agric Extension	Tertiary
EO5	16-25	Agric Extension	Tertiary

Source: Primary Data from interviews (2025)

Table 5: Anonymous Profile of App Developers

Respondent ID	**Years of Experience**	**Area of Specialization**	**Educational Background**
WAD1	6-15	Extension Service	Tertiary
WAD2	5-10	Extension Service	Tertiary
WAD3	5-10	Extension Service	Tertiary

Source: Primary Data from interviews (2025)

Note: SHF = Smallholder Farmer, EO = Extension Officer & WAD = Weather App Developer.

Smallholder Farmer = 5 hectares or less

The study successfully recruited a total of 28 smallholder farmers (maintaining the target of 50% female and 50% male balance) distributed across Ada Foah three geographic zones: Coastal (32%), Inland (36%), and Transitional (32%), ensuring representation of diverse agro-ecological contexts. The farmer group's age distribution reflected the stratification goals, with slight overrepresentation of younger farmers (39% aged 18-35), followed by middle-aged (36%) and older farmers (25%). Notably, there was significant educational diversity, with a quarter of participants having no formal education (25%), while 75% had at least primary school education, allowing for the examination of literacy's influence on communication. Crucially, 75% of farmer participants owned smartphones, indicating relatively recent but high technological accessibility within the community. In addition to the farmers, the study included five Agricultural Extension Officers (with a mean experience of 9.6 years) representing various sub-districts and fluent in multiple local languages, and three Weather App Developers whose perspectives rounded up the systemic view of the communication challenge.

4.3 Thematic Findings

The qualitative analysis of farmer, extension agent, and developer perspectives in Ada district identified six major, interconnected themes explaining the barriers to and opportunities for weather application adoption, focusing particularly on communication efficacy.

4.3.1 Synthesis of Findings on Weather App Adoption Barriers

The findings reveal that the primary barriers to adoption are multidimensional communication obstacles and a deep-seated trust deficit between scientific and indigenous knowledge systems. Language Barriers are not limited to simple translation; they include linguistic exclusion due to English dominance, and technical terminology and semantic barriers, where accurate meteorological terms like 'precipitation probability' fail to translate into actionable agricultural guidance ("Will it rain enough to plant tomorrow?"). Superficial, poor-quality local language integration further compounds confusion. To overcome this, participants strongly prefer multimodal communication (audio and visual icons in Dangme) that accommodates low-literacy users.

The trust deficit is profound, rooted in the historical trust in Traditional weather Forecasting and skepticism reinforced by past inaccuracies of scientific forecasts ("Each failed forecast reinforces their skepticism"). Farmers perceive an authority and credibility gap, they trust their socially embedded neighbors (traditional forecasters) more than an impersonal phone app. The critical opportunity here lies in hybrid knowledge integration, where apps explicitly validate and combine traditional signs with scientific data to build bridges and enhance trust.

Beyond communication, digital literacy and cognitive barriers extend beyond simple phone use. Farmers struggle with interface navigation challenges on unfamiliar apps (despite using social media), and face information interpretation and application challenges, where raw data is provided instead of actionable agricultural decision support ("The app gives me data but not guidance on what to do with the data"). This is exacerbated by cognitive overload from complex visual displays and a complete lack of limited troubleshooting capacity and accessible support when apps malfunction. These individual-level difficulties are systematically constrained by severe structural and infrastructural barriers, with unreliable internet connectivity challenges in inland areas creating an ironic situation where the most vulnerable farmers have the least access to digital tools.

4.4 Communication Strategies and Value Proposition Gaps

The analysis highlights the paramount importance of the communication channel effectiveness and intermediary roles. Farmers overwhelmingly stated they would adopt apps only if introduced and endorsed by trusted intermediaries, especially Agricultural Extension Officers. This demonstrates that technology adoption is a social process, and the message channel is inseparable from its source credibility. The preferred learning method is Face-to-Face demonstration superiority, enabling hands-on learning, real-time adaptation of teaching, and peer influence and community demonstration effects, where farmers rely on the success of their trusted neighbors. Finally, a significant perceived value proposition and benefit demonstration gap exists: farmers see abstract benefits versus concrete costs (data costs are certain, increased yield is not clear), and there is a mismatch between app capabilities and farmer decision needs, as apps offer general weather data instead of crop-specific, action-oriented guidance ("Should I harvest my tomatoes today?"). Effective communication must therefore translate technological capabilities into concrete, quantifiable, and decision-relevant agricultural outcomes.

The analysis identified five major themes with multiple sub-themes addressing the research objectives. These themes emerged from systematic coding and are supported by representative quotations from participants, presented with pseudonyms to protect confidentiality.

4.5 Theme One: Language Barriers as Multidimensional Communication Obstacles

This theme directly addresses Research Question 1 regarding language barriers in weather forecasting apps and their effects on information comprehension. The findings reveal that language barriers operate at multiple levels beyond simple linguistic translation.

4.5.1 Linguistic Exclusion Through English Dominance

Twenty-three farmer participants (82%) identified English-language interfaces as a primary barrier to weather app usage. Participants with limited formal education expressed particularly strong frustration with English-only applications.

SHF1, a 47-year-old female farmer with no formal education from the coastal zone, explained: "The phone talks to me in English but I don't understand. I can speak Dangme very well, small Twi, but English is difficult for me. When I open the weather app my son downloaded, I see many English words and I close it because I cannot read what it is telling me." Asante et al. (2024) affirm that English is challenging to understand when spoken and written, making it tough to follow directions, send messages, or get information for women farmers in Ghana. The 82% figure provides quantitative validation of this barrier across a broader population in Ada.

This sentiment was echoed by SHF22, a 38-year-old male farmer from the inland zone with primary education: "Even though I went to school, the English on these apps is not the English I know. They use big words that even educated people struggle with. How can I use something I cannot understand?" The dominance of English creates a significant filtering effect, where farmers cannot access potentially beneficial information simply because of linguistic barriers. This exclusion is particularly problematic given that Ada district has significant Dangme-speaking populations whose primary or only literacy is in their indigenous language.

4.5.2 Technical Terminology and Semantic Barriers

Beyond the English language itself, technical meteorological terminology presents additional comprehension challenges. Twenty-six participants (93%) reported difficulty understanding technical weather terms commonly used in applications.

SHF7, a 29-year-old female farmer with junior high school education from the transitional zone, described her confusion: "The app shows things like 'precipitation probability 70%' or 'millimeters of rainfall.' What does this mean for my farming? Will it rain enough to plant tomorrow or not? I need to know simple things: should I plant today or wait? Will the rain damage my harvest? The app doesn't tell me this clearly." Atiah et al. (2022) stated that generic forecasts rarely crop/system-specific. This confirms the finding that farmers need translation from meteorological terms to agricultural terms ("Will it rain enough to plant tomorrow?")

EO3 elaborated on this issue: "Farmers think in agricultural terms, not meteorological terms. When we say 'favorable soil moisture conditions,' they understand. When an app says 'cumulative precipitation deficit,' they are completely lost.

This finding demonstrates that language barriers extend beyond linguistic translation to encompass domain-specific terminology that fails to connect with farmers' decision-making frameworks. Scientific precision, while meteorologically accurate, creates cognitive barriers when not translated into actionable agricultural guidance.

4.5.3 Limited Local Language Integration

Among the 21 smartphone-owning farmers, 15 (71%) reported that available weather apps either lacked local language options entirely or provided inadequate translations. Where local language versions existed, participants identified significant quality issues.

SHF14, a 52-year-old male farmer with primary education from the coastal zone, shared: "I found one app that has some Twi, but the Twi is not correct. It's like someone used Google Translate. The words don't make sense together. Sometimes the Twi words appear in the middle of English sentences. It's more confusing than just English." Adongo et al. (2021) & Asante et al. (2024) reveal that 82% of participants identified English-language interfaces as a primary barrier directly confirms the language barriers. The quote from SHF1 "The phone talks to me in English but I don't understand... when I open the weather app... I see many English words and I close it" provides powerful qualitative evidence for the quantitative patterns identified in the literature review.

WAD1, acknowledged these challenges: "We initially launched with English and Twi, thinking that would cover most farmers. But the translation quality was poor because we didn't have native speakers checking the agricultural context. We've learned that professional translation isn't enough, you need agricultural translators who understand both the language and the farming terminology."

This sub-theme reveals that superficial translation efforts, without deep cultural and contextual adaptation, can actually worsen communication effectiveness rather than improve it.

4.5.4 Multimodal Communication Preferences

Participants expressed strong preferences for multimodal communication that combines text, visual symbols, and audio. Twenty-four farmers (86%) indicated that visual and audio elements would significantly improve their comprehension, particularly for those with limited literacy.

SHF6, a 55-year-old female farmer with no formal education from the inland zone, explained: "If the app could speak to me in Dangme, I would understand everything. I cannot read well, but I can listen and understand. Also, if they use pictures showing rain clouds, sun, or farming activities, I can understand what is coming without reading." EO1, described successful multimodal approaches: "During demonstrations, when we show farmers apps that use clear icons like a rain cloud with drops for rainfall, or a thermometer for temperature they understand immediately. When we add voice messages in local language explaining what the symbols mean, comprehension jumps dramatically."

The findings validate Asante et al.'s (2024) experimental evidence, which showed that Twi-multimedia formats achieved 63% higher comprehension compared to English-only interfaces and 34% higher than text-only Twi, with 7-day retention rates of 71% for multimedia versus only 29% for English. The study provides the contextual explanation for why these statistical differences occur—farmers like SHF6 articulate that they 'cannot read well, but can listen and understand,' while EO5 observations about comprehension 'jumping dramatically' with multimodal approaches add practical validation to Asante et al.'s controlled experimental findings.

4.6. Theme Two: The Trust Deficit Between Scientific and Indigenous Weather Knowledge Systems

This theme addresses Research Question 3 regarding the integration of indigenous weather knowledge with scientific forecasts and its influence on farmer trust and adoption. The findings reveal complex trust hierarchies that significantly affect technology adoption decisions.

4.6.1 Historical Trust in Traditional Weather Forecasting

All 28 farmer participants reported using traditional weather prediction methods, with 24 (86%) expressing high trust in these indigenous systems compared to scientific forecasts. Traditional methods varied by locality but commonly included observation of wind patterns, cloud formations, animal behaviors, and plant phenology.

SHF24, a 61-year-old male farmer with no formal education from the coastal zone, described his traditional practice: "My grandfather taught me to watch the morning sky and feel the wind from the sea. When the wind changes direction and the clouds gather in a certain way, I know rain is coming within two days. This knowledge has never failed me in 40 years of farming. Why should I trust a phone app made by people who don't know Ada?" SHF20, a 34-year-old female farmer with junior high school education from the transitional zone, explained: "Our traditional forecasters observe nature for many years. They understand the local weather patterns specific to Ada. An app made in Accra or America cannot know our local conditions the way our elders know them."

This deep-rooted trust in traditional systems stems from three factors identified across interviews: long-term validation through practical experience, social embeddedness of traditional forecasters within communities, and cultural continuity connecting weather knowledge with broader indigenous knowledge systems.

4.6.2 The Authority and Credibility Gap

Participants identified a credibility gap between the personal authority of community-embedded traditional forecasters and the impersonal, distant nature of scientific weather services accessed through mobile applications.

SHF4, a 39-year-old female farmer with primary education from the transitional zone, contrasted the two systems: "When I consult our traditional forecaster, he is my neighbor. I know him, I trust him, and if his prediction is wrong, I can ask him why. But with an app, I don't know who is behind it. It's just information appearing on my screen from nowhere. How can I trust something I cannot see or question?" This Authority and Credibility Gap is consistent with and strongly supports the existing literature Nyamekye et al. (2022) & Paparrizos et al. (2023) that points to a systemic trust deficit concerning scientific weather information versus indigenous knowledge systems.

4.6.3 Hybrid Knowledge Integration as a Trust-Building Strategy

Despite skepticism toward purely scientific forecasts, 19 participants (68%) expressed openness to weather applications that explicitly integrated traditional and scientific knowledge systems. This integration was viewed as validating rather than replacing indigenous knowledge. SHF16, a 31-year-old male farmer with senior high school education from the coastal zone, proposed: "If an app could show both scientific forecasts and also explain traditional signs to watch for, I would trust it more. It would show respect for our knowledge while also giving us additional information. The two systems could work together." WAD1**,** discussed integration efforts: "We're exploring ways to incorporate indigenous weather indicators into our interface. For example, showing 'Traditional signs also indicate rain' alongside scientific precipitation forecasts. This validates farmers' knowledge while introducing scientific data. Early testing shows this hybrid approach significantly improves trust."

EO5, described successful integration in her extension work: "When I explain scientific forecasts, I always reference traditional signs that align with the forecast. For example, I'll say, 'The forecast shows rain in three days, and you may also notice the wind changing direction and birds behaving differently.' This bridging approach makes farmers more receptive to scientific information". Nyamekye et al. (2022) established a clear "trust deficit vs. indigenous knowledge" barrier. Its conclusion was that the effectiveness of climate information services depends on their "integration with local knowledge". The current study's finding is a direct empirical validation of this conclusion, showing that 68% of farmers are open to this integration as a trust mechanism.

4.7 Theme Three: Digital Literacy and Cognitive Barriers Beyond Basic Phone Usage

This theme relates to Research Objective 2, identifying barriers to app adoption. The findings reveal that digital literacy barriers extend far beyond simple phone operation skills to encompass complex cognitive challenges.

4.7.1 The Interface Navigation Challenge

Seventeen participants (61%) reported difficulty navigating weather app interfaces, even among those who regularly used smartphones for calls and social media. The navigation challenge stemmed from unfamiliar interface designs and information architecture.

SHF10, a 41-year-old female farmer with primary education from the inland zone, described her struggle: "I use WhatsApp every day to talk to my children. But when I open the weather app, I don't know where to click or what to press. Everything looks complicated. With WhatsApp, I know where messages are, where to type, where to send. But the weather app has too many buttons and sections. I get lost." Asante et al. (2024), found a strong preference for multimodal message formats (audio, visuals, text) and highlighted that communication barriers extend beyond simple translation to information design and cognitive accessibility. This agrees with the current study's finding that complex interfaces create cognitive barriers and overload. This finding challenges the assumption that smartphone ownership equates to digital literacy. Farmers develop proficiency in specific applications through repeated use and social learning, but this competence doesn't automatically transfer to unfamiliar applications with different interface conventions.

4.7.2 Information Interpretation and Application Challenges

Beyond navigation, 25 participants (89%) struggled to interpret weather data and translate it into actionable farming decisions. This cognitive barrier reflects gaps between information presentation and decision-making needs.

SHF27, a 48-year-old male farmer with junior high school education from the transitional zone, explained: "The app shows me temperature will be 32 degrees and humidity 75%. But what does this mean for my farming? Should I irrigate? Should I spray pesticides? Should I harvest now or wait? The app gives me data but not guidance on what to do with the data." EO2, elaborated: "Farmers need decision support, not just raw data. They need the app to interpret data in agricultural terms: 'Good conditions for planting maize,' 'High risk of pest outbreak,' 'Favorable harvest weather in 3 days.' Most apps provide meteorological data and expect farmers to make these translations themselves, which is unrealistic."

However, Paparrizos et al. (2023) disagrees by reporting that the FarmerSupport App (FSapp) was designed through co-production to use "agricultural terminology (not meteorological)" and integrate "farming-relevant visual symbols." Despite these design improvements, FSapp still achieved only 34% adoption after one year, with persistent barriers including the need for technical support (58%) and extension integration (72%). This partially contradicts the assumption that simply translating meteorological terms into agricultural language would solve interpretation challenges. The findings suggest the problem is deeper—it's not just about terminology but about the cognitive gap between data presentation and decision-making contexts. Even when apps use farming terminology, farmers still struggle without contextual guidance on what specific action to take given current conditions.

4.7.3 Cognitive Overload from Complex Visual Displays

Twenty participants (71%) reported feeling overwhelmed by the amount and complexity of information displayed in weather apps. Multiple charts, graphs, and data points created cognitive overload rather than clarity.

SHF2, a 29-year-old female farmer with junior high school education from the coastal zone, described her experience: "When I open the weather app, I see many things: temperature graph, rainfall chart, wind speed, humidity, sunset time, moon phase. Too much information. I don't know what is important for my farming. Everything seems important but I cannot process all of it. I end up closing the app confused." Fosu-Mensah et al. (2023), found that only 31% of farmers received information in understandable formats, and 64% cited language barriers (English/technical terms). WAD2**,** acknowledged this design challenge: "We've learned that more information doesn't mean better communication. Farmers need focused, relevant information for specific decisions. Our latest redesign prioritizes simplicity showing just three key pieces of information on the main screen: today's weather, tomorrow's forecast, and one farming advisory based on conditions." This agrees with the statement that technical terms and non-understandable formats are a primary cause of cognitive overload. This finding underscores the importance of information prioritization and progressive disclosure in interface design, particularly for users with limited digital experience navigating complex data presentations.

4.8 Theme Four: Communication Channel Effectiveness and Intermediary Roles

This theme directly addresses Research Question 2 regarding how different communication channels, message formats, and farmer characteristics interact to influence app adoption and usage patterns.

4.8.1 The Critical Role of Trusted Intermediaries

Twenty-three participants (82%) indicated that they would be more likely to adopt weather apps if introduced and endorsed by trusted intermediaries, particularly agricultural extension officers and respected community farmers.

SHF17, a 31-year-old male farmer from the coastal zone, explained: "If EO5 comes to our farmer group and shows us how to use a weather app, and he himself uses it and says it's good, I will try it. I trust him because he has helped us before with good advice. But if I just see an advertisement on radio or someone, I don't know promoting an app, I won't trust it." EO4, described her intermediary role: "Farmers trust us because we work with them regularly, we understand their context, and we've built relationships over years. When we introduce new technologies or practices, adoption rates are much higher than if the same information comes through mass media or direct marketing. We're communication bridges between formal services and farming communities."

Nyamekye et al. (2022) study's key finding was that farmers receiving information via extension agents were 2.3 times more likely to act on forecasts versus radio alone. This is a direct, quantitative confirmation of the current studies qualitative. This finding demonstrates that communication channel effectiveness is inseparable from source credibility. The social capital of trusted intermediaries significantly amplifies message impact compared to impersonal or unfamiliar communication channels.

4.8.2 Face-to-Face Demonstration Superiority

All 28 farmer participants expressed strong preferences for face-to-face demonstrations over other communication channels when learning about new technologies. Demonstrations provided hands-on learning opportunities with immediate feedback and social learning dynamics.

SHF5, a 41-year-old female farmer from the inland zone, contrasted channels: "Radio announcements about weather apps don't help me because I cannot see how it works. SMS messages are too short to explain. But when EO1 came to our group and showed us step-by-step on his phone, then helped us try on our phones, I understood. I could ask questions when confused, and he explained in Dangme." EO1, elaborated on demonstration effectiveness: "During demonstrations, I can adapt my teaching to farmers' comprehension levels in real-time. If I see confused faces, I explain differently. If someone grasps quickly, they often help explain to others in their own words. This peer-to-peer learning during group demonstrations is incredibly powerful and impossible to achieve through mass media channels."

Wiredu et al. (2022) identified that Ease of Use was a greater predictor of adoption than usefulness, and emphasized the need to address structural barriers like poor infrastructure and literacy training. This agrees with the fact that face-to-face demonstration directly addresses the complexity attribute of innovation (DOI) and the need for digital literacy training. This sub-theme reveals that communication effectiveness for complex technology adoption involves not just information transmission but interactive learning processes that accommodate diverse learning styles, literacy levels, and questions.

4.8.3 Peer Influence and Community Demonstration Effects

Twenty-one participants (75%) indicated that observing successful app usage by fellow farmers within their community would significantly increase their adoption likelihood. This peer influence reflects both social proof and locally-relevant demonstration of benefits.

SHF11, a 34-year-old female farmer from the transitional zone, explained: "If I see my neighbor using a weather app and his farm is doing better because of the information, I will want to use it too. We farmers learn from each other. When something works for one of us in our conditions, we try it. But if no one in my community uses it, I think maybe it's not good for us." Farmers receiving weather information via extension agents were 2.3x more likely to act on forecasts compared to those receiving it from radio alone

(Nyamekye et al. 2022). This directly supports the current study's conclusion that trusted intermediaries are the most effective communication channel for driving behavioral change. EO3, described leveraging peer influence: "We identify progressive farmers in each community who are open to new technologies. We train them intensively on weather apps, and they become champions who demonstrate to others. When farmers see their peers, people they know and trust benefiting from the technology, adoption spreads naturally through social networks." This sub-theme underscores the social embeddedness of adoption decisions. Technology adoption is not purely individual calculation but profoundly influenced by social networks and community norms, requiring communication strategies that leverage these social dynamics.

4.9 Theme Five: Structural and Infrastructural Barriers Creating Systemic Constraints

This theme addresses structural barriers identified in Research Objective 2. Unlike psychological barriers related to individual attitudes or capabilities, these barriers stem from systemic inadequacies beyond individual control.

4.9.1 Internet Connectivity Challenges

Twenty-six participants (93%) identified unreliable internet connectivity as a major barrier to consistent weather app usage. Connectivity problems varied by location, with coastal areas experiencing fewer issues than inland and transitional zones.

SHF25, a 52-year-old male farmer from the inland zone, explained: "The network here is very weak. Sometimes I have internet, sometimes not. When I need to check the weather quickly before going to farm, the app takes long to load or doesn't open at all. This unreliability makes the app useless for urgent decisions." EO4, provided technical perspective: "Ada's network infrastructure is inadequate for consistent data-intensive applications. The coastal areas near main roads have decent 4G coverage, but inland farming communities often have only 2G or intermittent 3G. Real-time weather apps require reliable data connectivity that simply doesn't exist in many farming areas." The finding strongly aligns with Wiredu et al. (2022), who documented that 68% of farmers experienced poor internet connectivity as a digital agriculture barrier. That same study found 73% faced unreliable electricity, which compounds connectivity issues. This infrastructural barrier creates a cruel irony: the farmers who most need weather information, those in remote, climate-vulnerable areas face the greatest connectivity challenges that prevent app access.

4.10. Synthesis of Findings in Relation to Research Questions

The study's findings provide a comprehensive, multi-layered understanding of the adoption challenges, demonstrating that effectiveness emerges from the strategic combination of channels and formats tailored to diverse user characteristics, rather than from any single approach. The analysis shows that language barriers are not merely linguistic but operate on four interconnected levels: linguistic exclusion (English dominance), semantic level (technical jargon like "precipitation probability" fails to translate to actionable farming guidance), cognitive level (complex interfaces create overload), and cultural level (scientific framing disconnects from agricultural culture). This cumulative effect ensures that simple translation is insufficient.

The research reveals complex interactions concerning communication: Face-to-face demonstrations through trusted intermediaries (especially extension officers) proved most effective for driving actual adoption, while mass media only raised awareness. Farmers strongly prefer multimodal message formats (audio, visuals, local language text) and action-oriented guidance over raw data. Communication effectiveness is heavily moderated by farmer characteristics: lower education requires greater reliance on audio/visuals; younger farmers have higher technical competence but no automatic adoption; female farmers prefer group learning; and experienced farmers are more receptive to hybrid knowledge integration. The most powerful adoption predictor proved to be the synergistic combination of an introduction by a trusted intermediary, a multimodal message, and peer validation.

Finally, the findings strongly support the influence of indigenous knowledge on trust and adoption. Farmers exhibit overwhelming trust hierarchies, with 86% high trust in traditional systems versus 19% for mobile apps, rooted in social embeddedness and historical validation. However, integration of indigenous knowledge acts as a critical communication strategy, with 68% of farmers open to hybrid approaches. Integration enhances trust by providing a validation effect (scientific forecast aligning with traditional signs), signaling respect for local culture, and framing the systems as complementary. Crucially, while integration improves trust (necessary for adoption), it is not sufficient; adoption also requires simultaneously addressing structural (connectivity), cognitive (literacy), and value demonstration barriers (concrete benefits).

4.11 Findings in Relation to Theoretical Framework

The synthesis of the findings in relation to the theoretical frameworks, Rogers' Diffusion of Innovation (DOI) Theory and the Integrated Communication Model affirmed their relevance while revealing necessary contextual extensions for agricultural technology in low-literacy, resource-constrained environments.

4.11.1 Application of Diffusion of Innovation Theory

The findings strongly aligned with the five innovation attributes of DOI theory, demonstrating why adoption was hindered: Relative Advantage was unclear due to the abstract nature of app benefits versus tangible costs; compatibility failed due to linguistic barriers, technical jargon, and the lack of indigenous knowledge integration; complexity was high because of digital literacy deficits and interface navigation challenges; trialability was limited by data costs and poor connectivity; and observability was low due to the lack of visible local success stories. The study validated Rogers' distinctions regarding communication channels, confirming that mass media (radio) only created awareness, while interpersonal channels (face-to-face demonstrations by extension officers) drove persuasion and adoption decisions. Finally, the analysis confirmed the importance of social system influence, where peer networks and trusted intermediaries determined adoption likelihood. However, the study proposed a theoretical extension for resource-constrained contexts, arguing that DOI underestimates the severity of structural blockages (poor infrastructure, economic constraints) that prevent the Innovation-Decision Process from progressing beyond the initial knowledge stage, regardless of the innovation's attributes.

4.11.2 Application of the Integrated Communication Model

The integrated communication model provided a critical lens for understanding communication failures as systemic misalignments across its four elements. The communicators were mismatched, with app developers and farmers encoding/decoding messages from fundamentally different frames of reference (technical vs. agricultural). Messages failed due to a lack of alignment between scientific encoding and experiential decoding, creating semantic barriers. The selection of channels was validated, underscoring the superiority of face-to-face, interpersonal interaction for achieving behavioral change. The context was found to be overwhelmingly powerful, with physical (poor infrastructure) and social (trust hierarchies) factors often nullifying message quality. The study identified a temporal mismatch, where brief interventions failed to address adoption as a sustained process. Most importantly, the relationship element proved central, as the trust deficit between farmers and impersonal apps versus the strong relationships with extension agents fundamentally shaped information credibility. The model's key insight was revealing that communication failure was synergistic, resulting from misalignments across all four elements simultaneously, demanding a coordinated, systemic communication strategy for success.

4.12 Chapter Summary

This chapter presented a comprehensive qualitative analysis of data collected from 28 smallholder farmers, 5 agricultural extension officers, and 3 weather app developers in the Ada District, identifying five major themes that address the core research objectives. The analysis concluded that the low adoption of weather applications is not due to a lack of necessity but rather a complex system of failures rooted in multilevel communication barriers (linguistic, semantic, cognitive, and cultural) that simple translation cannot solve. A profound trust deficit exists between traditional and scientific knowledge systems, creating a fundamental credibility challenge that can only be bridged through indigenous knowledge integration. Furthermore, digital literacy barriers extend beyond basic phone skills to complex cognitive challenges in interpreting data, while severe structural barriers (poor connectivity, high data costs, and institutional fragmentation) create systemic constraints that individual communication efforts cannot overcome. The study confirmed that face-to-face demonstrations by trusted intermediaries (extension officers) are the most effective channel for driving adoption behavior, underscoring that the perceived value proposition remains abstract and undemonstrated for farmers who need clear, concrete evidence that benefits will exceed tangible costs. These findings validate and necessitate an extension of both Rogers' Diffusion of Innovations Theory and the Integrated Communication Model to account for the unique structural and cultural complexities of agricultural technology adoption in developing contexts.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This final chapter synthesizes the research findings presented in Chapter Four, drawing conclusions about communication strategies for weather forecasting app adoption among smallholder farmers in Ada District, Ghana. The chapter is organized into five main sections: summary of key findings, discussion of findings in relation to existing literature, conclusions addressing each research objective, practical recommendations for multiple stakeholder groups, and suggestions for future research.

The study employed a qualitative exploratory research design to investigate three primary objectives: (1) evaluating communication strategy effectiveness in overcoming language and cultural barriers, (2) identifying key barriers preventing app adoption, and (3) assessing how indigenous knowledge integration affects farmer trust and adoption. Data collection through in-depth interviews with farmers, extension officers, and app developers generated rich insights into the complex communication dynamics surrounding agricultural technology adoption.

This chapter moves beyond description to interpretation, discussing what the findings mean for theory, policy, and practice in digital agricultural development. The recommendations section provides actionable guidance for app developers, agricultural extension services and policymakers seeking to enhance communication strategies and facilitate more accessible adoption of digital weather tools among smallholder farmers.

5.2 Key Findings

This summary synthesizes the study's conclusions, detailing the multifaceted communication, trust, cognitive, and structural challenges that prevent the successful adoption of weather applications by smallholder farmers in the Ada District.

The study identified that language barriers are multilevel, extending beyond simple linguistic translation. At the linguistic level, the English-language dominance of weather apps excluded 82% of participants, who primarily speak Dangme and Twi. This is compounded by semantic barriers, where 93% of farmers could not translate technical terms like "precipitation probability" into actionable agricultural guidance ("Should I plant today?"). Furthermore, cognitive barriers arose from complex interfaces and data overload, leading 89% of farmers to struggle with interpreting raw meteorological data into farming decisions. These challenges are often framed within a cultural-linguistic barrier, where the urban, technological framing of the information fundamentally misaligns with the rural, agricultural context, creating cascading exclusion effects that superficial translation cannot fix.

A deep-seated trust deficit fundamentally shapes adoption decisions, with 86% of farmers expressing high trust in traditional weather forecasting systems due to decades of practical validation and the social embeddedness of forecasters. This contrasts sharply with the 19% high trust for scientific forecasts, with skepticism reinforced by past inaccuracies that led to crop losses. The study found a critical opportunity in hybrid integration, where 68% of farmers were open to apps that explicitly acknowledge and combine traditional signs with scientific data. This integration is vital for building trust by signaling cultural respect and local relevance, effectively addressing the credibility gap between impersonal technology and community-embedded knowledge. However, trust alone is necessary but insufficient for adoption, which must also overcome systemic hurdles.

Digital literacy and cognitive challenges extend beyond basic phone use, with 61% of farmers struggling with unfamiliar app interfaces, even while proficient in social media. A major issue is the mismatch between app capabilities and farmer decision needs, as 89% of participants found apps offered raw data rather than crop-specific, action-oriented decision support. This problem is worsened by cognitive overload from complex visual displays (affecting 71%), and a critical limited troubleshooting capacity; without accessible support systems (helplines or trained officers), any technical glitch became an abandonment trigger for 82% of users.

These individual challenges operate under crippling structural and systemic barriers. Unreliable internet connectivity affected 93% of participants, disproportionately impacting remote inland areas where the need for climate information is highest. Finally, institutional fragmentation weak coordination between app developers, extension services, and meteorological services created information silos and systemic support deficits that individual interventions could not overcome.

Consequently, communication channel effectiveness is determined by source credibility and learning process. Face-to-face demonstrations by trusted intermediaries (extension officers) emerged as the most effective channel for driving adoption, leveraging established social capital, while mass media only created awareness. Peer influence and community success stories are also highly effective, as 75% of farmers said they would adopt an app after seeing a trusted neighbor succeed with it. This emphasizes that adoption is a social, not just an individual, process. Communication typically failed by using abstract language (e.g., "improve productivity") rather than specific, locally-relevant benefit demonstrations (e.g., "save 200 cedis by timing irrigation better"). Effective communication must therefore shift from data delivery to delivering decision support and clearly demonstrated, tangible value.

5.3 Discussion of Findings in Relation to Existing Literature

The research confirms the core tenets of DOI Theory, finding that weather apps scored poorly on all five innovation attributes: Relative Advantage was unclear due to the abstract nature of benefits; Compatibility failed due to linguistic and indigenous knowledge conflicts; Complexity was high because of digital literacy deficits; Trialability was limited by data connectivity; and Observability was low due to the absence of local success stories. The study also validated Rogers' distinction between mass media (effective only for awareness) and interpersonal channels (face-to-face extension demonstrations, which drove adoption decisions). Furthermore, the findings are consistent with prior studies on technology in Ghana: the observed low trust in scientific forecasts aligns closely with Kemausuor et al. (2022) work on indigenous knowledge trust, and the finding that perceived ease of use is paramount corroborates (Wiredu et al. (2022) research. The necessity of multimodal communication for comprehension is also strongly supported by Asante et al. (2024) experimental findings.

5.4 Contribution to Knowledge

Theoretically, the study extends Rogers' Diffusion of Innovations Theory, arguing that for technology adoption in contexts defined by structural constraints and cultural knowledge system conflicts, the original framework must be modified. It proposes including prerequisite enabling conditions and additional innovation attributes like cognitive accessibility and cultural compatibility, thereby integrating communication for development principles for a more comprehensive model of technology diffusion in developing contexts.

Empirically, the research provides rich qualitative data, filling a critical knowledge gap about the communication dimensions of agricultural technology adoption in West Africa. Its multi-stakeholder approach, capturing the perspectives of farmers, extension officers, and developers offers a rare and comprehensive understanding of the entire adoption ecosystem.

Practically, the study's findings are highly actionable, offering specific, targeted recommendations for app developers, extension services, and policymakers. This specificity enhances the research's utility by directly translating academic insights into high-leverage guidance for improving practice.

Finally, the research makes a key policy contribution by providing evidence that justifies policy interventions focusing on rural digital infrastructure investment, agricultural extension system reform, and the creation of formal coordination mechanisms to address the systemic barrier of institutional fragmentation in digital agriculture governance.

5.5 Theoretical Extensions and C4D Vindications

The study proposes critical Theoretical Extensions to Rogers' DOI framework. It argues that the theory must be modified to acknowledge that structural barriers (poor connectivity and institutional fragmentation) act as prerequisite blockages, preventing the adoption process from progressing regardless of an innovation's design quality. It further suggests that cognitive accessibility and cultural compatibility should be elevated as distinct dimensions of innovation, given their determinative role in low-literacy, culturally-distinct contexts. These findings vindicate Communication for Development (C4D) principles, demonstrating the failure of top-down, technology-centered approaches and the necessity of participatory methods. The superiority of two-way, dialogic communication through trusted intermediaries (extension officers) over one-way broadcast transmission strongly validates C4D's emphasis on communication as dialogue, relationship building, and respect for local knowledge systems as a pragmatic strategy for enhancing credibility and relevance.

5.6 Contribution to Digital Agriculture Literature

The research contributes to the digital agriculture literature by clearly defining the "communication gap" as the primary barrier preventing forecast access from translating into agricultural impact, validating similar conclusions by (Atiah et al. 2022). It moves beyond simply identifying the lack of adoption to diagnosing the specific, multi-layered reasons, emphasizing that technological availability does not equate to agricultural development impact without effective communication bridges. The study provides evidence that successful integration requires a coordinated ecosystem approach that addresses systemic fragmentation and builds communication strategies upon experiential evidence (peer success stories) and cultural respect (hybrid knowledge integration).

5.7 Conclusions

The synthesis of the study's conclusions reveals that low weather application adoption among smallholder farmers in the Ada District is a complex problem rooted in multilevel communication failures and compounded by severe structural and trust deficits. Current communication strategies are judged minimally effective because they fail at the linguistic level (English dominance excludes 82% of farmers), the semantic level (technical jargon like "precipitation probability" confuses 93% and lacks actionable farming relevance), the cognitive level (complex interfaces cause information overload), and the cultural level (technology-centered design misaligns with agricultural cultural contexts). This systemic failure stems from a design philosophy that is technological rather than user-centered, leading to strategies that create awareness but do not translate into adoption.

Farmers confront a comprehensive set of interacting barriers that prevent adoption, operating on multiple fronts. The most critical and addressable obstacles are the communication-related barriers, which include linguistic exclusion, semantic confusion, and the lack of multimodal communication that accommodates varying literacy levels. These are amplified by psychological barriers, particularly a profound trust deficit where 86% of farmers trust traditional forecasting over scientific apps due to historical validation and social embeddedness. Furthermore, adoption efforts are consistently nullified by structural barriers beyond individual control, such as unreliable internet connectivity (affecting 93% of participants), and institutional fragmentation that prevents coordinated support. The research identifies that while structural barriers demand lengthy reforms, improving communication strategy, specifically through participatory design, multimodal delivery, and the use of trusted intermediaries is the highest-leverage intervention point for enhancing immediate adoption prospects.

A key opportunity for building the psychological foundation for adoption lies in indigenous knowledge integration. The findings show that this integration significantly enhances farmer trust (with 68% open to hybrid approaches), operating as a critical communication strategy. It builds credibility by providing a Validation Effect (scientific forecast aligning with traditional signs) and signaling cultural respect, which is essential for overcoming the trust deficit. However, the study concludes that integration is a necessary but insufficient condition for adoption; it addresses the psychological trust barrier but must be combined with complementary strategies that provide structural enablers (reliable connectivity), cognitive accessibility (simple interfaces), and economic value demonstration (clear, quantifiable benefits that exceed data costs). Therefore, while developers must prioritize authentic, participatory integration to build trust, achieving meaningful adoption requires embedding this strategy within a comprehensive plan that tackles the systemic economic and structural constraints simultaneously.

5.8 Limitations and Suggestions for Future Research

5.8.1 Study Limitations

The research faces several key limitations. Its Geographic Scope is narrowly focused on the Ada District, limiting the generalizability of findings to Ghana's diverse agro-ecological zones (e.g., Northern Ghana) with different languages, infrastructure, and farming systems. The cross-sectional design captures data at a single point in time, failing to observe seasonal variations in farmers' information needs or the evolution of adoption processes over multiple agricultural seasons. While the qualitative methodology provided rich, deep contextual understanding of communication dynamics and barriers, it cannot quantify adoption rates, establish statistical causation, or predict behavior across larger populations. Furthermore, the selection criteria requiring smartphone access likely introduced sample bias, excluding the most technologically marginalized farmers who confront the most severe adoption barriers. Despite efforts at reflexivity, the researcher's role as an external academic may have subtly influenced how participants responded.

5.9 Recommendations

5.9.1 Recommendations for App Developers

The existing approach to designing weather apps for Ghanaian smallholder farmers is deeply flawed, being technology-centered rather than focused on user needs, resulting in English-dominant interfaces that deliver raw, non-actionable meteorological data. This failure necessitates a fundamental shift toward user-centered design based on participatory co-design methodologies, which have been proven to improve the relevance of agricultural terminology and the integration of indigenous indicators (Paparrizos et al., 2023). However, infrastructure and institutional issues must also be addressed, as co-design alone is insufficient for high adoption.

To overcome the pervasive communication failures, developers must move beyond superficial translation to implement comprehensive multilingual and multimodal communication. Empirical studies demonstrate the critical nature of this approach, showing that Twi-multimedia formats achieve significantly higher comprehension and retention rates compared to English-only or even text-only local language content, especially among less-educated farmers (Asante et al., 2024). Furthermore, there is a strong need to integrate scientific and indigenous knowledge systems, as farmers exhibit a profound trust deficit in impersonal scientific forecasts (Kemausuor et al., 2022). Traditional forecasts, which are highly trusted, must be leveraged by collaborating with local forecasters to show convergent validity with scientific data, framing the information as complementary tools rather than competing systems.

Crucially, the apps must evolve from raw data delivery to providing crop-specific decision support that translates forecasts into actionable advice ("Plant within next 3 days"). The research highlights that the communication gap lies not in meteorological accuracy but in the lack of decision support and institutional fragmentation. While weather apps can have a decent reach, extension officers remain the most effective channel for achieving high actionability due to their role as contextualizing intermediaries who translate forecasts into system-specific, behavior-oriented guidance (Atiah et al., 2022). This strongly validates the need for coordinated, multi-channel strategies where trusted intermediaries facilitate the effective adoption of digital tools.

5.9.2 Recommendations for Agricultural Extension Services

The research indicates that the effectiveness of digital weather tools is hampered by the fact that Extension Officers (EOs) are neither formally recognized nor adequately equipped as digital agriculture intermediaries. This minimal institutional integration treats digital tools as peripheral, ignoring their potential to drive behavioral change.

To address this, the study recommends formally repositioning EOs as crucial digital communication bridges. Evidence supports this: farmers who received weather information via Extension Agents were 2.3 times more likely to act on forecasts compared to those using radio alone, demonstrating their capacity to overcome trust deficits and contextualize information into actionable guidance (Nyamekye et al., 2022). This structural change requires significant investment in digital literacy training for EOs and equipping them with demonstration devices and standardized training modules, a necessity reinforced by findings that ease of use is a stronger predictor of adoption than perceived usefulness (Wiredu et al., 2022).

Furthermore, extension services must implement structured, multi-session training programs that utilize hands-on practice, peer learning groups, and continuous technical support, as initial design quality alone is insufficient for sustained usage (Paparrizos et al., 2023). EOs are also tasked with actively bridging scientific and traditional knowledge systems by engaging local forecasters as partners, aligning with Communication for Development principles that demand culturally grounded, participatory approaches respectful of indigenous knowledge. This integration is a crucial strategy for building the trust required to make scientific forecasts relevant and reliable within the farming community.

5.9.3 Recommendations for Government and Policy Makers

The study reveals that the widespread failure of weather app adoption is fundamentally rooted in structural constraints and institutional fragmentation, rather than just individual farmer factors. The primary barrier is the high cost of data and phones, compounded by severe poor network connectivity in rural farming areas—an infrastructure crisis where 93% of participants cited unreliable internet as a major obstacle (Wiredu et al., 2022). This ironically prevents the most climate-vulnerable farmers from accessing the tools designed to help them.

To overcome these systemic issues, policymakers must adopt a comprehensive National Digital Agriculture Policy Framework. This framework must prioritize direct investment in rural digital infrastructure to guarantee minimum connectivity (Wiredu et al., 2022) and subsidize data costs for agricultural applications.

Furthermore, the government must address institutional fragmentation (Atiah et al., 2022). This involves formally integrating digital tools into official extension programs by mandating digital literacy training for all extension officers. The ultimate policy goal, supported by Rogers' (2003) theory on supportive social systems, is to establish coordination mechanisms between meteorological agencies, extension services, and developers. This ensures that digital tools transition from being peripheral projects to central components of agricultural policy, effectively translating scientific data into actionable guidance through a unified, well-resourced system.

5.10 Suggestions for Future Research

Based on these limitations, future research should pursue several directions. Comparative Regional Studies are needed to replicate this research across Ghana's different agro-ecological zones to identify context-specific versus universal communication principles. Longitudinal Adoption Studies should track farmers and interventions over multiple agricultural seasons to understand temporal dynamics, moving beyond the cross-sectional snapshot. To quantify impact, Quantitative Adoption Modeling and Communication Strategy Experimental Research (e.g., randomized controlled trials comparing different message formats or integration approaches) are required to measure statistical predictors and causal effects. Specific focused research should address the economic and social dimensions, including economic impact assessments quantifying the income and productivity benefits of app use (addressing the value demonstration gap) and gender-specific communication research to develop strategies that effectively address women farmers' unique constraints and preferences. Finally, Institutional Coordination Studies and Infrastructure Investment Studies are necessary to guide policy and assess the optimal investments required to address the systemic structural barriers identified in this research.

REFERENCES

Adarkwah, F., Annan, S. T., Anyamesem-Poku, A., & Santiago, P. K. (2018). Real estate development and land grabbing in Ghana: A review of impact and policy responses. *Journal of Food Security, 6*(3), 119–126. https://doi.org/10.12691/jfs-6-3-4

Adjei-Nsiah, S. (2012). Promoting cassava as an industrial crop in Ghana: Effects on soil fertility and farming system sustainability. *Applied and Environmental Soil Science, 2012*, Article 940954. https://doi.org/10.1155/2012/940954

Adongo, T. M., Kuuire, V. Z., & Kangmennaang, J. (2021). Language barriers in digital agricultural technologies in Ghana. *Journal of Rural Development, 45*(3), 234–251.

Adu-Gyamfi, R., Obeng-Koranteng, G., & Mensah, A. K. (2023). Mobile technology penetration in rural Ghana: Implications for agricultural development. *African Journal of Agricultural Research, 18*(4), 445–462.

Akuriba, M. A., Haasnoot, M., Roosmalen, L., Dahm, R., Hermans, L., Kwakkel, J., & Slager, K. (2022). Barriers and opportunities for climate adaptation in rural Ghana. *Climate and Development, 14*(8), 721–735.

Amikuzuno, J., & Donkoh, S. A. (2024). Climate variability and smallholder agriculture in sub-Saharan Africa: Evidence from Ghana. *Agricultural Systems, 215*, Article 103842.

Antwi-Agyei, P., Dougill, A. J., Fraser, E. D., & Stringer, L. C. (2021). Climate change impacts and adaptation strategies in Ghana's agricultural sector. *Environmental Research Letters, 16*(5), Article 054046.

Asante, F., & Amuakwa-Mensah, F. (2022). Digital agricultural platforms in Ghana: Adoption and utilization patterns. *Technology in Society, 68*, Article 101890.

Asante, F., Wiredu, A. N., & Martey, E. (2024). Language barriers and digital literacy in Ghanaian agriculture. *Information Development, 40*(2), 178–195.

Asante-Addo, C., Mockshell, J., Zeller, M., & Siddig, K. (2023). Mobile phone penetration and agricultural information access in rural Ghana. *Telecommunications Policy, 47*(3), Article 102485.

Ascroft, J., & Masilela, S. (1994). Participatory decision making in Third World development. In S. A. White, K. S. Nair, & J. Ascroft (Eds.), *Participatory communication: Working for change and development* (pp. 259–294). Sage Publications.

Atiah, W. A., Amekudzi, L. K., Akum, G. N., Quansah, E., Antwi-Agyei, P., & Danuor, S. K. (2022). Climate information services and agricultural decision-making in Ghana. *Climate Services, 28*, Article 100325.

Awokuse, T. O., & Owusu, A. (2023). Cultural contexts in agricultural technology adoption: Evidence from Ghana. *Food Policy, 115*, Article 102398.

Awotide, B. A., Karimov, A. A., Diagne, A., & Nakelse, T. (2023). The impact of seed vouchers on poverty reduction among smallholder rice farmers in Nigeria. *World Development, 162*, Article 106117.

Ayamga, J., Pabi, O., Amisigo, B. A., Fosu-Mensah, B. Y., & Codjoe, S. N. A. (2021). Annual and intra-annual climate variability and change of the Volta Delta, Ghana. *Environmental Monitoring and Assessment, 193*(4), Article 233. https://doi.org/10.1007/s10661-021-08986-3

Berkeley Investors Club. (2019, May 11). *Agriculture sector - Crop production in Ghana*. https://club.berkeleyme.com/agriculture-sector-crop-production-in-ghana/

Berrang-Ford, L., Siders, A. R., Lesnikowski, A., Fischer, A. P., Callaghan, M. W., Haddaway, N. R., ... & Canosa, I. V. (2021). A systematic global stocktake of evidence on human adaptation to climate change. *Nature Climate Change, 11*(11), 989–1000.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2024). Gender dimensions of agricultural vulnerability in Ghana. *Global Food Security, 30*, Article 100565.

Codjoe, S. N. A., Nyarko, B. K., Coop, P., Nelson, W. A., Atiglo, D. Y., Ofori-Danson, P. K., Nicholls, R. J., Adger, W. N., Hutton, C. W., & Hanson, S. E. (2020). The Volta Delta, Ghana: Challenges in an African setting. In R. J. Nicholls, C. W. Hutton, W. N. Adger, S. E. Hanson, M. M. Rahman, & M. Salehin (Eds.), *Ecosystem services for well-being in deltas: Integrated assessment for policy analysis* (pp. 57–76). Springer. https://doi.org/10.1007/978-3-030-23517-8_4

Codjoe, S. N. A., Owusu, G., & Burkett, V. (2023). Indigenous knowledge and climate adaptation in Ghana's agricultural sector. *Environmental Management, 71*(4), 789–802.

Cudjoe, S., & Alorvor, S. K. (2021). Indigenous knowledge practices and community adaptation to coastal flooding in Ada East District of Ghana. *Journal of Environmental Management, 282*, Article 111939. https://doi.org/10.1016/j.jenvman.2021.111939

Darkwah, S. A., Verter, N., & Essel-Gaisey, F. (2023). Digital literacy challenges in rural Ghana: Implications for agricultural development. *Telematics and Informatics, 76*, Article 101913.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Derbile, E. K. (2021). Climate variability and change in Ghana: Stocktaking and implications for agricultural development. *Environment, Development and Sustainability, 23*(8), 11549–11575.

Expatlife Ghana. (2024, April 4). *How many languages are spoken in Ghana (Ghana tour guide)*. https://expatlifeghana.com/languages-spoken-in-ghana/

Fosu-Mensah, B. Y., Okoffo, E. D., Darko, G., & Gordon, C. (2023). Farmers' adaptation strategies to climate variability in the forest-savanna transition zone of Ghana. *Environmental Development, 45*, Article 100792.

GeoPoll. (2024, August 23). *Mobile penetration and internet usage in Ghana*. https://www.geopoll.com/blog/mobile-penetration-and-internet-usage-in-ghana/

Ghana Statistical Service. (2021). *2021 Population and Housing Census: General report volume 3A, Population of regions and districts*. https://statsghana.gov.gh/

Gyampoh, B. A., & Asante, W. A. (2024). Climate risks and smallholder agriculture in Ghana: A vulnerability assessment. *Climate Risk Management, 43*, Article 100547.

Hoffman, M., Lubell, M., & Hillis, V. (2014). Linking knowledge and action through mental models of sustainable agriculture. *Proceedings of the National Academy of Sciences, 111*(36), 13016–13021.

Issaka, S. A. (2023). Eruditing from indigenous adaptation strategies for resilient and sustainable coastal erosion management in southeastern Ghana. *Discover Sustainability, 4*, Article 123. https://doi.org/10.1007/s43621-023-00123-z

Jayson-Quashigah, P. N., Appeaning Addo, K., Amisigo, B., & Wiafe, G. (2020). Assessment of the dynamics of the Volta river estuary shorelines in Ghana. *Geoenvironmental Disasters, 7*, Article 19. https://doi.org/10.1186/s40677-020-00151-1

Kemausuor, F., Obeng, G. Y., Brew-Hammond, A., & Duker, A. (2022). Traditional weather prediction and climate adaptation among smallholder farmers in Ghana. *Climate and Development, 14*(6), 543–558.

Kuhlmann, K., Nordahl, L. M., & Montes de Oca Munguia, O. (2020). Cultural factors in agricultural technology adoption: A systematic review. *Agricultural Systems, 181*, Article 102804.

Laube, W., Schraven, B., & Awo, M. (2012). Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Climatic Change, 111*(3–4), 753–774.

Limantol, A. M., Keith, B. E., Azabre, B. A., & Lennartz, B. (2022). Farmers' perception and adaptation practice to climate variability and change: A case study of the Vea catchment in Ghana. *SpringerPlus, 5*, Article 830.

Lybbert, T. J., & Sumner, D. A. (2012). Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy, 37*(1), 114–123.

Lykke, A. M., Kristensen, M. K., & Ganaba, S. (2021). Traditional weather forecasting methods among farmers in Burkina Faso and northern Ghana. *Weather, Climate, and Society, 13*(2), 345–362.

Mapfumo, P., Adjei-Nsiah, S., Mtambanengwe, F., Chikowo, R., & Giller, K. E. (2017). Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development, 5*, 6–22.

McNamara, K. E., Clissold, R., Westoby, R., Piggott-McKellar, A. E., Kumar, R., Clarke, T., ... & Nunn, P. D. (2012). An assessment of community-based adaptation initiatives in the Pacific Islands. *Nature Climate Change, 2*(3), 201–206.

Media Foundation for West Africa. (2022, August 22). *How a private company's salt mining is undermining livelihoods, human rights, press freedom*. https://mfwa.org/issues-in-focus/how-a-private-companys-salt-mining-is-undermining-livelihoods-human-rights-press-freedom/

Ministry of Business Development. (n.d.). *Agriculture*. Government of Ghana. https://mobd.gov.gh/agriculture/

Ministry of Food and Agriculture. (2021). *Agriculture in Ghana: Facts and figures 2021*. Statistics, Research and Information Directorate (SRID). https://mofa.gov.gh/site/images/pdf/AGRICULTURE%20IN%20GHANA%20(Facts%20&%20Figures)%202021.pdf

Mongabay. (2022, March 7). *As rising seas destroy Ghana's coastal communities, researchers warn against a seawall-only solution*. https://news.mongabay.com/2022/03/as-rising-seas-destroy-ghanas-coastal-communities-researchers-warn-against-a-seawall-only-solution/

Naab, F. Z., Abubakari, Z., & Ahmed, A. (2022). Indigenous weather knowledge and modern forecasting: Integration challenges in northern Ghana. *Climate and Development, 14*(4), 335–350.

Nyamekye, C., Dewulf, A., Van Slobbe, E., Termeer, K., & Pinto, C. (2022). Climate information services and farmer decision-making in northern Ghana: A longitudinal assessment. *Climate Services, 26*, Article 100281.

Nyong, A., Adesina, F., & Elasha, B. O. (2020). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change, 12*(5), 787–797.

Nyong, A., Adesina, F., & Elasha, B. O. (2021). Indigenous weather knowledge systems in African agriculture: Contemporary relevance and integration challenges. *Agricultural Systems, 189*, Article 103065.

Ochieng, J., Kirimi, L., & Mathenge, M. (2017). Effects of climate variability and change on agricultural production: The case of small-scale farmers in Kenya. *NJAS-Wageningen Journal of Life Sciences, 77*, 71–78.

Odjugo, E. S., et al. (2024). Sand mining deteriorates soil fertility and farming livelihoods around Accra, Ghana. *Scientific Reports, 14*, Article 16824. https://doi.org/10.1038/s41598-024-66656-z

Ofosu-Asiedu, K., Senayah, J. K., & Akaba, S. (2023). Context specificity in weather information services: Lessons from Ghana's agricultural sector. *Information Development, 39*(3), 456–471.

Onyeaka, H., Tamasiga, P., Nkouam, S. M., Miri, T., Obileke, K., Umenwoke, O., ... & Okafor, C. (2024). Climate variability and agricultural productivity in sub-Saharan Africa: Current challenges and future prospects. *Sustainable Production and Consumption, 35*, 1–15.

Osei-Owusu, P., Badu, E., Aning-Agyei, M. A., Anaman, K. A., & Belford, J. E. (2023). Economic vulnerability and climate adaptation among smallholder farmers in Ghana. *Agricultural Economics, 54*(2), 234–248.

Panzou, G. L., Fobane, J. L., Kondjo, F., Kimbatsa, D. D., & Ngoba, S. F. (2023). Technology adoption patterns among smallholder farmers in Central Africa. *Technology in Society, 72*, Article 102156.

Paparrizos, S., Gbangou, T., Ludwig, F., van Slobbe, E., Dewulf, A., Termeer, C., & Fleskens, L. (2023). Co-production of climate information services: Lessons from the development of the FarmerSupport App in Ghana. *Climate Services, 30*, Article 100356.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

ScienceDirect. (2024). *Digital literacy and agricultural technology adoption in developing countries*. Elsevier. https://www.sciencedirect.com

Servaes, J. (2008). *Communication for development and social change*. Sage Publications.

Tetteh-Ahinakwah, B., Amekudzi, L. K., Quagraine, K. A., Annor, T., Klutse, N. A. B., & Aryee, J. N. A. (2024). Temperature variability in coastal Ghana: A day-to-day variability framework. *Theoretical and Applied Climatology, 155*, 6565–6585. https://doi.org/10.1007/s00704-024-05004-7

Vincent, K., Daly, M., Scannell, C., & Leathes, B. (2017). What can climate services learn from theory and practice of co-production? *Climate Services, 6*, 48–59.

Wikipedia. (2025, September 18). *Languages of Ghana*. https://en.wikipedia.org/wiki/Languages_of_Ghana

Wiredu, A. N., Asante, F., & Martey, E. (2022). Digital agriculture transformation in Ghana: Opportunities and challenges. *Agricultural Systems, 201*, Article 103456.

Wiredu, A. N., Mensah, A., & Gyasi, K. O. (2023). Social networks and agricultural technology adoption in rural Ghana. *Social Networks, 72*, 89–102.

World Bank. (2017). *ICT in agriculture: Connecting smallholders to knowledge, networks, and institutions* (Updated ed.). World Bank.

World Travel Guide. (2025, February 18). *Ghana weather, climate and geography*. https://www.worldtravelguide.net/guides/africa/ghana/weather-climate-geography/

Ziervogel, G., Bharwani, S., & Downing, T. E. (2008). Adapting to climate variability: Pumpkins, people and policy. *Natural Resources Forum, 30*(4), 294–305.

APPENDIX I

INTERVIEW GUIDE FOR SMALLHOLDER FARMERS, EXTENSION OFFICERS AND WEATHER APP DEVELOPERS

Part 1: Background and Contextual Information

1. Can you tell me about yourself and your farming activities here in Ada?
2. What are the main challenges you face in your farming activities, especially related to weather and climate?
3. How important is weather information for your farming decisions? Can you give me specific examples?

Part 2: Current Weather Information Sources and Practices

4. Where do you currently get information about weather and climate for your farming?
5. Which of these sources do you trust the most? Why do you trust them?
6. Can you describe how you use traditional or indigenous methods to predict weather? What signs do you look for?
7. What type of weather information is most useful for your farming decisions?

Part 3: Mobile Technology and Digital Literacy

8. Do you own a smartphone? If yes, how long have you been using it? If no, do you have access to one?
9. Have you ever used any mobile applications (apps) before? Which ones? How easy or difficult was it to learn?
10. What language do you prefer when using your phone? Why?
11. Can you read and write in that language? How comfortable are you reading information on a phone screen?

Part 4: Awareness and Experience with Weather Apps

12. Have you heard about weather forecasting applications or apps for farmers? Where did you hear about them?
13. Have you ever used any weather app for farming? If yes, which one(s)? If no, why not?

For those who have used weather apps:

14. How did you first learn about the app? Who introduced it to you?
15. Can you walk me through how you use the app? What do you do first, second, and so on?

16. Is the app available in a language you understand well? If not, how do you manage?
17. Have you continued using the app since you started? If you stopped, why?

For those who have NOT used weather apps:

18. What has prevented you from using weather apps?
19. If someone showed you how to use a weather app, would you be interested in trying it? What concerns would you have?

Part 5: Communication and Language Barriers

20. If a weather app was available in Dangme (or your local language), would that make a difference for you? How?
21. When you receive weather information, do you prefer it in text (written words), pictures/symbols, voice messages, or videos? Why?

Part 7: Communication Channels and Support Systems

22. If you had questions about how to use a weather app, who would you ask for help?
23. Have you ever received any training on using smartphones or apps for farming? If yes, how helpful was it?
24. Would you prefer to learn about weather apps through: one-on-one training, group demonstrations, radio programs, or other ways?

Part 8: Perceived Benefits, Barriers, and Adoption Factors

25. What benefits do you think you could get from using a weather forecasting app?
26. What are the main obstacles that would prevent you or other farmers like you from using weather apps regularly?

Part 9: Recommendations and Future Perspectives

27. If you could design a perfect weather app for farmers in Ada, what features would it have? How would it work?
28. What advice would you give to people who are trying to help farmers use weather apps?
29. Is there anything else about weather information, mobile apps, or communication that you think I should know to understand your situation better?

INTERVIEW GUIDE FOR AGRICULTURAL EXTENSION OFFICERS

Part 1: Background and Role

1. Can you tell me about your role as an extension officer in Ada district? How long have you been working in this position?
2. How many farmers do you typically work with, and what are the main crops or farming systems in your coverage area?
3. What are the most pressing challenges farmers in your area face related to weather and climate?

Part 2: Current Weather Information Communication

4. How do you currently communicate weather and climate information to farmers? What methods or channels do you use?
5. How do farmers typically respond when you provide them with weather information? Do they act on it? What influences their response?
6. Have you noticed differences in how different groups of farmers (e.g., men vs. women, young vs. old, educated vs. less educated) receive and use weather information?

Part 3: Experience with Digital Agricultural Technologies

7. Are you familiar with weather forecasting apps designed for farmers in Ghana? Which ones have you encountered?
8. Have you personally used any weather apps in your extension work? If yes, which ones and how do you use them?
9. Have you tried to introduce or promote any weather apps to the farmers you work with? Can you tell me about that experience?
10. What has been the response from farmers when you've introduced digital tools or apps? What reasons do they give for accepting or rejecting them?
11. In your observation, what percentage of farmers in your area own smartphones? How does this affect your communication strategies?

Part 4: Barriers and Challenges to App Adoption

12. Based on your experience, what are the main barriers preventing farmers from adopting weather forecasting apps?
13. Can you describe specific incidents where farmers struggled to understand or use weather apps? What were the main difficulties?

Part 5: Communication Strategies and Trust-Building

14. How do you build trust with farmers when introducing new information or technologies? What communication strategies work best?
15. Have you found ways to integrate or bridge traditional weather knowledge with scientific forecasts in your communication with farmers? How do farmers respond to this approach?

Part 6: Training and Support Systems

16. Have you received any training on using digital agricultural technologies or communicating about them to farmers? Was it adequate?
17. What kind of support do you need to better help farmers adopt and use weather apps?

Part 7: Institutional and Policy Context

18. How well coordinated are weather information services from different providers (meteorological agencies, app developers, NGOs, etc.) in your area?
19. What institutional support exists for promoting digital agricultural technologies among farmers? What gaps exist?
20. Are there any policies or programs from the Ministry of Food and Agriculture that specifically support digital weather information services for farmers?

Part 8: Recommendations and Future Directions

21. Based on your experience, what communication strategies would be most effective for increasing weather app adoption among farmers in Ada?
22. If you could redesign weather app communication and promotion strategies, what would you do differently?
23. What features or characteristics would make a weather app more useful for both extension officers and farmers?
24. What role should extension services play in the promotion and support of digital weather information services?

INTERVIEW GUIDE FOR WEATHER APP DEVELOPERS

Part 1: Background and App Overview

1. Can you tell me about your organization and your role in developing weather forecasting applications for farmers?
2. Which weather application(s) has your organization developed or worked on? What is the primary purpose of the app?

3. Who is the target audience for your app? How did you identify and define this target audience?
4. What motivated your organization to develop a weather app specifically for farmers in Ghana?

Part 2: Design Philosophy and User-Centered Approach

5. Can you describe the development process for your app? How did you gather information about farmers' needs and preferences?
6. Did you involve farmers or agricultural stakeholders in the design and development process? If yes, how? If no, why not?
7. How did you decide on the app's interface design, features, and functionality? What guided those decisions?
8. What consideration did you give to users with limited digital literacy or formal education?

Part 3: Language, Communication, and Accessibility

9. In what language(s) is your app available? How did you decide on these languages?
10. Are there plans to add more local languages? What challenges have you faced or do you anticipate in multilingual development?
11. Does your app use any non-text communication methods like icons, images, audio, or video? Why or why not?
12. Have you tested your app with actual farmers to assess comprehension and usability? What did you learn from that testing?

Part 4: Communication and Promotion Strategies

13. What communication strategies have you used to promote your app to farmers? Which channels have you used?
14. Have you partnered with agricultural extension services, farmer organizations, or other intermediaries to reach farmers? How has that worked?
15. What role do demonstrations, training sessions, or community events play in your communication strategy?

Part 5: Adoption Patterns and User Feedback

16. How many downloads or active users does your app currently have? How has adoption progressed over time?
17. What user feedback have you received about your app? What do farmers say they like? What complaints or difficulties do they report?
18. What reasons do farmers give for not continuing to use your app after initially downloading it?

Part 6: Trust, Indigenous Knowledge, and Cultural Factors

19. How do you address farmers' trust concerns regarding scientific weather forecasts, especially when they may conflict with traditional predictions?
20. Have you considered integrating indigenous weather knowledge or traditional forecasting methods into your app? Why or why not?
21. How do you ensure your app is culturally appropriate for Ghanaian farming communities?
22. What cultural or social factors have you found to influence farmers' willingness to adopt and use your app?

Part 7: Barriers and Challenges

23. From your perspective as a developer, what are the main barriers preventing farmers from adopting your app?
24. Have you faced challenges in making your app financially sustainable while keeping it affordable or free for smallholder farmers?
25. What challenges have you encountered in communicating complex meteorological information in simple, actionable terms?

Part 8: Collaboration and Institutional Support

26. How do you collaborate with meteorological services, agricultural institutions, or research organizations?
27. What support have you received (or not received) from government agencies or agricultural institutions?
28. What gaps exist in the ecosystem supporting digital agricultural innovation in Ghana?

Part 9: Future Development and Recommendations

29. What improvements or new features are you planning for your app based on user feedback and adoption patterns?
30. What advice would you give to other developers or organizations creating digital tools for smallholder farmers in Ghana?
31. From a communication perspective, what do you think is needed to increase weather app adoption among Ghanaian farmers?

APPENDIX II

ANALYSED FINDINGS FROM SMALLHOLDER FARMERS, EXTENSION OFFICERS & WEATHER APP DEVELOPERS.

RESPONDENT SHF1

Section 1: Current Weather Information Sources

The respondent primarily relies on traditional methods from elders, who observe the sky, wind, and bird behavior. They also use personal observation learned from their grandmother (reading clouds, feeling the wind).

Section 2: Awareness and Experience with Technology

The respondent has limited awareness of weather apps, having only heard about them from their son and noting they don't own a smartphone. They would be interested if the app could help their farming, but it must speak in Dangme and require slow, repeated instruction due to age and illiteracy.

Section 3: Language and Literacy Barriers

The biggest problem is illiteracy; the respondent cannot read English or Twi, making text-based apps unusable. They need voice-based information in Dangme that explains the forecast and gives specific farming advice. Pictures (like rain clouds or sun) could also help them understand the information without needing to read.

Section 4: Trust and Traditional Knowledge

The respondent would trust a traditional forecaster over a phone app because he is known, accessible, and the app is an unseen machine. To gain trust, the phone app would need to demonstrate respect for, or even combine its data with, traditional knowledge. They believe both systems working together could be beneficial.

Section 5: Learning and Support Needs

Learning would require an Extension Officer to teach their women's farmer group slowly, repeatedly, and using their local language (Dangme). The respondent would also need support from younger people (children/younger farmers) and patient teachers for continuous help.

Section 6: Perceived Value and Benefits

The primary motivation would be the ability to save crops from damage (e.g., being warned two days before sudden rain). The benefits must be clear, real, and proven by seeing them work for neighbors first.

Section 7: Infrastructure Challenges

Cost is a major obstacle: the respondent cannot afford a smartphone (600-1,000 cedis) or monthly internet bundles. Weak network coverage in their farm area is another practical problem preventing the use of internet-dependent technology.

Section 8: Recommendations

The respondent suggests the government should help with cheaper phones (or loans) and make internet for farming free or very cheap. They need the Extension Officer to visit more often (e.g., weekly) to show the phone and explain the weather in Dangme.

RESPONDENT SHF2

Section 1: Current Weather Information Sources

The respondent primarily relies on community elders, who have been predicting weather by watching clouds, wind, and crab behavior near the estuary. She also uses personal observation from her 28 years of farming. Though her children sometimes relay radio news, she trusts the elders more.

Section 2: Experience with Weather Apps

The respondent's son gave her a phone with an app, but she couldn't use it because everything was in English and the symbols/numbers were confusing. She finds navigating apps and finding things difficult, noting the phone has too many buttons, and she forgets quickly after her son's brief instruction.

Section 3: Trust in Traditional vs Scientific Forecasts

She does not trust the phone app more than traditional forecasters because she does not know who is behind the app or if they understand specific Ada weather. She trusts traditional forecasters because they are known, care about their farms, and are accessible for questions, whereas the app is an unknown entity.

Section 4: Language and Communication Needs

For usefulness, the app must speak to her in Dangme via voice messages providing actionable advice like "harvest your pepper now". Since she cannot read, the app needs simple pictures (e.g., big rain clouds, sun) and should tell her what to do rather than giving technical information like "70% precipitation".

Section 5: Barriers to Adoption

Major barriers include illiteracy (cannot read English or Twi well), the complexity of the app interface, and a lack of support since her son is absent and the Extension Officer doesn't know about the apps. Most importantly, she doesn't see a clear benefit over the already reliable traditional methods.

Section 6: Learning and Support Needs

She needs patient, face-to-face teaching from someone who speaks Dangme and understands her illiteracy, preferably the Extension Officer teaching their women farmers' group. Training should involve multiple, slow, step-by-step sessions (e.g., 4-5 times) with group practice, and participants need a way to reach the Extension Officer for help.

Section 7: Peer Influence

She would be motivated to use the app if she saw fellow women farmers in her group using it successfully to avoid crop losses and improve farm timing. Learning from peers is preferred over learning from strangers or her son, as co-farmers understand her level, can teach her in Dangme, and don't make her feel stupid.

Section 8: Perceived Value

The app's value lies in its ability to help her avoid losses worth of drying pepper from unexpected rain and optimize input use by timing planting and irrigation better. The benefits must be clear, regular, and quantifiable, such as saving or more per season, to justify the effort of learning the difficult technology.

Section 9: Recommendations

The top recommendations are that the app must use voice in Dangme for non-literate women, be extremely simple (just the main information needed), and include patient teaching with continuous support from Extension Officers. Developers should also respect traditional knowledge, showing how the app can supplement, not replace, existing methods to build trust.

RESPONDENT SHF3

Section 1: Current Weather Information Sources

The respondent relies 100% on traditional methods, observing the sky, wind, and consulting the community forecaster, who has never failed her in 30 years. She finds radio news difficult to understand due to English language and lack of local specificity. Traditional knowledge is superior.

Section 2: Awareness of Weather Apps

She has limited awareness, only hearing about "apps" from her grandson, and does not own a smartphone as they are for "educated people" she believes. She would only be interested if the technology demonstrably helped her farming and if the Extension Officer taught her slowly using her Dangme language. She is currently satisfied with her traditional methods.

Section 3: Language and Communication Barriers

The app must be voice-first and speak in Dangme with simple, actionable phrases (e.g., "plant now"), as her illiteracy makes all written words useless. It must rely on simple pictures (dark cloud, sun) for communication, and the phone interface needs to be extremely simple with minimal buttons. She requires a trusted person to teach her many, many times as she is old and learns slowly.

Section 4: Trust and Traditional Knowledge

She is skeptical of distant, unknown scientists behind the app and prefers traditional forecasting due to its generational wisdom specific to Ada. Trust would be built if the app actively combined scientific and traditional signs, which would "speak my knowledge language" and verify the information. This combination is essential for her to believe in the technology.

Section 5: Digital Literacy Barriers

Major barriers include severe illiteracy, lack of experience with touchscreens and navigation, and physical issues like weak eyesight and rough fingers. She faces a fear of breaking the expensive device and quickly forgets instruction, requiring continuous, patient, and repeated teaching. She notes one or two training sessions are insufficient for an illiterate old woman.

Section 6: Structural Barriers

The primary structural obstacles are the high cost of a smartphone and the inability to afford monthly data bundles from her small farm income. Unreliable electricity (two days without power) necessitates walking to a paid charging station, and weak network coverage near her farm means the app would fail when and where it is needed most.

Section 7: Trusted Intermediaries

She completely trusts Extension Officers because they are known, speak perfect Dangme, and understand their farming challenges. Training must be in small groups led by the Extension Officer in Dangme over multiple, slow sessions. Post-training, she requires continuous support from a local community member or the Extension Officer to fix inevitable problems.

Section 8: Perceived Value

The app's value is in avoiding financial losses and saving money/labor by preventing seed failure through better planting time advice. The app must prove these benefits to her with clear results; she suggests a free trial for one season to see if it truly helps before committing.

Section 9: Recommendations

The app must be very simple, voice-first in Dangme, use pictures, and be free or very cheap (maybe a public service) to be accessible. It must work without internet when necessary and combine traditional and scientific knowledge to build trust. Finally, it requires continuous support and patient, repeated training by Extension Officers.

RESPONDENT SHF4

Section 1: Current Weather Information Sources

The respondent primarily trusts her traditional methods (sky/wind observation taught by her mother) and the local forecasters. She occasionally receives information from the Extension Officer but relies heavily on the proven traditional way.

Section 2: Language and Communication Barriers

The main barrier is complete illiteracy in any language, making written apps useless, compounded by the complexity of modern phones which causes a fear of damage. For utility, the app must speak in Dangme via voice and rely on simple, clear pictures to convey the forecast.

Section 3: Trust in Traditional vs. Scientific Forecasts

She is skeptical of the app's unknown source and doesn't trust it more than her proven local forecasters. To build trust, the app must accurately predict local rain repeatedly and actively respect and combine its scientific data with traditional knowledge.

Section 4: Structural Barriers

The key financial barriers are the high cost of a smartphone and the inability to afford monthly data bundles from her small income. Structural challenges include unreliable electricity for charging the phone and pervasive weak network coverage on the farming plots.

Section 5: Perceived Value

The app must offer clear, quantifiable benefits, specifically by helping her save money through preventing crop losses (like damaged pepper) and optimizing planting time to avoid seed waste. The benefits must be significant enough to justify the learning effort, and she needs to see them proven by her peers first.

Section 6: Learning and Support Needs

Training must be slow, hands-on, and repeatedly conducted by a trusted person, like an Extension Officer, teaching her women's group in Dangme. She requires a strong, local support person (a trained farmer champion) to provide continuous assistance after the initial teaching sessions.

Section 7: Recommendations

The app must be made affordable (e.g., subsidized phones) and redesigned to be simple and voice-based in Dangme, while actively respecting traditional knowledge. The crucial factor for adoption is community-based, repeated training led by trusted figures like the Extension Officer, with continuous local support.

RESPONDENT SHF5

Section 1: Current Weather Information Sources

The respondent relies completely on traditional methods taught by her mother, observing the morning sky, wind, and animal behavior (birds, ants). She also trusts the community elder, who has been predicting weather for 50 years and is "never wrong." She trusts her own eyes and the elders more than information relayed from the radio by her son.

Section 2: Language and Technology Barriers

The core barrier is illiteracy (cannot read English or Dangme), making any app with writing useless, coupled with her fear and confusion regarding modern smartphones. She requires the app to speak to her in Dangme via voice messages, and suggests the Extension Officer could send a daily voice note explaining the forecast.

Section 3: Structural Barriers

The high cost of a smartphone and the inability to afford monthly internet bundles are major financial obstacles from her small income. She gave her gifted smartphone to her grandson because she couldn't use it, and she has no network coverage on her farm, making an internet-dependent app impractical.

Section 4: Trust and Traditional Knowledge

She does not trust the app more than her trusted community elder forecasters because she doesn't know who makes the app or if they understand the local Ada weather. Trust would be built if the app could be seen to work successfully for her neighbors, proving its value, and if it respected her traditional knowledge by working alongside it.

Section 5: Preferred Learning Method and Support

Learning must be hands-on, slow, and repeated by the Extension Officer in her women's group using Dangme language. She needs a system for continuous support from the Extension Officer or a local expert to help her fix problems and answer questions after the initial training.

Section 6: Perceived Value and Willingness to Pay

The app must provide clear, real, and quantifiable value by helping her save money worth of damaged crops or on irrigation costs. She would only pay a small amount if she sees the benefits working for 3-4 months first on a free trial.

Section 7: Community and Peer Influence

She would be convinced to try the technology if she saw five or six women in her farmer group using it successfully and achieving better farm results. Hearing a real success story from a trusted co-farmer or having the group leader recommend it would be the most convincing factor.

RESPONDENT SHF6

Section 1: Current Weather Information Sources

The respondent primarily trusts the traditional forecasters, who are highly reliable (85% correct) and use local observations (clouds, wind, birds) to predict weather two days out. She also listens to radio in Twi, but finds it too general for their specific Ada area, and the Extension Officer only visits infrequently.

Section 2: Awareness and Experience with Weather Apps

She has heard of weather apps and her son downloaded one but she struggled and stopped using it after a few weeks. The complexity of the interface (too many buttons/links) and her difficulty with reading the English text made the app unusable for her. She now uses her smartphone only for calls, WhatsApp, and mobile money.

Section 3: Structural and Literacy Barriers

Major barriers include her illiteracy (cannot read English or Twi), weak eyesight, and the high cost of monthly data bundles for the internet. Furthermore, the weak network signal on her farm and unreliable electricity for charging are practical obstacles that make internet-dependent technology challenging to use effectively.

Section 4: Trust and Traditional Knowledge

She distrusts the app because it is unknown and comes from Accra, while she trusts the local knowledge of traditional forecasters. Trust would be built if the app could be seen to work accurately over time and, crucially, if it combined scientific data with traditional signs and was introduced by the trusted Extension Officer.

Section 5: Preferred Learning Method

Training must be face-to-face in her women's group, led by the trusted Extension Officer over multiple, slow sessions using the Dangme language. The training should involve a shared phone for practice and allow the women to learn from each other to build confidence.

Section 6: Value and Willingness to Pay

The app's value is in providing specific advice for planting, harvesting, and saving money by preventing crop losses. She would only pay a small amount if the app were proven to work, as she cannot risk money on unproven services.

Section 7: Recommendations

The app must be simple, voice-based in Dangme, and work offline (download once, use all week) to overcome literacy and network issues. It requires continuous support (helpline/local champion), must combine traditional and scientific forecasts, and should be subsidized/free for poor farmers like her.

RESPONDENT SHF7

Section 1: Current Weather Information Sources

The respondent relies primarily on traditional observation (sea breeze, cloud color, animal behavior) and trusted community forecasters, finding them more accurate for short-term forecasts. She also listens to FM (Dangme/Ga broadcast) and occasionally receives WhatsApp updates from her children.

Section 2: Awareness and Experience with Weather Apps

She has high awareness of weather apps, having seen them on her children's phones, but she cannot use them due to her illiteracy, making all written words useless. The apps are too complex and she lacks the consistent, patient support needed to learn navigation and overcome language barriers.

Section 3: Trust and Traditional Knowledge

She distrusts the app because its source is unknown and it does not account for the specific local microclimate and natural signs of Ada like traditional forecasters do. Trust would only be established if the app were introduced by the Extension Officer and if it actively combined its data with traditional signs for verification.

Section 4: Communication Needs

The app must be voice-based in Dangme with simple, large symbols (e.g., sun, cloud) because she cannot read any text. The messages should be actionable and context-specific, offering advice like "Harvest your pepper today" rather than just providing abstract scientific numbers like precipitation percentages.

Section 5: Structural Barriers

The high cost of a smartphone and the unaffordability of monthly data bundles are the primary financial constraints from her small income. Practical barriers include weak network coverage on the farm and unreliable electricity for charging, making a reliable app difficult to maintain.

Section 6: Learning and Support Needs

Training must be done face-to-face in her women's cooperative, led by trusted Extension Officers, and must be patient, slow, and repeated over multiple sessions. She needs continuous, local support (e.g., a helpline or a trained young farmer) to help her with inevitable technical problems and forgotten steps.

Section 7: Perceived Value

The app must provide clear economic value by helping her avoid crop losses and optimize input use (e.g., saving money on irrigation). She cannot afford to pay for the service and believes basic weather information should be provided free or highly subsidized.

Section 8: Recommendations

The app must be simple, voice-first in Dangme, and capable of working offline to overcome literacy and network issues. Developers must partner with trusted intermediaries (Extension Services) and actively respect traditional knowledge to foster adoption and trust among older farmers.

RESPONDENT SHF8

Section 1: Current Weather Information Sources

The respondent relies entirely on traditional observation (sky, wind, animals) learned from his father over 38 years, who is his main teacher and has never failed him. He trusts these local, proven methods far more than information relayed from the radio or his children's phones.

Section 2: Experience with Weather Apps

Although he owns a gifted smartphone with an app, he cannot use it due to complete illiteracy and the app's use of confusing English words, icons, and numbers. He quickly forgot the brief instructions and, fearing he would break the expensive device, now only uses the phone to receive calls.

Section 3: Language and Communication Barriers

To be useful, the app must speak in Dangme via voice messages that deliver simple, actionable farming advice (e.g., "plant today"), not technical data. The interface must use clear pictures/symbols and allow him to repeat the voice note to fully understand the instruction.

Section 4: Trust in Traditional vs. Scientific Forecasts

He distrusts the app because he doesn't know if it understands specific Ada weather, contrasting it with the trusted local forecasters. Trust requires the app to prove its accuracy repeatedly and, most importantly, respect and integrate traditional knowledge with the scientific forecast.

Section 5: Structural Barriers

The key barriers are his illiteracy, the inability to afford monthly internet bundles from his small income, and unreliable electricity for charging the phone. Furthermore, weak network coverage on the farm renders the internet-dependent app useless precisely when the information is needed most.

Section 6: Learning and Support Needs

Learning requires patient, hands-on, and repeated training over 4-5 sessions by a trusted person, preferably the Extension Officer, teaching the farmer group in Dangme. Continuous support from a local "champion" or a helpline is crucial for him to manage inevitable technical issues and retain the complicated instructions.

Section 7: Peer Influence and Motivation

He would be motivated to use the app only after seeing other elderly co-farmers in his group succeed in avoiding crop losses and improving yields. Learning from peers is preferred because they share his language and education level and don't make him feel stupid.

Section 8: Perceived Value and Willingness to Pay

The app's value is in providing precise, long-term forecasts that help him avoid major financial losses. While basic weather should be free, he suggests premium features that cost a small fee.

Section 9: Recommendations

The app must be simple, voice-first in Dangme, use pictures, and work offline, requiring patient, repeated training from trusted Extension Officers. Crucially, developers must respect traditional knowledge by combining it with scientific data and making the app affordable or free.

Section 10: Integration of Traditional and Scientific Knowledge

He suggests integrating traditional knowledge through two methods: including visual indicators (pictures/videos) of traditional signs (e.g., low-flying birds) with their interpretations in the app, and creating a local forecaster partnership to display the elder's daily predictions alongside the scientific data. This dual approach would verify information and teach the younger generation.

RESPONDENT SHF9

Section 1: Current Weather Information Sources

The respondent utilizes various modern sources, including the Ghana Meteorological Agency on Facebook, Google weather, and FM radio broadcasts. However, they primarily trust their father's traditional methods (observing sky, wind, ants) when information conflicts, as it is more accurate for their specific local microclimate.

Section 2: Experience and Challenges

Even as an educated user, the respondent finds the existing apps too complicated with unnecessary features and requiring too many clicks to access the core forecast. They distrust the apps' short-term accuracy compared to traditional knowledge, as the forecasts are not hyperlocal enough for their microclimate.

Section 3: Communication Needs and Design

For the majority of illiterate farmers, the app must be voice-based in Dangme and communicate using simple pictures/icons. The information should be highly simple and actionable, offering specific advice ("plant today") instead of confusing scientific data and numbers.

Section 4: Trust and Traditional Knowledge

Trust must be earned through proven, superior accuracy over traditional methods and by actively respecting local knowledge. The respondent suggests the app should display the traditional forecaster's prediction alongside the scientific forecast so they can compare and verify.

Section 5: Learning and Support Needs

Training for illiterate farmers must be face-to-face, hands-on, and repeatedly taught over multiple sessions in small groups led by the trusted Extension Officer. The focus should be on practical application (linking weather to farming decisions) and not technical skills.

Section 6: Structural and Financial Barriers

The high cost of smartphones and the recurring expense of monthly data bundles are the primary financial obstacles. Infrastructural issues include weak network coverage on the farm and unreliable electricity for charging, rendering the app useless where it is most needed.

Section 7: Perceived Value and Superiority

The app's superior value lies in providing accurate 7-day or 14-day forecasts for long-term planning, feature traditional methods lack. It could also offer more specific details like hourly timing and specific rainfall amounts, and should ideally combine both traditional and scientific methods. Until the apps deliver these superior, hyperlocal advantages, traditional methods will remain dominant.

Section 10: Recommendations and Future Outlook

Developers must come to the farm to design apps with farmers, simplifying the interface to focus on a few perfectly working features. The app needs voice-first content in Dangme and requires patient, long-term commitment to training, support, and actively respecting and integrating traditional knowledge.

RESPONDENT SHF10

Section 1: Current Weather Information Sources

The educated respondent uses multiple modern sources, including Google weather, news on TV, and information shared on WhatsApp farming groups. Despite using these apps, he still relies heavily on his grandfather's traditional methods and personal observations, as the traditional forecasts are more accurate for their specific local area.

Section 2: Limitations of Current Digital Sources

Existing online sources only provide general information that is not specific enough for crucial farming decisions, such as the required planting moisture level or the time of day for rainfall. The forecasts often lack essential details like the precise timing or amount of rain, making them inferior to his grandfather's hyper-local knowledge.

Section 3: Trust and Traditional Knowledge

He has an integrated approach, combining scientific data with his grandfather's observations, but he trusts the traditional method more when information conflicts. Trust in an app requires proven, hyper-local accuracy that is superior to traditional methods and must offer long-term (7-14 day) forecasts, a clear advantage over traditional sources.

Section 4: Structural and Design Barriers

The main digital barrier is the weak network coverage on the farm, which slows the app down and makes it unreliable when and where it is needed most. He requires the app to have a simple, clean design that minimizes clicks to quickly access the forecast, avoiding the confusing clutter of existing apps.

Section 5: Communication and Advice Needs

The app must provide information that is highly specific and actionable for farming, giving advice like 'spray your crops today' or 'expect light rain tomorrow morning' instead of just raw weather data. It should also integrate traditional knowledge by displaying scientific data alongside the traditional forecaster's prediction.

Section 6: Learning and Support Needs

Training should focus on practical application, demonstrating how to translate the weather data into specific farming decisions, and must be delivered by a trusted professional like the Extension Officer. He suggests a system where farmers can call or WhatsApp the Extension Officer for advice directly from the app.

Section 7: Perceived Value and Willingness to Pay

The app's value must be quantifiable by helping him avoid crop losses or optimizing input use, which justifies the effort of using the technology. He would be willing to pay a small fee for premium, hyper-local features, provided the app offers clear, superior value over free sources.

Section 10: Recommendations and Design Preferences

He recommends the app provides hyper-local forecasts specific to a certain radius, a voice-first option in Dangme for less educated farmers, and the ability to work offline after downloading the forecast once. The design must be extremely simple, with minimal buttons, focusing on quality, accurate information tailored for farming decisions.

RESPONDENT SHF11

Section 1. Current Weather Information Sources

SHF11 relies heavily on the traditional forecaster, whose predictions based on clouds and wind are highly trusted after 28 years of farming. She also exchanges observations with her farmer group and occasionally hears radio information from her son, but she cannot use phone apps due to having only a basic phone.

Section 2. Language and Literacy Barriers

She is strongly interested in a voice-based app in her native Dangme language that speaks actionable advice directly to her. SHF11 notes that current technology is designed only for educated, literate people using English, which leaves her excluded from the benefits of modern tools.

Section 3. Trust in Traditional vs. Scientific Methods

SHF11 trusts her traditional forecaster more than an unknown phone source because he is local, experienced, and can be questioned when wrong. However, she believes her trust would increase if the app showed how the scientific forecast and traditional signs could work together.

Section 4. Learning Preferences and Support Needs

She requires slow, patient, and repeated training from trusted Extension Officers within her farmer group where she feels comfortable. This teaching must be face-to-face and strictly in Dangme, with ongoing support to help her remember the simple steps.

Section 5. Structural Barriers

Major economic and infrastructural challenges include the high cost of smartphones and expensive internet data, which she would rather spend on seeds or fertilizer. Furthermore, frequent power cuts, poor network coverage, and her weak eyesight make using modern, battery-intensive devices impractical.

Section 6. Community and Peer Influence

She needs to see other women in her farmer group successfully using the app and benefiting from it before she commits her time to learn. Peer success stories from people facing the same challenges are necessary to convince her that the technology is truly made for illiterate women like her.

Section 7. Perceived Value and Benefits

The primary benefit that would motivate adoption is saving crops and investments by knowing exactly when rain will occur. Accurate forecasts would ensure better planting timing to save seeds and protect costly pesticide investments from being washed away.

Section 8. Recommendations

The technology must be designed for illiteracy: voice-based and picture-based with no reading required. It should be very simple—starting with basic weather and advice—and respect her traditional knowledge by showing how it aligns with the scientific forecast.

RESPONDENT SHF12

Section 1. Current Weather Information Sources

SHF12 primarily relies on traditional methods: observing the sky and wind, and listening to traditional. She cannot use radio or her daughter's weather app because of language barriers and illiteracy, only receiving second-hand information. Her main source is trusted local observation and the advice of elders.

Section 2. Language and Communication Barriers

She expresses a strong preference for a voice-based app in Dangme that simply talks to her with specific advice, as she can hear and understand perfectly, despite being unable to read. Information should also be conveyed through big, clear pictures (like clinic wall charts) that simply represent sun, rain, or wind, avoiding small, complex visuals.

Section 3. Trust in Traditional vs. Scientific Forecasts

SHF12 completely trusts the traditional forecaster, whose multi-generational knowledge she considers proven and reliable. She distrusts the phone forecast because she cannot see, know, or question the source behind it. However, she would be willing to try an app if it included and respected traditional signs alongside the scientific forecast, especially if the two sources agreed.

Section 4. Digital Literacy Challenges

Phones are difficult due to illiteracy, which renders all written words useless, and fear of pressing the wrong small buttons and breaking the expensive device. Compounding this are weak eyesight (struggling with tiny letters/bright screens) and the inability to see the screen in bright farm sunlight.

Section 5. Learning and Support Needs

She requires the trusted Extension Officer to conduct slow, repetitive, group training in the Dangme language. The training should involve practical application on their own phones, with support from patient young people or fellow farmers who understand technology. She only trusts people she knows, like the Extension Officer or respected group members, not strangers.

Section 6. Perceived Value and Motivation

The primary motivation is avoiding losses due to sudden rain while drying. Valuable benefits include knowing the best time to plant to save money on seeds and the hard work of re-planting. The app must be free or very cheap and must not consume expensive data bundles frequently.

Section 7. Infrastructure Challenges

The major infrastructure hurdles are a weak, unreliable network near the coast, which often shows no signal bars, making it impossible to check the weather. Frequent electricity cuts lasting up to two days prevent her from charging her phone, rendering it useless when the battery dies. Additionally, sharing the phone with her daughter means she loses access when the device leaves the house.

Section 8. Design Recommendations

Her ideal app would be very simple, opening to just three big pictures showing today's and tomorrow's weather. Crucially, it must include one clear piece of advice in Dangme, such as "Plant today" or "Harvest your tomatoes before Friday".

RESPONDENT SHF13

Section 1. Current Weather Information Sources

SHF13 mainly relies on what her husband hears on FM and, more reliably, the predictions of their traditional forecaster, who is 90% correct. She also uses her own ability to read clouds and the changing smell of the wind from the sea, a skill taught by her mother and grandmother. Radio forecasts are sometimes wrong, while her traditional sources are trusted for short-term accuracy.

Section 2. Experience with Weather Apps

Her daughter downloaded an app on their shared phone, but SHF13 gave up after three tries because the interface was entirely in English and the screen had too much information. She struggles with tiny writing due to weak eyesight. She relies on her daughter to check the weather information for her.

Section 3. Language and Communication Barriers

The app must speak in real, local Dangme and utilize large, simple pictures or symbols for communication, as she can recognize pictures but not read words. A voice button that activates a woman's voice speaking specific, actionable advice in Dangme would be perfect, much like using WhatsApp voice messages with her children.

Section 4. Trust and Indigenous Knowledge

SHF13 does not trust scientific forecasts as she believes the scientists do not understand local Ada weather, unlike the traditional forecaster, who lives in the area and can explain his predictions. She suggests that she would trust the forecast strongly if the app confirmed the scientific prediction with the traditional signs, allowing her to verify the signs herself outdoors.

Section 5. Digital Literacy Challenges

Beyond language, the app was too complicated with too many pages that caused her to get lost or led to errors she couldn't fix due to messages in English. The phone required a constant internet connection, which is unreliable at the coast, and the app used up expensive data bundles too quickly. This makes the app economically unviable compared to the free information from our forecaster.

Section 6. Structural Barriers

The biggest infrastructure problems are the unreliable network signal and frequent electricity cuts that prevent phone charging. Furthermore, she must share the phone with her daughter who needs it for her fish business, limiting SHF13's access to the weather app. She would prefer her own simple, dedicated device for calls and weather.

Section 7. Trusted Intermediaries

She believes she could learn if Extension Officer Grace or a younger, tech-savvy woman in her group named Comfort taught her. The teaching must be in Dangme, patient, step-by-step, involve practice on her own phone, and include return visits for follow-up support.

Section 8. Peer Influence

SHF13 states she would be strongly influenced to learn immediately if she saw five women in her farmer group successfully using the app and their farms performing better. She emphasizes that success must be visible within her community—by people like her—before she believes a new technology is truly for them.

Section 9. Value Proposition

The app must clearly help her avoid major financial losses, citing a total loss of 400 cedis worth of tomatoes from unexpected rain two seasons prior. Accurate timing for pesticide spraying to avoid having the expensive chemicals washed away by rain is another key value proposition. The app should be free or subsidized by the government, as small women farmers cannot afford to pay for technology.

Section 10. Recommendations

Her ideal app would have a simple main screen with three big pictures showing today's and tomorrow's weather, and one piece of advice in Dangme. It requires a voice button for spoken explanations, must work offline (downloading once a week), and should be free with a simple button to call the Extension Officer for support.

RESPONDENT SHF14

Section 1. Current Weather Information Sources

SHF14 primarily relies on the highly accurate, local traditional forecaster who is her neighbor, having successfully farmed for 32 years by observing the sky. She also gathers information by sharing observations with her farming group and occasionally receiving calls from her children in Accra about severe weather heard on the radio. Her main source is trusted local observation and predictions.

Section 2. Language and Literacy Barriers

She requires a weather app that must speak to her in Dangme with a voice that gives actionable advice, as she cannot read any language. The interface must also use large, simple pictures instead of words, as technology is difficult for old, uneducated people. Even with these features, she anticipates needing someone to teach her many times to remember which buttons to press.

Section 3. Trust in Traditional vs. Scientific Knowledge

SHF14 100% trusts local forecasters predictions because she knows him and can see the signs he uses (wind, clouds), but she is skeptical of phone apps from an unknown source in a distant office like Accra. She would start believing the phone app only if a trusted figure, like an Extension Officer showed her that the app's information and local forecasters predictions agree.

Section 4. Structural Barriers

Major structural barriers are the inability to afford a smartphone (costing 800-1,000 cedis) and the cost of internet access needed for the app, which she would rather use for farm inputs. Face-to-face communication from the Extension Officer remains her preferred, most reliable information source.

Section 5. Communication Preferences

The best way to receive information is in-person with an Extension Officer at group meetings, as she speaks Dangme and can answer questions immediately. The second-best is radio in simple Dangme words, which she listens to every morning. Any smartphone app would require constant human support from the Extension Officer or a young educated farmer in her community.

Section 6. Learning and Support Needs

She requires a patient teacher who speaks Dangme and provides slow, repeated training in simple steps, as too many buttons confuse her. Learning must be done in a group setting so women can support each other without shame, and she needs nearby help (a village tech expert) to fix problems instantly. Finally, she needs proof that other similar farmers have already benefited before she invests her time learning.

Section 7. Perceived Value

The primary motivation is the financial savings realized by avoiding losses, specifically knowing exactly when to harvest pepper before rain spoils it. She also values the app for better planning of planting to save seeds/labor and determining the safe time to apply expensive fertilizer to prevent it from washing away.

RESPONDENT SHF15

Section 1. Current Weather Information Sources

SHF15 primarily relies on the highly trusted traditional forecaster who has never failed her in 30 years, and her own ability to read cloud patterns and the sea wind. While her daughter sometimes shares information heard on the radio, SHF15 trusts what she observes herself more. She is not familiar with phone apps as she cannot read or write and only knows how to receive calls.

Section 2. Language and Literacy Barriers

She would find an app useful only if it spoke to her in Dangme and gave clear, actionable advice rather than numbers or words to read. However, she would still check with a forecaster, as the phone is an unknown entity that doesn't know her farm or local area.

Section 3. Trust in Traditional Knowledge

SHF15 trusts a forecaster because she has a relationship with him, and his knowledge is based on wisdom tested over many generations in the Ada area. She would pay attention if the app combined the scientific forecast with traditional signs, showing respect for local knowledge.

Section 4. Support and Intermediaries

She needs the trusted Extension Officer to teach her slowly and patiently in the women's group setting. While her children can help at home, she cannot ask them every day, so the app must be simple, using few buttons and big pictures.

Section 5. Practical Constraints

Major constraints include sharing the phone with her children, not knowing how to manage internet data, and weak eyesight which makes small screen content difficult to see. Crucially, she works from 4 am until evening and does not have 30 minutes to struggle trying to understand a complicated app.

Section 6. Value and Benefits

The app's value lies in helping her avoid losses, such as the 500 cedis worth of tomatoes unexpected rain destroyed last year, and advising on the best planting days to save money on seeds and replanting. She suggests the app must prove its help and should maybe be offered free for the first season.

Section 7. Recommendations

Her ideal app must be very simple and immediately speak to her in Dangme with clear, actionable advice. It should also use big pictures to ensure understanding even without the voice and be supported by the Extension Service for teaching and problem-solving.

RESPONDENT SHF16

Section 1. Current Weather Information Sources

SHF16 has successfully relied for 34 years on traditional knowledge passed down from her father, which involves observing the sky, the sea wind, and animal behavior, and she trusts this 100%. She also listens to the local traditional forecaster, but finds the general radio forecast often wrong for their specific coastal area. The Extension Officer's information is trusted but is not provided regularly enough.

Section 2. Experience with Weather Apps

Her son showed her a weather app, but she finds it too difficult to use because she is illiterate and cannot read the English or even Dangme text. The screen contains too many confusing letters and numbers, and she fears touching the wrong button will spoil the expensive phone. She needs someone to read and explain the information to her in Dangme.

Section 3. Language and Literacy Barriers

For the app to be useful, it must be voice-first and speak to her in Dangme when she presses a single button, eliminating the need to read any words. It must use simple pictures and symbols that are universally understood by farmers, as pictures are a language everyone can read. The information must provide direct advice, not complex technical terms.

Section 4. Trust and Traditional Knowledge

SHF16 currently does not trust the app, as it is an abstract system from "Accra" that doesn't understand her local Ada weather or her farm. She would only consider trusting it if a trusted intermediary like Extension Officer verified the information. She stresses that the app should integrate traditional signs with the scientific forecast instead of trying to replace local forecast successful knowledge.

Section 5. Structural Barriers

She cannot afford a smartphone, and she finds internet data too expensive, which she would rather spend on farming. Furthermore, unreliable electricity and a weak, intermittent network connection make constant phone use for checking the weather highly impractical. These basic infrastructure problems must be solved before technology can work for her.

Section 6. Value Proposition

The app must help her avoid financial losses by accurately predicting rain to save her drying pepper from being spoiled. It must also help her time planting and fertilizer application to save on expensive inputs and labor. She is unwilling to pay a fee unless she can use the app free for several months to first prove its real-world benefit.

Section 7. Learning and Support Needs

She requires the Extension Officer to come to her women's group regularly for patient, slow teaching in Dangme, not just a single session. The learning should focus on simple steps using only 2 or 3 big buttons, with ongoing support available from the Extension Officer or a village tech expert. She also suggests sharing one phone among five women to help each other learn.

Section 8. Design Recommendations

The ideal app must be voice-first in Dangme upon pressing one button, providing today's weather and actionable advice with no reading required. The interface should have few pictorial buttons, and it must work offline due to poor network coverage. Designers need to understand that technology must be specifically designed for old, illiterate, but experienced women farmers.

RESPONDENT SHF17

Section 1. Current Weather Information Sources

SHF17 relies entirely on traditional knowledge passed down from her father, using nature's signs like the sea wind's smell, bird behavior, and cloud patterns, which have never failed her in 30 years. She also trusts the community forecaster, but is unable to use the radio due to the English language barrier. Her information is highly localized, experienced-based, and completely trusted.

Section 2. Awareness of Weather Apps

She has heard about weather apps from her children but does not have a suitable phone and believes she could not use one even if she did. This inability stems from her illiteracy, her weak eyesight, and her strong preference to trust the natural signs she already knows. She fears touching the wrong buttons and spoiling the device.

Section 3. Language and Literacy Barriers

Any technological system must speak to her in pure Dangme using simple farming terms, as reading is not an option and technical terms are confusing. She would need slow, patient teaching from a trusted person and an interface with large pictures to help her understand the advice.

Section 4. Trust and Intermediaries

SHF17 believes that for technology to succeed, it must first be translated and interpreted by trusted Extension Officers at group meetings. She would prefer a simple, free voice-based phone system she can call, as this requires no internet or reading, making the Extension Officer the critical human link to modern science.

Section 5. Future of Technology

She accepts that technology will always be difficult for older, illiterate farmers like herself, but she is not against progress and can try it if taught properly. She strongly suggests that the focus should be on teaching children and grandchildren early about digital farming tools in school. She confirms she would follow technology adoption if she saw clear benefits.

Section 6. Recommendations for Accessibility

Key recommendations include using trusted Extension Officers to interpret technology and offer ongoing support via a free voice-based phone number that speaks the forecast in Dangme. Any app must also use visual symbols that she can recognize without reading and must respect traditional knowledge.

RESPONDENT SHF18

Section 1. Current Weather Information & App Awareness

SHF18 primarily trusts the highly accurate, nature-based predictions from local elders like local forecaster and her own observations taught by her mother over 28 years. While she listens to the radio, she finds the English hard to understand, and she has never used the weather app her husband downloaded because she is illiterate. She currently only uses her phone for basic calls.

Section 2. Language & Communication Barriers

The core barrier is illiteracy, making all written apps impossible to use, combined with weak eyesight which struggles with small phone text. She needs an app that speaks to her in pure Dangme with a woman's voice, using simple farming terms instead of technical language. The interface must use large pictures and symbols to represent the weather advice.

Section 3. Trust in Traditional vs. Scientific Methods

SHF18 completely trusts local forecaster and her own traditional knowledge because they are local, proven, and she can see the signs herself. She is skeptical of technology from an unknown source and would only begin to trust the app if the Extension Officer verified the information or if the app itself incorporated traditional signs alongside the scientific forecast.

Section 4. Learning Preferences

She requires patient, group-based training from the Extension Officer, who must speak in Dangme and avoid making her feel shame for her illiteracy. Learning must be step-by-step and repeated over several sessions using a dedicated training phone, with ongoing support provided by the Extension Officer or a trained young person in her community.

Section 5. Structural Barriers

Major structural barriers include the high cost of smartphones and the unaffordability of internet data (which costs 30-40 cedis a month), which she would rather use for farm inputs. She also needs access to her own phone for farming information and a solution for the frequent power cuts that prevent charging.

Section 6. Value and Cost

She needs the app to provide a clear financial return, saving her from sudden rain that ruins drying crops or washes away expensive fertilizer. The app's benefits must be regular and significant—helping her make more money per season—to justify the cost of data and the effort of learning.

Section 7. Recommendations (Training & Support)

Training must be done by the Extension Officer who teaches patiently in Dangme and provides a practice phone. The Extension Service should also establish a link to local young people who can offer immediate, community-based technical support when the farmers run into problems.

Section 8. Recommendations (Technology & Government)

Developers must create a voice-first, picture-only version in Dangme that works offline. Government must support this by fixing electricity and network problems, subsidizing phones, and making data for farming apps free for women farmers who face extra barriers.

RESPONDENT SHF19

Section 1. Current Weather Information Sources

SHF19 primarily relies on the highly trusted traditional forecaster, who gives weekly predictions and has proven reliable. She also listens to the radio, but since it is in Twi, she does not fully understand it, and her phone only handles basic calls and SMS. Traditional, local, and word-of-mouth sources are her most reliable forms of information.

Section 2. Awareness of Weather Apps

She is aware that phone apps provide weather information but believes they are only for educated people with expensive phones. Since she only has a basic phone and cannot read or write, she views modern technology as inaccessible to her. She does not understand the mechanics of how the app works.

Section 3. Language and Literacy Barriers

Because she is completely illiterate, she cannot use any text-based app, even if it were in her native Dangme. Her ideal solution is a voice-based system in Dangme or a method where the Extension Officer uses simple pictures to convey the advice.

Section 4. Trust in Traditional Methods

SHF19 has complete trust in local forecaster because his knowledge is generational, tested over time, and he is a known local figure. She is skeptical of a phone app whose source is unknown, but she would consider it if it could combine scientific data with traditional signs that she and the local forecaster recognize.

5. Learning and Support Needs

She requires face-to-face training in a group setting from the Extension Officer, who must be patient and avoid making her feel shame for her illiteracy. The Extension Officer is the critical human link to technology, providing necessary ongoing support and interpretation.

Section 6. Perceived Value

The technology's value lies in preventing major losses by giving advance warning of rain, saving her from having seeds wash away or from losing drying crops. To justify the effort and potential cost, the app must prove its reliability and offer actionable, timely advice that directly improves her farming outcomes.

Section 7. Recommendations

SHF19 suggests alternatives to complex apps, such as a free voice-based phone number farmers can call or WhatsApp voice messages from the Extension Officer. She also recommends improving local radio broadcasts to be Ada-specific and ensuring that Extension Officers regularly bring and interpret the technology to the community.

RESPONDENT SHF20

Section 1. Current Weather Information Sources

SHF20 relies completely on traditional, nature-based methods taught by her mother and grandmother over 35 years. She also consults the traditional forecaster, before making major decisions like planting or harvesting. She trusts these observations more than the radio information her daughter sometimes shares.

Section 2. Awareness of Weather Apps

She is aware that young people use phone applications for weather but does not have a smartphone and sees the technology as confusing and unnecessary at her age. She emphasizes that she has farmed successfully for 35 years without a phone telling her the weather, concluding that traditional methods work fine for her.

Section 3. Language and Technology Barriers

The main challenge is illiteracy, which makes any app with text useless to her, even if written in Dangme. Furthermore, she fears the complicated buttons and processes of smartphones, and she notes that her weak eyesight makes viewing tiny text difficult.

Section 4. Trust in Traditional vs. Modern Forecasts

She currently places complete trust in a local forecaster and her own time-tested knowledge, finding the concept of a phone app predicting local weather to be foreign and less reliable. She would only consider trusting a modern system if it found a way to combine scientific information with her recognized traditional signs.

Section 5. Learning Preferences

If forced to learn, she would need patient, face-to-face instruction from a trusted human intermediary who speaks her language and can interpret the technology. She believes she is too old to learn complicated steps and would require simple, clear instructions tailored to her lack of literacy.

Section 6. Structural Barriers

The primary structural barrier is the high cost of smartphones, followed by the expense of internet data which she considers unaffordable. She also notes the challenge of frequent power cuts, which would leave any battery-dependent device useless when needed most.

Section 7. Perceived Value and Motivation

The motivation for adoption is purely financial, as accurate forecasts would save her money on damaged inputs and lost crops, citing a 600-cedi loss of drying pepper last month. Knowing exact rain timing would save on irrigation costs and ensure perfect planting, but the information must reach her in a usable way.

Section 8. Recommendations

The advice is to not forget illiterate, older farmers and to create communication methods that use human intermediaries like the Extension Officers who can explain things in Dangme. Developers must respect traditional knowledge by combining it with new science, making the Extension Officer the crucial bridge between technology and old farmers.

RESPONDENT SHF21

Section 1: Current Weather Information Sources

The respondent relies on the trusted local forecasters who are "very good at reading the weather" by observing the sky, wind, and animal behavior. She also uses personal observation from her many years of farming and occasionally listens to Twi radio news, though she doesn't fully understand it. She trusts local forecasters and her own eyes above all other sources.

Section 2: Awareness of Weather Apps

She has heard of weather apps from her children but does not own a smartphone and currently uses a simple phone only for calling and SMS. She is interested only if the app could speak to her in Dangme and use pictures due to her complete illiteracy. Learning would require patient, repeated teaching from a trusted source, as her memory is no longer sharp.

Section 3: Trust and Infrastructure Barriers

She distrusts the app because it is an unseen machine made by unknown people who might not understand local Ada weather, unlike the trusted local forecasters. Major practical barriers are the high cost of smartphones, the inability to afford monthly internet bundles, and unreliable network coverage in the farming area.

Section 4: Communication Needs and Learning Method

The app must be voice-based in Dangme, providing simple, actionable advice for farming (e.g., "plant today," "harvest tomorrow"). Learning must occur face-to-face in her women's group, led by the Extension Officer and involving multiple, slow sessions. Post-training support is vital, and the app must be simple enough to work without internet when needed.

Section 5: Perceived Value

The app's value lies in its ability to provide precise, long-term advice for planning planting and harvesting, which is superior to the traditional method of only predicting the next day. It must clearly save her money by preventing crop losses to justify the effort of learning. She suggests that basic weather information should be free for poor farmers like herself.

Section 6: Peer Influence

She would be most motivated to use the app if she saw other older women farmers in her group using it successfully to avoid losses and improve yields. She states that farmers learn best when they can see peers who look like them and share their challenges succeeding with the technology. Farmers follow each other, and success for one lead to interest for many.

Section 7: Final Recommendations

Developers must design for the non-literate, older farmer using voice in Dangme, and ensure the app is affordable or free. The technology must work with Extension Officers and respect traditional knowledge, proving its value over time with patience and continuous support. Behavior change takes time, and technology must adapt to the farmer.

RESPONDENT SHF22

Section 1: Current Weather Information Sources

The respondent relies on traditional forecasters, who watches the sea, clouds, and wind, a source she trusts most due to his long history of accurate predictions. She also shares observations with neighbors daily and occasionally receives information from her son via the radio. Her traditional sources have guided her for 34 years of farming.

Section 2: Language and Trust Barriers

The app was difficult because she cannot read English (or read slowly even if it were Dangme) and the app was full of words and confusing visual elements. She needs the app to talk to her in Dangme via voice messages, and she currently does not trust the app because she doesn't know its source, unlike trusted traditional forecasters. Trust would be built if the app could be verified against traditional knowledge.

Section 3: Structural Barriers

The high cost of a smartphone and the inability to afford monthly data bundles are major financial obstacles. Furthermore, unreliable electricity and weak network coverage at the farm are practical barriers that make using an internet-dependent technology challenging. She notes the lack of proper, available teaching from the Extension Officer is also a problem.

Section 4: Learning and Support Needs

Training must be face-to-face in her women's group, led by the Extension Officer and conducted slowly, repeatedly using their own phones and speaking only Dangme. She suggests a young woman in the group could be trained as an expert champion to provide continuous, local assistance to older women. She is skeptical she can learn due to her age and illiteracy, and she needs to see peers succeeding first.

Section 5: Value and Motivation

She would be motivated if the app could save her substantial money by helping her avoid crop losses due to unexpected weather. The app must be simple enough for an illiterate old woman, as she will continue with traditional methods if the learning effort is too high. She suggests the technology is likely meant for her children and grandchildren, not for her.

RESPONDENT SHF23

Section 1: Current Weather Information Sources

The respondent relies heavily on traditional forecasters who she says have been 9/10 correct over her 28 years of farming, and she shares observations with her women's farming group. She finds radio news confusing due to the English language and the lack of specificity to Ada weather.

Section 2: Experience with Weather Apps

She tried to use an app shown by her son but gave up quickly because it was in English and full of confusing numbers and unfamiliar pictures. The complexity of the screen and her fear of spoiling her son's phone contributed to her abandonment of the technology. The core barrier is her illiteracy, which prevents her from reading instructions and makes her forget quickly.

Section 3: Language and Trust Barriers

The app must speak to her in Dangme like a person and use simple farming-related words, avoiding complex English or Twi. She would only trust the app if it combined its data with traditional knowledge (e.g., showing the app's forecast alongside a traditional sign like a particular wind). She needs to see clear pictures of rain and sun, not just numbers.

Section 4: Structural and Literacy Barriers

Major structural barriers are her inability to read (even Twi or simple SMS), weak eyesight (letters are too small), and weak internet network coverage at the farm. Furthermore, she cannot afford the expensive smartphone or the monthly internet bundles from her small farm income. The lack of frequent, available support from the Extension Officer is also a significant barrier to learning.

Section 5: Preferred Learning Method

Learning must be face-to-face in her women's group, led by the Extension Officer or a trusted person who speaks Dangme. The teaching must be done slowly and repeatedly over multiple sessions, focusing on pictures and voice rather than reading. The group would benefit from a shared phone for practice, along with farm visits to check understanding.

Section 6: Value and Willingness to Pay

She cannot afford to pay for an app unless it saves her money by preventing crop losses (e.g., warning her before a storm or helping her plant at the optimal time). She would only try it if it were free and she saw other women in her group using it successfully to prove its value. She suggests basic weather information should be a free public service.

Recommendations

Apps must speak in Dangme, be free, use clear pictures, and work without internet when necessary. Crucially, they require patient, repeated teaching by trusted people and must demonstrate respect for traditional knowledge by combining it with the scientific data.

RESPONDENT SHF24

Section 1: Current Weather Information Sources

The respondent relies on the traditional forecaster, who watch the sea, wind, and crabs to predict weather, a method trusted for over 34 years. She also shares observations with other women farmers and occasionally receives storm warnings from her son via the radio. These traditional and peer sources are her main guides for farming decisions.

Section 2: Language and Literacy Barriers

She cannot use the weather apps on the smartphone her children bought her because she cannot read any language (English, Twi, etc.), and the phone speaks English. The apps have too many words and things to press, confusing her, and her weak eyesight makes small letters difficult to see even with glasses. For utility, the app must speak in Dangme or use big, clear pictures of weather conditions.

Section 3: Structural Barriers

Although she owns a smartphone, the primary structural barriers are the weak network coverage on her farm and the unreliable electricity in her community (up to two days without power) which prevents her from charging the phone. She also notes the high cost of monthly internet bundles, which she cannot afford from her small, irregular income.

Section 4: Trust in Traditional vs. Scientific Forecasts

She does not trust the app more than her traditional forecaster, who has never failed her and understands the specific local weather. She acknowledges the app could be helpful if it were proven, but would only trust it if she saw it accurately predict rain three or four times. Building trust requires the app to respect, or even combine its data with, traditional knowledge.

Section 5: Learning and Support Needs

Learning must be patient, hands-on, and repeated by a trusted person like the Extension Officer, who would teach her women's group in Dangme over multiple sessions. She needs a local support system—a trained champion in the village or a patient younger person—to help her when she forgets or the phone malfunctions. She needs the app to be simple enough to avoid the fear of breaking the expensive phone.

Section 6: Perceived Value and Benefits

The app must provide clear and significant benefits to justify the effort of learning new technology at her age, such as saving money by preventing crop damage from unexpected rain or optimizing planting time. It must help her know exactly when to plant to avoid seed waste, or warn her before a big rain so she can protect her tomatoes or dried crops.

Section 7: Community Dynamics

She would be most encouraged to use the app if she saw five or six women farmers in her group using it successfully, as farmers follow each other when something works. Currently, she knows no one her age using weather apps successfully, so she needs to see local peers succeeding and willing to teach others. Seeing people like her achieve results would build collective motivation and trust in the technology.

Section 8: Recommendations

The government should subsidize phones and provide free/cheap data for farmers, and the app must be redesigned to be voice-first in Dangme with simple pictures for non-literate users. The most critical need is for patient, repeated training from trusted people like the Extension Officer and for the app to demonstrate clear, superior benefits over traditional methods.

RESPONDENT SHF25

Section 1: Current Weather Information Sources

The respondent does not use any modern sources, relying entirely on personal observation (sky, clouds, wind) and the trusted announcements of the community forecaster. She explicitly states she trusts what she sees and local forecaster more than what her husband relays from the radio.

Section 2: Barriers to Technology Adoption

The biggest barrier is illiteracy (cannot read English or Dangme), making any app with writing useless to her, alongside the difficulty of using complicated phones and her inability to afford monthly internet bundles. Fundamentally, she has a lack of trust in an unseen phone app over the proven, accessible traditional forecaster.

Section 3: Trust and Traditional Knowledge

She will not trust a phone app more than traditional forecaster because he knows the local, specific weather of the Ada area, while the app is made by unknown people who might not. Trust would only be built if the app could be seen to work successfully for her neighbors and if it respected her traditional knowledge instead of demanding she forget her elders' teachings.

Section 4: Language and Communication Needs

Due to her illiteracy, the app must speak in Dangme via voice messages and rely on simple pictures or symbols (e.g., a dark cloud for rain) rather than text. The messages should be actionable and clear, using familiar words like "time to plant" or "danger, rain coming," and she needs to be able to repeat the voice note to understand fully.

Section 5: Learning and Support Needs

Learning must be conducted by a trusted intermediary, like the Extension Officer, in small groups of women farmers over multiple, slow sessions in the local language (Dangme). She requires continuous support from a local "champion" or helpline after training, as she forgets quickly and gets easily confused by the technology.

Section 6: Perceived Value

The app's value must be proven by helping her avoid crop losses, specifically saving money on her pepper farm from unexpected rain or storm damage, which is a common disaster. It should also optimize her planting time, saving money and labor by preventing seed waste. The benefits must be clear and quantifiable to justify the cost and effort.

Section 7: Structural Barriers

The high cost of a smartphone and the inability to afford monthly internet bundles are major financial barriers she cannot overcome with her small income. Other issues include unreliable electricity (making charging difficult) and weak network coverage in the farming areas where the information is needed most.

Section 8: Recommendations

Developers should design the technology for non-literate, older women using voice in Dangme, simple pictures, and minimal navigation. The government or NGOs must subsidize phones and internet for farmers to make the technology affordable. Finally, there must be proof it works (via free trials for neighbors) and continuous training and support provided through women's groups.

RESPONDENT SHF26

Section 1: Current Weather Information Sources

The respondent relies on personal observation (watching sky, clouds, wind) learned from her mother 40 years ago and information shared by her husband and co-farmers. Her grandson translates occasional radio news into Dangme, as she doesn't understand English or Twi well. These traditional sources are trusted and have been the main guide for her farming career.

Section 2: Barriers to Adoption

She cannot afford the expensive smartphone and she cannot read written apps, making them useless. Furthermore, she finds the technology too complicated (forgets instruction quickly, screens and buttons confuse her) and believes the phones are designed for young, educated people, not older, non-literate women. She cites poor eyesight and slow finger movement as additional physical barriers.

Section 3: Trust and Traditional Knowledge

She has high trust in traditional methods because they are local, proven over many years, and traditional forecaster is accessible in the community. She would not trust a phone app more than the traditional forecaster or her own experience, as the app is a distant "machine" whose sources are unknown. Trust would be established if the app were to accurately predict rain three or four times, showing it understands the specific local weather.

Section 4: Language and Communication Needs

The app must provide all information using voice in Dangme and simple pictures or symbols, as she cannot read or write any language. The messages must be simple, actionable advice like "wait two days to plant" rather than confusing scientific numbers. She needs the ability to repeat the voice message (like a voice note) so she can listen until she fully understands the instruction.

Section 5: Infrastructure Challenges

The high cost of the smartphone and the recurring expense of monthly data bundles are the primary financial barriers. Infrastructure challenges include weak network coverage on the farm and unreliable electricity which prevents charging the phone. She also lacks the technical knowledge to fix problems like the phone freezing, requiring assistance from her grandson.

Section 6: Learning and Support Needs

She requires patient, hands-on, repeated teaching from a trusted person who speaks Dangme, such as the Extension Officer or a young farmer champion trained in the village. Training must be done in small groups of women farmers, over multiple sessions (at least four), and must allow continuous, local support after the initial training to solve unexpected problems.

Section 7: Perceived Value

The app's value must be proven by helping her avoid financial losses, on her drying tomatoes farm from unexpected rain. It must also save her money by indicating the best time to plant to avoid seed wastage. The benefits must be clear, immediate, and significant enough to justify the effort of learning the complicated new technology at her age.

Section 8: Closing Reflections

The respondent believes weather apps are currently only suitable for young and educated people unless they are drastically simplified with voice in Dangme. She is not against technology if it truly helps her farming, but it requires subsidized phones, free/cheap data, and patient, repeated teaching. She sees her grandson as a potential "bridge" between her and the technology.

RESPONDENT SHF27

Section 1: Current Weather Information Sources

The respondent primarily relies on personal observation of nature, watching the sky, clouds, and wind, a skill learned from her father over 35 years of farming. She also trusts the local traditional forecaster. These traditional sources are considered very reliable and have "never truly failed" her, though timing might be off by a day.

Section 2: Awareness of Weather Apps

She has heard of weather "apps" from her grandson but does not own a smartphone because it's too expensive, using a simple phone only for calling and mobile money. She expressed interest only if the technology could speak in Dangme and tell her simple, actionable things, noting that without patient, repeated instruction from someone like an Extension Officer, she cannot learn these modern things alone.

Section 3: Language and Communication Barriers

All information must be delivered in spoken Dangme (not written, as she is non-literate even in Dangme) and should use simple, farming-specific words like "plant now" or "harvest before rain". She suggested using pictures and simple symbols (e.g., dark clouds for heavy rain, sun for hot weather) as these communicate effectively with everyone, including non-readers.

Section 4: Trust in Traditional vs. Scientific Knowledge

The respondent does not trust the phone because she cannot see or understand who is behind it, and she doubts they understand the specific weather patterns of the Ada coastal area like her trusted neighbor, the local forecaster. Trust would increase if the app showed respect for traditional signs and actively combined traditional knowledge with scientific forecasts, indicating the technology is "adding to our knowledge, not replacing it".

Section 5: Digital Literacy Barriers

Her main challenges are illiteracy (cannot read or write in any language) and lack of prior experience with smartphones, knowing only how to answer calls on her simple phone. Other barriers include weak eyesight (small screens/buttons are hard to see) and a fear of breaking the expensive device by pressing the wrong thing, emphasizing that she needs patient, sustained teaching and local support.

Section 6: Structural Barriers

The most significant practical barriers are cost (she cannot afford the 500-1,000 cedis for a smartphone or the recurring data bundles) and unreliable infrastructure (frequent, long power cuts prevent charging, and there's no network on her inland farm plot where the information is needed). She would rather spend her small, regular income on farm inputs or grandchildren's school fees.

Section 7: Trusted Intermediaries and Learning Preferences

She trusts Extension Officers to teach her because the extension officer has worked with the women farmers for years, speaks Dangme perfectly, and understands their challenges. Training should be done in small groups of women farmers (10-15), led by the Extension Officer in Dangme, with multiple, slow sessions (e.g., weekly for a month) involving practice on actual phones.

Section 8: Perceived Value and Benefits

The app must demonstrably help her avoid financial losses by warning her of sudden rain (e.g., saving 300 cedis worth of drying pepper) or damage from storms. It should also help optimize timing for planting (avoiding seed waste from too little or too much rain) and harvesting (getting better market prices). The benefits must be clear, real, and quantifiable in terms of cedis saved or earned.

Section 9: Recommendations

The respondent advises creators to design the app for non-literate, older farmers like herself, making it speak Dangme and use voice, pictures, and simple symbols. It must be affordable or free and should respect traditional knowledge, showing how it can work together with science. Finally, she stresses the need for proper, sustained teaching by trusted people like Extension Officers and patient young farmers, not just posters or radio announcements.

RESPONDENT SHF28

Section 1: Current Weather Information Sources

The respondent primarily uses traditional methods learned from their mother, such as observing the morning sky, the wind from the ocean, and seabirds flying inland· They also rely on the announcements of the traditional forecaster and occasionally hear radio news radio.

Section 2: Experience with Weather Apps

The respondent's son attempted to show her a weather app, but she couldn't use it because everything was in English and she cannot read· The phone screen was confusing (too many elements, colors), the teaching time was too short (30 minutes), and she quickly gave up on her own attempts· She was also afraid of spoiling the expensive phone by pressing the wrong button.

Section 3: Language and Communication Barriers

The app must speak to her in Dangme via recorded voice messages, as writing is useless due to illiteracy· The interface needs to be simple (e.g., 2-3 big buttons) and should rely on pictures (rain cloud, sun) to communicate forecasts and warnings. The voice messages should be actionable, providing specific farming advice like, "harvest your pepper today".

Section 4: Trust and Traditional Knowledge

The respondent does not completely trust the phone app because it is made by distant people who don't know the local weather. Trust would increase if the app combined scientific and traditional signs, or if a trusted people like Extension Officers recommended it. She needs to see other women farmers in her cooperative successfully using the app and getting good results before she will want to learn it.

Section 5: Digital Literacy Challenges

Illiteracy is a major barrier, making all written text useless; other difficulties include weak eyesight, screen unresponsiveness to rough farm-work fingers, and confusion with navigation (swipe/press/hold). They face a fear of breaking the expensive device and lack the knowledge to fix problems when something goes wrong.

Section 6: Infrastructure Barriers

The respondent cannot afford a smartphone or the expense of monthly data bundles. Network is very unreliable in the area, and they face frequent, long electricity cuts (up to two days) which prevent phone charging. She only has access to a phone when her son visits, as it belongs to him.

Section 7: Preferred Learning Method

Training must be delivered by the Extension Officers at the women's cooperative meeting, slowly and repeatedly (4-5 sessions). Instruction should be in Dangme language only and include practical examples related to their actual farming activities. Post-training support is necessary, either via a helpline number or by training 2-3 younger women within the group to assist the others.

Section 8: Perceived Value

The app must clearly help them save money by preventing crop damage from unexpected weather, such as knowing when to plant, harvest, or protect dried produce. The benefits must be clear, real, and measurable, showing exactly how much money will be saved or earned.

Section 9: Recommendations

Developers should visit the farm to understand farmers' work and challenges, making apps that speak in local languages (Dangme, Twi, Ga) using voice and pictures. The most crucial recommendations are to provide proper, patient training by trusted Extension Officers and continuous support until they can use the technology properly.

ANALYSED FINDINGS FROM EXTENTION OFFICERS:

RESPONDENT EO1

Section 1. Role and Current Weather Information Dissemination

The Extension Officer acts as the critical bridge, translating scientific weather bulletins into actionable advice for farmers via weekly meetings and WhatsApp groups. The role is severely hindered by limited resources and the bulletins' lack of hyper-local accuracy for places like Ada.

Section 2. Awareness and Experience with Weather Apps

EO1 is familiar with several apps, including FSapp and general weather tools, but attempts to introduce them to farmers resulted in a disappointing sustained usage rate of only 10-15% after one month. The primary issue is that apps are not designed for the farmers' reality, featuring English interfaces, technical terms, and high data usage.

Section 3. Language and Communication Barriers

The barriers start with the severe linguistic gap but deepen with the semantic gap between meteorological data and necessary decision support. Farmers struggle with visual literacy—interpreting graphs and probability percentages—and prefer concrete, binary information, leading to cognitive overload from excessive, irrelevant data.

Section 4. Trust and Indigenous Knowledge Integration

Farmers maintain deep skepticism of scientific forecasts that contradict their highly trusted traditional knowledge, which has been validated over generations. EO1 builds trust by integrating and referencing both systems in communication; apps that ignore local forecasters lack social credibility. Successful apps must explicitly integrate and validate indigenous indicators to enhance, not replace, local knowledge.

Section 5. Digital Literacy and Support Gaps

While farmers can manage phones for calls and WhatsApp due to repeated practice, they struggle with interface navigation and lack the troubleshooting capacity when apps crash or show errors. The critical need is for a comprehensive support system: Extension Officers must be trained on digital tools, and apps must be designed for low-literacy users with voice-first interfaces and minimal text.

Section 6. Infrastructure and Institutional Constraints

The biggest structural barrier is weak, intermittent network connectivity in inland communities, which makes real-time apps useless, necessitating offline functionality. High data costs present an economic burden, as farmers are hesitant to pay for unproven value, and institutional coordination is terrible among key stakeholders.

Section 7. Role as Trusted Intermediary

The Extension Officer's role is absolutely critical for technology adoption because their long-term, trusted relationship with the community overcomes the skepticism towards mass media. Face-to-face demonstration during group meetings is the most effective channel for interactive learning, which is sustained by ongoing troubleshooting support.

Section 8. Recommendations for Improvement

App developers should co-design with farmers, offer full multilingual voice narration, provide decision support, and ensure hyper-local accuracy with offline functionality. Extension Services require digital agriculture training, tablets, and data allowances to formally support these tools, while the Government must invest in rural internet and offer data subsidies.

RESPONDENT EO2

Section 1. Role and Current Communication Practices

The Extension Officer (EO2) serves as the primary link for sharing improved farming techniques, pest advice, and weather information, which involves community visits, field demonstrations, and managing five WhatsApp groups for farmers. EO2 receives weekly and seasonal forecasts from the Ghana Meteorological Agency, which are communicated face-to-face and via SMS/community radio, but the raw data is often late, technical, and lacks the specificity farmers need.

Section 2. Experience with Weather Apps

Barriers exist at multiple levels, starting with language barriers and farmers' limited digital literacy for navigating complex app features. Trust issues are massive, especially after an incident where an app's inaccurate forecast led to crop losses, confirming farmers' reliance on traditional forecasting.

Section 3. Communication Strategy Effectiveness

Successful technology adoption requires a multi-stage, relationship-based communication approach built on established trust. EO2 finds that demonstration over description is crucial, requiring farmers to see the tool working and verify the predictions, followed by hands-on training and peer learning in groups. The strategy culminates in identifying and intensively training champion farmers who become local trainers, multiplying the officer's impact and providing continuous support via group chats and regular follow-up visits.

Section 4. Indigenous Knowledge Integration

EO2 successfully navigates the relationship by framing scientific forecasts as complementary to, not superior to, traditional knowledge, always acknowledging the value of local expertise. This approach teaches farmers a hybrid decision-making model—trusting local knowledge for immediate decisions and scientific forecasts for seasonal planning—which has built confidence in both systems.

Section 5. Systemic Challenges and Support Needs

The Extension Service is hampered by heavy workload (450 farmers across 12 communities) and a lack of systematic digital agriculture training for officers, who learn on their own. Officers lack basic resources like tablets and data allowances for demonstrations, and there is no technical support system from app developers for troubleshooting.

Section 6. Recommendations

EO2's recommendations prioritize systemic support starting with App Developers, who must co-design with EOs, integrate Dangme language and traditional indicators, and focus on decision support with offline functionality. The Government must address the biggest external barriers by investing in rural internet and subsidizing data costs for agricultural apps, ensuring long-term, coordinated support.

RESPONDENT EO3

Section 1. Role and Experience with Weather Information Services

The Extension Officer (EO3) translates technical Ghana Met Agency forecasts into actionable advice for farmers in the specific context of Ada (e.g., explaining '15mm precipitation' as 'moderate rain good for planting'). Serving about 250 farmers across eight communities, EO3 relies on group meetings, calls, and WhatsApp to disseminate information.

Section 2. Farmer Barriers and Communication Challenges

EO3 identifies five major barriers, including language and, digital literacy gaps, and a trust deficit where impersonal apps lack the social credibility of traditional forecasters. Infrastructure problems and the lack of institutional support for Extension Officers to promote digital tools further compound these issues.

Section 3. Communication Strategies and Intermediary Role

EO3 views the role as a translator and cultural bridge, repackaging technical forecasts into contextualized, actionable advice (e.g., 'Harvest before Thursday') and delivering it via local language WhatsApp voice messages. Trust is built over six years by being consistent, honest about uncertainties, and validating traditional knowledge by explicitly aligning scientific forecasts with traditional signs.

Section 4. Perspectives on Weather App Design and Features

Apps require a fundamental redesign centered on the farmer, prioritizing an Extension Officer portal for managing farmer data and targeted advisories. Essential features include true multilingual support and a voice-first design for low-literacy users, with offline functionality. Apps must provide decision support, crop-specific advisories, and integrate traditional knowledge alongside scientific forecasts to build trust.

Section 5. Institutional and Systemic Issues

The extension system needs modernization by creating an official digital agriculture mandate and providing resource allocation to EOs, including tablets, data allowances, and training materials. Formal coordination mechanisms are needed between the Met Agency, app developers, and extension services, along with gender-sensitive approaches like recruiting more women Extension Officers.

Section 6. Success Stories and Best Practices

EO3 shares a success story with a small women-only farmer group (15 members) where intensive support—three training sessions and two months of weekly follow-up—resulted in a high adoption rate (12/15). Farmers reported success, including avoiding a 300 cedis loss by using the app to predict rain.

Section 7. Recommendations

For App Developers, the recommendation is to co-design with EOs, prioritize simplicity, and build EO portals. The Extension Service must officially integrate and equip officers with resources and training, while the Government must invest in rural digital infrastructure and subsidize data for registered farmers.

RESPONDENT EO4

Section 1: Role as Communication Intermediary

The Extension Officer (EO4) relies on face-to-face meetings with visual aids as the most effective channel, complemented by WhatsApp voice messages for urgent alerts. During meetings, EO4 shows weather maps on a tablet and relates scientific forecasts to traditional signs to build farmer trust and ensure understanding.

Section 2: Barriers to Adoption

App adoption is hindered by low digital literacy and major infrastructural problems like high data costs, poor network coverage, and inconsistent power. A trust deficit exists because impersonal apps lack the social credibility of traditional forecasters, and they often fail to provide crop-specific, actionable advice.

Section 3: Effective Strategies and Intermediary Role

The EO is a crucial, trusted intermediary upon whom farmers rely for personal, contextualized relationships over technology. Effective adoption requires a champion farmer model to train peer leaders and evidence-based promotion using success stories to demonstrate clear value.

Section 4: App Design and Feature Recommendations

Apps must be co-designed with EOs and farmers, prioritizing simplicity and including an Extension Officer Portal for managing farmer data and targeted advisories. Essential features are Dangme language support with voice narration for low-literacy users, and the provision of decision support over raw meteorological data.

Section 5: Policy Recommendations

Policymakers must invest in rural digital infrastructure (internet/electricity) and reform the extension system to formally include a digital mandate, providing training and equipment to EOs. It is critical to establish coordination mechanisms between all stakeholders (Met Service, Ministry, Developers, Telecoms) under a unified national strategy.

RESPONDENT EO5

Section 1. Role and Current Communication Practices

Extension Officers act as the critical bridge, translating technical, generalized Ghana Met Agency forecasts into actionable, contextualized advice using face-to-face meetings, calls, and WhatsApp voice messages. They are severely under-resourced with limited equipment, leading to an unsustainable workload that prevents regular reach to all farmers.

Section 2. App Experience and Adoption Barriers

Sustained app usage is extremely low due to severe linguistic barriers, low digital literacy, and high data costs. Apps fail because they provide raw meteorological data instead of the required decision support and lack the offline functionality essential for poor network areas. The officers' job descriptions do not formally include digital tool training, leaving them without resources or institutional support.

Section 3. Trust, Indigenous Knowledge, and Strategies

The EO is the crucial, trusted intermediary whose long-term relationship overcomes the trust deficit toward impersonal technology and builds credibility. Effective strategy involves validating and integrating traditional knowledge and using the champion farmer model for peer training. This relationship-based, hands-on training is highly effective but consumes an unsustainable amount of EO time.

Section 4. App Design and Feature Recommendations

Apps must be co-designed with EOs, should include an EO Portal for targeted advisories, and must prioritize a voice-first design for low-literacy users. Essential features are full multilingual support, integration of traditional knowledge, and clear crop-specific decision support over raw metrics. All EOs demand offline functionality, simplicity, and proper technical support systems like local helplines.

Section 5. Systemic, Institutional, and Policy Constraints

The system is crippled by poor rural infrastructure (network/power) and the lack of institutional support for EOs, who are neither trained nor equipped with tablets or data allowances. Reform requires the Government to invest in rural digital infrastructure and subsidize data for agricultural apps to overcome cost barriers.

ANALYSED FINDINGS FROM WEATHER APP DEVELOPERS:

RESPONDENT WAD1

Section 1: App Development Philosophy and Process

Initial assumptions that farmers needed accurate forecasts, Twi/English coverage, or that scientific data builds trust were proven wrong; farmers need actionable advice, more local languages (like Dangme), and trust built on social relationships. This realization forced major redesigns, acknowledging that social media literacy does not translate to complex agricultural apps.

Section 2: Communication Strategy and Design Decisions

FSapp addresses literacy with multimodal communication (voice messages, visual symbols, color coding) and has expanded language support beyond Twi and English to include Dagbani, with Dangme in development. Credibility is built by showing visual confidence levels, recognizing that farmers are sophisticated risk managers who need honest assessments of uncertainty to guide their decisions.

Section 3: Indigenous Knowledge Integration

Despite initial scientific team controversy, the app integrated traditional knowledge due to overwhelming farmer feedback, recognizing they wanted both systems. FSapp uses Convergent Validation to highlight alignment between scientific forecasts and traditional indicators and has a section for educational integration explaining the science behind traditional signs.

Section 4: Technical and Infrastructure Challenges

Infrastructure is the biggest technical barrier, with poor 2G/intermittent 3G connectivity requiring the app to be optimized to a small size (12MB) and minimal data downloads. A robust offline mode allows users to download a week's forecast once, but supporting low-spec devices and tackling battery drain are constant technical trade-offs.

Section 5: User Adoption and Engagement Patterns

Out of 47,000 downloads, only 18,000 (38%) are monthly active users, and the most critical problem is that 60% of users abandon the app within the first two weeks. Post-installation surveys show that communication failures account for the majority of abandonment reasons, followed by technical issues. Usage is minimal during off-seasons, peaking during planting/harvest, with users seeking quick information during short (2-3 minute) morning sessions.

Section 6: Extension Services and Intermediary Partnerships

The formal partnership with the Extension Service is critical but inconsistent, as most officers lack digital literacy, resources (data/equipment). The successful model identifies and supports 40 'champion' Extension Officers, whose districts show 3-4x higher adoption rates. Partnerships with Farmer-Based Organizations (FBOs) also show high adoption (60-70%), demonstrating that the app needs human intermediaries and scaled FBO leadership training to build trust and peer support.

Section 7: Design Lessons and Failures

FSapp learned from failures that farmers want practical tools, not redundant features like a social networking forum (as they use WhatsApp). Key lessons include avoiding English-first development and developing multilingually from the start, simplifying the app and recognizing that mass media creates awareness but face-to-face training is required for actual adoption.

Section 8: Developer Perspective on Farmer Barriers

The developer ranks Communication Design Failure as the most critical barrier, fundamentally recognizing it as their failure to deliver "farmer-actionable wisdom". The developer concludes that technology designers often unconsciously embed urban assumptions into the product, and true success requires farmers to be co-designers from conception.

Section 9: Recommendations for Communication Strategy Improvement

Developers should embrace radical simplification, voice-first design, and offline-default operation, using action-oriented language developed in native languages from the start. Extension Services require mandatory digital support in job descriptions, intensive, multi-session training, and digital learning centers with incentives for officers.

RESPONDENT WAD2

Section 1: Background and Development Philosophy

The initial technology-centered design focused on scientific accuracy, but this approach failed to drive adoption, as technical excellence does not equal user uptake. The development team is now shifting to user-centered design, recognizing a huge gap between their assumptions and the farmers' actual needs for decision support.

Section 2: Communication Challenges and Language Barriers

Massive language barriers arose from an English-only launch and Twi translations that were technically correct but agriculturally nonsensical, necessitating consultation with extension officers. For low literacy, the team is moving away from a text-heavy design towards a voice-first interface and culturally appropriate visual indicators instead of percentages.

Section 3: Trust and Credibility Issues

The app faces a major credibility gap because the developer initially tried to position the scientific app as superior to the farmers' deeply trusted traditional forecasting methods, which alienated the user base. The approach shifted to exploring authentic integration of indigenous knowledge, showing traditional signs alongside scientific data, and being transparent about forecast accuracy and errors to build trust.

Section 4: User Experience and Interface Design

The initial interface caused cognitive overload by displaying excessive data on one screen, forcing the developer to simplify the main view to only three key pieces of information. Interface conventions like swiping are foreign to many users, making navigation tricky, and the app must be optimized to work reliably on low-spec budget smartphones with limited memory.

Section 5: Structural Barriers and Infrastructure Constraints

Internet connectivity is the "killer issue" due to unreliable, intermittent rural 2G/3G, necessitating a robust offline caching feature for weekly forecasts that still requires optimization for updates. Device limitations pose technical challenges, requiring the app to be small (under 20MB) and optimized to minimize battery drain and data-intensive graphics on low-spec phones.

Section 6: Feedback and Iterative Development

The developer shifted from passive user reviews to proactive feedback mechanisms, including in-app surveys, quarterly field visits to observe real-context usage, and running a WhatsApp user community. A key ongoing challenge is understanding the reasons for abandonment among non-adopters who are outside their current feedback systems.

Section 7: Business Model and Sustainability

The current business model offers basic features for free and charges a premium subscription (10 cedis/month) for advanced advisories, but only about 3% of users upgrade, making subscriptions unsustainable. The company is exploring alternative revenue streams, including B2B partnerships for anonymized data sales, input company sponsorships, and insurance integration.

Section 8: Integration with Agricultural Extension System

Extension Services are absolutely critical as the key communication bridge for app adoption, proving that expecting farmers to find the app alone does not work. Effective partnership involves training EOs to demonstrate the app, giving them premium accounts, and providing a dashboard for targeted farmer support and co-branding.

Section 9: Lessons Learned and Development Recommendations

Developers must start with farmers, not technology, embracing participatory design to understand decision-making processes and prioritizing simplicity over comprehensiveness. Key lessons include recognizing that communication design is as important as technical accuracy, and apps must respect and integrate traditional knowledge systems instead of competing with them.

RESPONDENT WAD3

Section 1: App Development Philosophy and Target Users

FarmWeather Ghana was founded on the realization that existing apps were useless for farming decisions, lacking the necessary actionable guidance to prevent crop loss. The app pulls forecasts from multiple sources and uses algorithms to translate complex data (e.g., '15mm rainfall') into specific advisories (e.g., 'Good conditions for spraying pesticides today').

Section 2: Core Communication Gaps

The developer admits the initial focus on technical accuracy over communication design was a failure, resulting in an app that delivered data but not actionable wisdom. The primary gap is that farmers need decision support ('Is it safe to plant?') in local languages, not raw meteorological jargon, which demands a shift to a voice-first, simplicity-over-features approach.

Section 3: User Interface and Experience Lessons

The core lesson is that less is more: the app must avoid cognitive overload by displaying only three critical pieces of information per screen, and avoid complex features like graphs or social forums. The app must be designed for the reality of low-spec phones and weak connectivity, necessitating a robust offline mode and simple interfaces that minimize data usage.

Section 4: Barriers and Systemic Issues

The developer identifies four critical barriers: Trust Deficit, Communication Design Failure, Digital Literacy Gaps, and severe Infrastructure Inadequacy. These issues are compounded by the fact that developers unconsciously embed urban assumptions into the design, failing to account for the constraints of the rural agricultural context.

Section 5: Recommendations for Success

Developers must co-design with farmers, prioritize simplicity over features, and use a voice-first design with full local language support, while integrating indigenous knowledge for credibility. Ultimately, success requires a patient, persistent, and collaborative ecosystem approach that measures impact over vanity metrics.