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Determinants of smallholder maize farmers' access to weather information services: The role of socioeconomic and institutional factors in Ghana

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Abstract
The study evaluated the types of weather information smallholder maize farmers can access and the socio-economic and institutional factors affecting their ability to access them in the Northern Region of Ghana. The study used a mixed-method research design involving a combination of qualitative and quantitative methods. The population consisted of all the maize farmers in Mion municipality. A sample of 400 smallholder maize farmers was selected and determined using Cochran's sample size determination formula. Structured questionnaires were used for the quantitative data collection, while Focus Group Discussions and Key Informant Interviews were used for the qualitative data collection. The quantitative data were analysed using inferential statistics such as cross tabulation, bivariate factor analysis and bivariate probit regression model with the help of SPSS (version 27). Content analysis was then used to analyse the qualitative data. The findings showed that smallholder maize farmers in the study area have access to information on rainfall amount and distribution, temperature forecasts, wind speed and direction, onset and cessation of rain, seasonal forecasts, weather warnings, and other weather information. Bivariate regression analysis also indicated that knowledge of and use of weather information, reliability of weather information, input/output prices, and soil fertility management are significant factors influencing smallholder maize farmers' access to weather information in the study area. The study recommends that government and agricultural extension services should focus on spreading the identified forms of weather information to all maize farmers using mobile messages and local radio stations, as they form an essential part of farmers' decision-making. Furthermore, the capacity of farmers, especially elderly farmers, to access critical weather information and to make informed decisions on farming activities should be strengthened through training that should be supported by the Ministry of Agriculture and NGOs.

Keywords: Accessibility, weather information services, smallholders, maize farmers.

Introduction
Climate variability is one of the most threatening challenges of today's agricultural systems, especially for smallholder farmers who rely on weather-dependent production systems. Increased frequency of temperature changes, rainfall variability, drought, floods, and other climate change and variability-related hazards have increased production risks and reduced agricultural stability (IPCC, 2014; Porter and Magretta, 2014) [51]. Researchers have shown that climate change has negatively affected the productivity of agriculture worldwide, with an estimated loss of production of 1-5% per decade over the last 30 years (Porter and Magretta, 2014) [51]. In addition to crop losses, 2018 saw climate-related disasters cost the world some USD 225 billion in economic losses, of which floods and droughts were the biggest contributors (Arora, 2019) [13]. Weather and climate information services have thus become important tools to support agricultural decision-making because of these challenges. Weather forecasts are used at a time and in a way that can help the farmer make decisions about planting dates, when and how to apply inputs, when to irrigate, and when to harvest, which helps to minimise production risks and enhance farm management (Hansen, Pedersen, Peeters, Le Moullec, Albon, Herfindal, Sæther, Grotan & Aanes, 2019) [33]. Weather information is not just about the forecast information but also agronomic information that farmers can easily interpret and utilise in their individual farming practices (Dilling and Lemos, 2011a; Muema, Mburu, Coulibaly, & Mutune, 2018) [28, 45]. However, worldwide

examples demonstrate that the value of weather information is highly sensitive to farmers' ability to access, understand, and effectively use the information. One of the largest challenges for smallholder farmers in many developing countries is the lack of access to climate information (Dinku, Thomson, Cousin, del Corral, Ceccato, Hansen, & Connor, 2018; Street, 2016) [29, 60].

Other studies have found that the effectiveness of a weather information service is not just a function of scientific information but also the trust in the information source, previous farming experience, personal beliefs, and perceived climate risks (Arbuckle, 2015) [11]. Dissemination techniques have been employed across different countries; these include radio, television, extension services, face-to-face communication, mobile phones and digital platforms and farmers' preferences have been found to differ by gender and age (Cherotich, Saidu, & Bebe, 2012; Churi, Mlozi, Tumbo, & Casmir, 2012; Haworth, 2018) [23, 25, 34]. Africa is one of the areas in the world with a high vulnerability to climate variability due to its reliance on rain-fed agriculture, lack of irrigation and limited adaptation capacity (Sylla, 2016) [62]. Projections indicate continent-wide rise in temperature and increased rainfall variability and extreme climate events (Abegaz and Wims, 2015; Adebisi-Adelani and Oyesola, 2014) [2, 4]. The shifts are highly concerning for food security, especially for smallholder farmers who are less likely to have access to agricultural technologies and climate adaptation tools (Tacconi *et al*., 2023) [63]. This has therefore attracted a lot of interest from policymakers and researchers regarding the need to improve weather information services on the continent (IPCC, 2014). For the farmers in the Sub-Saharan region, weather information is seen as a cost-effective adaptation option that can help build farmers' adaptation capacity to climate shocks (Street, 2016) [60]. Reliable forecasts aid farmers in understanding environmental risks and in making decisions on adopting suitable agricultural technologies and adaptation strategies (Chisadza, 2020; Abegunde, Sibanda, & Obi, 2019) [3, 24]. Even with this awareness, there are still many African countries with low access and low usability to weather information. Weather forecasts are sometimes broadcast in a generalised format that is not very useful for the smallholder agricultural context (Muita, Dougill, Mutemi, Aura, Graham, Awolala, Nkiaka, Hirons, & Opijah, 2021; Van der Burgt *et al*., 2018) [46, 64]. In addition, the lack of good infrastructure, limited access to communication technologies, low levels of literacy, and poor extension support continue to limit farmers' capacity to access and utilise weather information effectively (Nyadzi, Nyamekye, Werners, Biesbroek, Dewulf, van Slobbe, Long, Termeer, & Ludwig, 2018) [48]. However, despite the potential benefits of technological innovations like mobile-based weather advisory services in enhancing information delivery, adoption has been hindered by factors such as network restrictions, data costs, and digital illiteracy (Selvam and Al-Humairi, 2023; Mapiye, Makombe, Molotsi, Dzama, & Mapiye, 2023) [42, 57].

The agricultural sector in Ghana is very sensitive to climate variability due to the fact that most of the crops are rain-fed and are heavily reliant on the seasonal rainfall patterns (Hussain, Butt, Uzma, Ahmed, Irshad, Rehman, & Yousaf, 2020) [36]. The country is facing more erratic rainfall patterns, a rise in temperature, and repeated droughts and floods that pose threats to smallholder farmers' livelihoods and the attainment of food security goals (Alidu, Man, Ramli, Mohd Haris, & Alhassan 2022; Antwi-Agyei *et al*. and Nyantakyi-Frimpong, 2021; Asante and Amuakwa-Mensah, 2015) [7, 9, 14]. These challenges are especially acute in the Northern Region, one of Ghana's driest ecological areas, where farming is predominantly rain-fed, and the farmers lack livelihood options (Abdul-Razak and Kruse, 2017; Akudugu, 2013; Dazé and Echeverría, 2016; Nyssen, den Ouden, Bindewald, Brancalion, Kremer, Lapin, Raats, Schatzdorfer, Stanturf, Verheyen, & Muys, 2024) [5, 27, 49]. The Government of Ghana and development partners have launched various weather information programmes to improve farmers' access to climate information. The use of radio, mobile phones, farmer organisations and community-based meteorological services to reach smallholder farmers has been promoted by organisations like the Adventist Development and Relief Agency (ADRA), Farm Radio International (FRI), Care Gulf Agriculture and Natural Resources (CGANR), and the German Development Cooperation (GIZ) (Darfour and Rosentrater, 2016) [26]. These interventions have been successful in making farmers available to a wider range of weather information services: rainfall forecasts, seasonal forecasts, temperature information, drought warnings, and advisory messages via radio, television, extension officers, and farmer-based organizations (Haworth, Biggs, Duncan, Wales, Boruff, & Bruce, 2018) [34].

However, weather services in northern Ghana are not uniformly available. Despite these gains, farmers still face climatic and non-climatic problems such as poverty, limited credit, poor infrastructure, poor road networks, lack of irrigation facilities, and insufficient extension services, which affect their ability to access and use weather information (Antwi-Agyei *et al*., 2015; Alidu *et al*., 2022) [10]. Recent research indicates that the usefulness of weather information on the farm depends not just on its availability, but also on its reliability, relevance, understandability, and application by farmers in their farm operations (Dinku *et al*., 2018; Hansen *et al*., 2019) [33]. Although considerable research has been conducted on climate change perceptions and adaptation strategies in Ghana (Akudugu, 2013; Armah *et al*., 2024; Bawakyillenuo, 2016; Etwire *et al*., 2013; Laube *et al*., 2012; Mabe *et al*., 2014; Quaye, 2008; Sarpong and Anyidoho, 2012; Wossen, 2018; Yaro *et al*., 2017) [5, 12, 18, 29, 31, 39, 40, 52, 54, 66, 67], there remains limited empirical evidence on the specific types of weather information services available to smallholder maize farmers and the socioeconomic and institutional factors that determine their access to such services. While recent studies have recognised the critical importance of weather information to agricultural decision-making (Alsharef and Hassan, 2024; Boansi *et al*., 2021) [8, 22], they also identified the continued challenges of extension service capacity, the ability of extension services to disseminate information, and farmers' ability to access localised and timely weather forecasts (Nyadzi *et al*., 2018; Kassem, 2021) [38, 48]. To make weather information systems accessible, relevant, and responsive to the needs of smallholder maize farmers in the Northern Region of Ghana, these gaps need to be addressed.

Methodology

Research design

A cross-sectional mixed-method research design involving both quantitative and qualitative methods was used for the study. The data collected from the quantitative component were used to determine the availability of weather information services and socioeconomic and institutional factors affecting farmers' access to weather information, while the data collected from the qualitative component were used to provide an in-depth understanding of farmers' experiences and perceptions using Focus Group Discussions (FGDs) and Key Informant Interview (KIIs) guides. The Regional Ministry of Food and Agriculture's (MoFA) records indicate that there are about 122,665 registered with the MoFA as smallholder maize farmers in the Northern Region (MoFA, 2022).

The sample size was determined using Cochran's (1967) sample size determination formula as:

$$n = \frac{N}{1+Ne^2} \text{ ....}(1)$$

Where n = sample size
N = target population of smallholder maize farmers
e = marginal error (5%)

Thus, N = 122,666.
$n = 122{,}666/1+122{,}666\ (0.05)^2 = 398.70 = 400$

The sample size of respondents was calculated as about 399 and rounded to 400 to allow for possible non-response and to increase the representativeness of the sample. A multi-stage sampling technique was used. The Northern Region was purposively chosen because it is highly reliant on rain-fed agriculture and exposed to climate variability and change. Then, a simple random sampling technique was used to select eight districts. In addition, two major maize-producing communities were purposively selected in each district, yielding sixteen study communities. Lastly, registered maize farmers were sampled using stratified random sampling to ensure adequate representation of farmers in the study communities. Additionally, the key informant interview and focus group discussion participants were purposively selected because of their experience and knowledge about maize production and weather information services.

Table 1: Sampled districts, communities, and their respective sizes

S/N	Districts	Frequency/ Percentages	Communities	Sampled Size	Percentages
1	Mion	68 (17.1%)	Kulinkpegu	37	9.3
			Sang	31	7.8
2	Zabzugu	51(12.7%)	Waribogu	30	7.5
			Korili	21	5.2
3	Nanumba North	49 (12.3%)	Nakpaa	29	7.3
			Kabi	20	5.0
4	Nanumba South	55 (13.7%)	Tampoaya	28	7.0
			Nakpayili	27	6.7
5	Kumbungu	53 (13.2)	Buglang	30	7.5
			Tibung	23	5.7
6	Savelugu	51 (12.8)	Lang	24	6.0
			Kadia	27	6.8
7	Karaga	34 (8.5)	Pishigu	14	3.5
			Nyong	20	5.0
8	Gushegu	39 (9.7%)	Kpatinga	20	5.0
			Zulugu	19	4.7
total	8	100	16	400	100

Source: Field Survey (2026)

Source of Data

Primary data were obtained directly from the maize farmers who are smallholders. Structured questionnaires were used for face-to-face interviews to collect quantitative data, while Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were used for the collection of qualitative data.

Data analysis

The qualitative data were analysed using content analysis, and verbatim quotations were used to support key findings (Vassakis, 2022) [65]. The quantitative data collected were coded, cleaned, and analysed using the Statistical Package for Social Sciences (SPSS) Version 27. Descriptive and inferential statistics were used to analyse the data, including frequencies, percentages, cross-tabulation, and regression. The data were presented in tabular and graphical format to highlight the distribution of weather information services and dissemination channels farmers have access to. The variables considered as explanatory variables were the following: usefulness of weather information, ability to understand and use weather information, availability of weather information, reliability of weather information, access to agricultural extension services, Farmer Based Organizations (FBOs) membership, access to credit, input price, output price, soil fertility management, government policies, availability of resources, technical knowledge, rainfall patterns, and temperature. The variables that were statistically significant in relation to the farmers' access to weather information were then analysed using the Bivariate Probit Regression Model to determine the socioeconomic and institutional variables that are significantly related to the farmers' access to weather information. The Bivariate Probit Regression Model provides strong estimates because it models correlated binary outcomes and tests relationships identified in the exploratory analysis (Gong and Johnson, 2021) [32]. The model was specified as:

$$Yi = \beta0 + \beta1X1 + \beta2X2 + \cdots + \beta nXn + \varepsilon$$

Where:
Y = Accessibility to weather information;
X_1-X_n = socioeconomic and institutional explanatory variables;

β_0 = intercept;
β_1-β_n = regression coefficients;
ε = random error term.

Results and Discussions

Types of weather information services available to smallholder maize farmers

This subsection presents the various types of weather information services available to smallholder maize farmers in the study area. Access to timely and reliable weather information is essential for informed agricultural decision-making, particularly in rain-fed farming systems where crop production depends heavily on weather conditions. Weather information services provide farmers with forecasts and advisories on rainfall, temperature, drought, wind, humidity, and other climatic conditions that influence farming activities. Such information enables farmers to make appropriate decisions regarding land preparation, planting, fertilizer application, pest and disease management, irrigation, and harvesting, thereby reducing production risks and improving farm productivity. Examining the types of weather information services available to the respondents provides an understanding of the range of climate information accessible to maize farmers and its potential role in enhancing agricultural productivity in the study area.

Respondents were provided with different types of weather information and asked to select Yes or No for types that were available to them and those that were not available to them, respectively. The study revealed that, of the 94.0% of respondents who indicated Yes, most (81.6%) selected Yes for the availability of rainfall amount and distribution, while the remaining respondents (18.4%) selected No. Farmers with access to reliable information indicated that it helps them in planning their activities, avoids the waste of money (e.g., on fertilizer that might wash away), and ultimately increases their seasonal yield. Accurate information is critical for making adaptive decisions in response to erratic rainfall patterns (Alhassan *et al*., 2025) [6]. The results again revealed that 75.2% confirmed that information on temperature (minimum, maximum, average) was available to them, while only 24.8% denied the availability of temperature information. According to, Baffour-Ata *et al*., (2022) [16], access to weather information services, including temperature data, enhances farmers' decision-making capacities. The study further revealed that most respondents (60.2%) agreed that information on wind speed and direction was available to them, whereas 39.8% indicated that they did not have access to information on wind speed and direction. This confirms the study of Bediako-Kyeremeh *et al*., (2024) [19], which found that, by understanding wind patterns, farmers can make strategic decisions such as optimizing the timing and direction of pesticide or fertilizer application to avoid drift, adjusting irrigation schedules to counteract the drying effects of wind on the soil, and strategically placing windbreaks (like trees or fences) to protect delicate crops from mechanical damage or soil erosion caused by strong wind. Again, 69.6% of respondents had access to information on the onset and cessation of rains, while the remaining 30.4% denied having access to this information. Late onsets and early cessations of rains affect planting decisions and require investment in modern weather information services to complement traditional knowledge (Atiah *et al*., 2021) [15]. The majority of the respondents (80.0%) accepted the fact that seasonal forecasts (e.g., onset, duration) were available to them, and a minority of them (20.0%) indicated non-availability of seasonal forecasts (e.g., onset, duration) to them. This aligns with the findings of Manzvera *et al*., (2024) [41]. that the majority of maize farmers accessed and used seasonal weather forecasts to make concrete, anticipatory farming decisions such as selecting suitable maize varieties and scheduling planting dates, which highlights the direct applicability and value of these forecasts in agricultural planning. Again, the study revealed that most respondents (81.7%) selected "Yes" to support the availability of weather warnings (e.g., storms, floods), while the remaining 18.3% selected "No," indicating that weather warnings (e.g., storms, floods) are not available. Finally, a large number of respondents (93.5%) said other types of weather information were available to them, while only 6.5% said no other type of weather information was available apart from what was presented to them. According to the findings of Baffour-Ata *et al*., (2024) [17], 86% of smallholder farmers used weather information services, including weather warnings, to manage climatic risks for improving proactive measures.

This was evident as maize farmers in the Buglang community indicated, " We are very much aware of the availability of rainfall forecasts and wind direction through a local radio programme called 'Kparilim Saha,' in which we have been educated on information regarding when to start farming and information on the variety of seeds suitable for current weather. Weather information helps us know when the rains will start so we can prepare adequately for the season and select the best variety of maize seeds for our farms. Last year we planted late, and the rain came later, and the water was too much, and the crops got destroyed, but this year, our reliance on rainfall forecasts has helped increase our farm yield…….'' (Focus Group Discussion at Buglang community, Kumbungu district, Northern region, Ghana, September 2025).

Table 2: Types of Weather Information Available to Maize Farmers, Frequency and Percentages

Variables	Frequency		Percentages (N) = 375	
	Yes	No	Yes	No
Rainfall amount and distribution	306	69	81.6	18.4
Temperature (minimum, maximum, average)	282	93	75.2	24.8
Wind speed and direction	226	149	60.2	39.8
Onset and cessation of rains	261	114	69.6	30.4
Seasonal forecast (onset, duration)	300	75	80.0	20.0
Weather warnings (storms, floods)	306	69	81.6	18.4
Others	351	24	93.5	6.5

Source: Field Survey (2026)

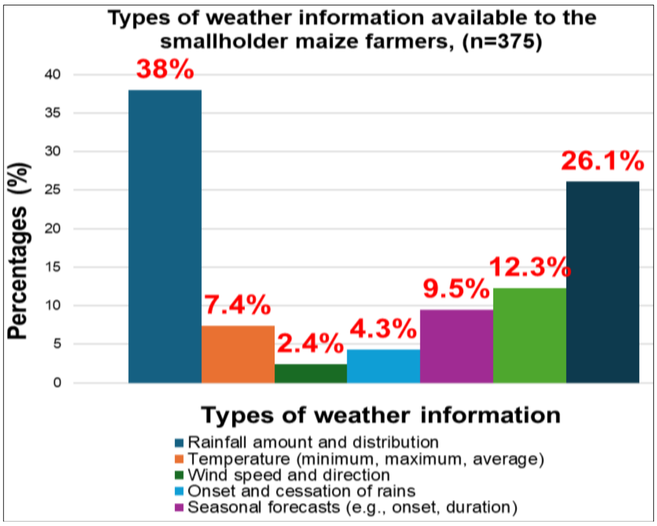
Specific types of weather information very common to smallholder maize farmers.

Respondents were given the opportunity to select the weather information they used most often. According to Field Shofiyati *et al*., (2024) [59], examples of weather information available to farmers include rainfall amount and distribution, temperature (minimum, maximum, and average), wind speed and direction, onset and cessation of rains, seasonal forecast (onset and duration), and weather warnings (storms and floods). The study also indicates that most respondents (38.0%) selected rainfall amount and distribution, while 26.1% chose other types of weather information. This confirms a study by Shaibu *et al*. (2025) [58]. that smallholder maize farmers have access to rainfall and climate information, which helps them manage risks. These findings indicate that while challenges in timeliness exist, many smallholder maize farmers in high-production areas (e.g., Ghana) are increasingly receiving and utilizing information on rainfall amount and distribution.

Again, 12.3% and 9.5% settled on weather warnings information (e.g., storms and floods) and seasonal forecasts (onset and duration), respectively. Similarly, some farmers (7.4%) opted for temperature (minimum, maximum, and average), while the remaining 4.3% and 2.4% chose onset and cessation of rains and wind speed and direction, respectively. According to Ofoegbu and New (2022) [50], smallholder farmers using weather information for decision-making, including when to plant, weed, and harvest, had a 13 percentage point higher technical efficiency than non-users. This confirms the finding of Abdoulaye *et al*. (2021) [1]. that a consistent negative relationship exists between growing-season wind speed and maize yield, indicating an average of a 9.4% decrease in maize yield for every 1 m/s increase in wind speed. Bhandari *et al*., (2023), found that on average, a 1% increase in green snap wind damage led to a yield loss of about 29.25 kg per hectare, causing significant economic losses to producers and extreme weather event risks to crop production. Elahi *et al*., (2022) [30]. also found that the adverse effects of extreme weather events, including windstorms and hailstorms, on wheat crops were significant, especially when occurring close to harvest time, and that severe storms cause an average of 43 mounds of wheat damage per hectare.

Another key informant from Nakpayili indicated that ‘’since the use of weather information established trust and confidence and was intended to support us to manage our farms well, we are always looking forward to more education on our farming practices.' "There was a period of extreme heat, and most plants suffered, especially crops planted in May. Our crops are usually destroyed by the heat any time we plant with the early rains, but now, with awareness of temperature and the onset and cessation of rains, we know the right time for planting. This year, we planted our maize in July, instead of our usual May/June, and the yield is more than before………..,’’ (Key Informant Interview, Nakpayili Community, Nanumba South district, Northern region, Ghana, November 2025).

The above views suggest that farmers in the Northern Region, in one way or another, have access to some level of weather information for their farming activities. The above information can be seen in Figure 1 below.



Source: Field Survey Data (2026)

Fig 1: Specific weather information common to smallholder maize farmers

Sources of weather information available to maize farmers

The source of weather information is an important factor influencing its accessibility, credibility, timeliness, and utilization in agricultural decision-making (Savari, Zhoolideh, and Limuie, 2024) [55, 56]. Weather information may be disseminated through several channels, including radio, television, agricultural extension officers, mobile phones, farmer-based organizations, the Ghana Meteorological Agency, non-governmental organizations, and interpersonal networks such as fellow farmers and community leaders. The effectiveness of these sources depends on their availability, reliability, ease of access, and farmers' ability to understand and apply the information provided. Identifying the major sources of weather information available to maize farmers is therefore essential for assessing the effectiveness of existing dissemination channels and for informing strategies to improve the delivery and utilization of weather information services, thereby enhancing maize productivity in the Northern Region of Ghana.

The study sought to identify respondents' sources of weather information by asking them where they obtained it. Respondents cited the following sources: radio, television, extension officers, Farmer-Based Organizations (FBOs), phone calls/WhatsApp, and the internet/weather apps/Facebook. This confirms the observation made by Mapiye *et al*., (2023) [42] that several sources of weather information are available to smallholder and commercial farmers. These sources include radio, television, agricultural extension officers, Farmer-Based Organizations (FBOs), phone calls, SMS, and others. Other sources of weather information were also available, such as WhatsApp, Facebook, and the internet. However, only a few maize farmers in the study area reported sourcing weather information through these sources in the study communities. Of the 94.0% of respondents who indicated they accessed weather information, they were asked to state the source for each variable. The study revealed that, for rainfall amount and distribution, the majority of respondents (54.6%) identified radio as their source of weather information, while 23.0% identified television as their source of weather information. Another group of respondents (4.0%) stated that they received weather information from extension officers, whereas 8.0% received their weather information from Farmer-Based Organizations (FBOs). However, a few respondents (8.3%) stated that they received weather information from phone calls/WhatsApp, and the remaining 2.1% said they received weather information from the internet/weather apps/Facebook. Additionally, for temperature forecasts, the study found that most respondents (41.1%) chose radio as their main source of weather information (minimum, maximum, and average), and 33.4% also said they received weather information through television. Furthermore, a few of the respondents (12.0% and 3.7%) received weather information from extension officers and farmer-based organizations (FBOs), respectively. The remaining farmers (9.2% and 0.6%) received weather information from phone calls/WhatsApp and the internet/weather apps/Facebook, respectively. For wind speed and direction, the study found that a good number of farmers (39.3% and 30.1%) chose radio and television as their sources of weather information, respectively. A few farmers (9.2% and 10.4%) identified extension officers and farmer-based organisations (FBOs) as their sources of weather information, and the remaining farmers (9.2% and 1.8%) stated that they received weather information from phone calls/WhatsApp and the internet/weather apps/Facebook, respectively. Furthermore, for the onset and cessation of rains, the majority of respondents (43.3%) identified radio as their source of weather information, while 31.0% identified television as their source of weather information. Another group of respondents (5.2%) stated that they received weather information from extension officers, whereas 12.8% received their weather information from farmer-based organizations (FBOs). However, a few respondents (7.1%) stated that they received weather information from phone calls/WhatsApp, and the remaining farmers (0.6%) said they received weather information from the internet/weather apps/Facebook. Again, under weather warnings (storms, floods), the study revealed that most respondents (41.1%) chose radio as their main source of weather information for weather warnings (storms, floods), and 40.8% also stated that they received weather information through television. Furthermore, a few of the respondents (3.4%) and (7.7%) received weather information from extension officers and farmer-based organizations (FBOs), respectively. Lastly, 4.9% and 2.1% of farmers received weather information from phone calls/WhatsApp and the internet/weather apps/Facebook, respectively. Finally, for other sources of weather information, the study revealed that a small number of farmers (2.1% and 1.2%) chose radio and television as their source of weather information, respectively. The majority of the farmers (92.0% and 3.1%) identified extension officers and farmer-based organizations (FBOs) as their source of weather information, respectively, and the remaining farmers, 1.0% and 0.6%, stated that they received weather information from phone calls/WhatsApp and the internet/weather apps/Facebook, respectively.

A key informant from Nakpali Waribogu lamented that

“For the past years, our crops used to be destroyed completely by the wind and drought, leaving us with nothing to feed on until recently, when we started monitoring the wind speed and other weather warnings through radio and television stations. Now that we know where the wind is coming from, we plant our crops across the wind to reduce the damage and also heed the advice about weather warnings by our extension officers and colleague farmers during our meetings...." (Key Informant Interview, Nakpali Waribogu community, Zabzugu district, Northern region, Ghana, December 2025).

Table 3: Sources of Weather Information Available to Farmers

Variables	Sources of Weather Information Available to Maize Farmers	Frequency	Percentages
Rainfall Amount and Direction	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	205 86 15 30 31 8	54.6 23.0 4.0 8.0 8.3 2.1
		375	100
Temperature (Minimum, Maximum, Average)	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	154 125 45 14 35 2	41.1 33.4 12.0 3.7 9.2 0.6
		375	100
Wind Speed and Direction	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	147 113 35 39 35	39.3 30.1 9.2 10.4 9.2

		6	1.8
		375	100
Onset and Cessation of Rains	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	162 116 20 48 27 2	43.3 31.0 5.2 12.8 7.1 0.6
		375	100
Seasonal Forecast (onset, duration)	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	153 152 13 25 30 2	40.8 40.5 3.4 6.7 8.0 0.6
		375	100
Weather Warnings (storms, floods)	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	154 153 13 29 18 8	41.1 40.8 3.4 7.7 4.9 2.1
		375	100
Others	Radio Television Extension officers FBOs Phone calls/WhatsApp Internet/weather app/Facebook	7 5 345 12 4 2	2.1 1.2 92.0 3.1 1.0 0.6
Total. 375 - 100			

Source: Field Survey (2026).

Major sources of weather information available to maize farmers

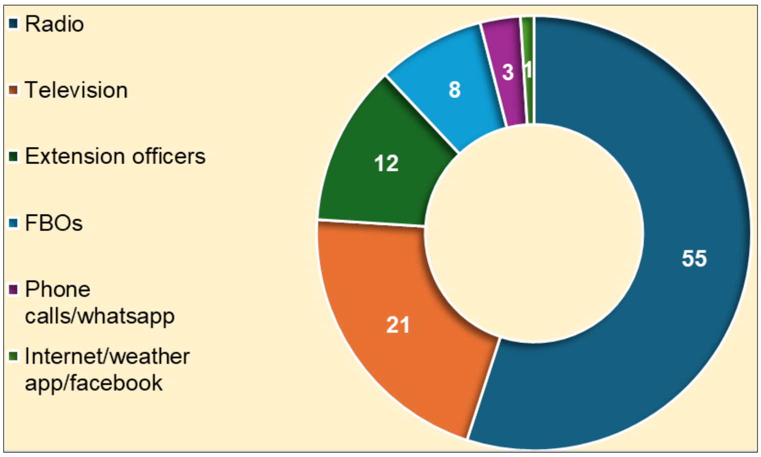
Respondents were asked to identify the major sources of weather information available to them. Out of the 94.0% of respondents who accessed weather information in the study area, 55.0% identified radio as their main source of weather information, and 21.0% indicated that television was the most common source of weather information to them. Additionally, extension officers and farmer-based organizations (FBOs) were identified as the major sources of weather information to 12.0% and 8.0% of the respondents, respectively. Finally, 3.0% selected phone calls as the most common source of weather information, while 1.0% identified the internet as a major source. A study conducted by Cherotich *et al*., (2012) [23]. indicated that different pathways are used to transmit weather information to smallholder farmers and that men and women have distinct preferences for receiving climate change information. Radio, television, extension officers, and face-to-face contact are some of the available techniques for delivering information to smallholder farmers. Boansi *et al*., (2021) [22]. demonstrate that access to weather information can lead to significant improvements in crop yields by providing farmers with optimal planting schedules, helping them manage water resources more efficiently, and reducing the risk of crop failure. Other sources of weather information were WhatsApp, Facebook, and weather apps, where farmers buy data to source weather information, as was explained in a focus group discussion (FGD) at Sang community:

"In the planting season, we usually sit by our television sets in the night to monitor agricultural programmes which help us know when to start planting for the year, but sometimes we don’t see all the Programmes. Because of that, we always carry our radio sets along to the farms, with the intention of hearing some information about the rains and how to go about the season...’’ (Focus Group Discussion, Sang Community, Mion district, Northern region, Ghana, October 2025).

A key informant, who is also one of the leaders of the district maize farmers association, reported that

"Last year, we had information about planting date and fertilizer application from the extension officer through our farmer-based organization (FBO) that supports us to cultivate maize in large quantities for both consumption and export. The registered farmers were educated on weather information and onboarded on a WhatsApp group through which we receive messages in respect of weather information, which was helpful…’’ (Key informant interview, Kpatinga, Gushegu District, Northern region, Ghana, October 2025).

In a focus group discussion at Kadia Community, participants said, "We received weather information either through SMS or phone calls, and sometimes both SMS and phone calls, from a local non-governmental organization (NGO) called 'Maisara Ariziki,' which supports us with seeds, fertilizer, chemicals, and other inputs and also guides us on how to apply them with agreed terms to be repaid with maize. When we follow the instructions given to us, we end up getting a higher yield…' (Focus Group Discussion, Kadia Community, Savelugu district, Northern Region, Ghana, September 2025. Figure 2 presents an analysis of farmers’ responses to the question about the major source of weather information common in the region for them to access.



Source: Field Survey (2026).

Fig 2: Sources of weather information for smallholder maize farmers

Socioeconomic and institutional factors influencing smallholder maize farmers' capacity to access weather information.

This presents the results and discussion of the factors likely to influence maize farmers' access to weather information in the study area. The dependent variable, weather accessibility contribution to maize yield, is limited to two outcomes: accessibility and non-accessibility. Initially, bivariate analysis was conducted to examine the relationship between each explanatory variable and the dependent variable, the influence of access to weather information on maize yield. This analysis enabled the study to identify variables significantly associated with smallholder maize farmers' access to weather information before estimating the multivariate probit regression model. Variables that were statistically significant at the bivariate level were considered important predictors of weather information accessibility and were subsequently included in the multivariate analysis. The bivariate analysis results in Table 2 revealed that respondents' ability to understand and use weather information, reliability of weather information, input/output prices, and soil fertility management all influence maize farmers' decision to access weather information in the study area. Specifically, respondents' ability to understand and use weather information and input/output prices were all significant at the 1% level of significance, while reliability of weather information and soil fertility management were significant at the 5%.

Respondents' ability to understand and use weather information

Respondents' ability to understand and use weather information was found to influence weather information accessibility and contribute to maize yield at a 1% level of significance, with a P-value of $P < 0.001$. This means there is very strong statistical evidence that access to weather information is associated with maize yield. Specifically, the p-value ($p < 0.001$) indicates that the probability of observing the relationship by chance, assuming there is no relationship, is less than 0.1%. Since $p < 0.001$ is much smaller than the conventional 1% significance level ($\alpha = 0.01$), the null hypothesis that access to weather information has no effect on maize yield is rejected. Therefore, the study concludes that weather accessibility contributes significantly to maize yield. The effectiveness of using weather information is strongly linked to the farmers' ability to understand and apply relevant agro-meteorological advisories. That is, the ability to interpret daily forecasts informed farm operations, such as choosing the date for land preparation, sowing, fertilising, and weeding (Ouédraogo *et al*., 2023).

Reliability of weather information

Reliability of weather information was found to influence weather accessibility and contribute to maize yield at a 5% level of significance, with a P-value of $P < 0.016$. This means there is very strong statistical evidence that reliability of weather information is associated with maize yield. Specifically, the p-value ($p < 0.016$) indicates that the probability of observing the relationship by chance, assuming there is no relationship, is less than 0.5%. Since $p < 0.016$ is much smaller than the conventional 5% significance level ($\alpha = 0.05$), the null hypothesis that weather accessibility has no effect on maize yield is rejected. Therefore, the study concludes that weather accessibility has a statistically significant contribution to maize yield. This was confirmed by Bistline *et al*., (2024) [21], who found that the reliability and accuracy of weather information significantly influence its accessibility and subsequent contribution to farmers' yield.

Input/output prices

Input/output prices were found to influence weather accessibility and contribute to maize yield at a 1% level of significance, with a P-value of $P < 0.009$. This suggests that input and output prices are important factors influencing farmers' access to weather information, which translates into improved maize yield. In practical terms, even when farmers have access to weather information, they still need to be able to purchase inputs such as improved seeds, fertilizers, herbicides, and pesticides at affordable prices. Likewise, receiving fair prices for their maize provides the financial incentive and resources to invest in recommended farming practices based on weather forecasts. Statistical significance at the 1% level means there is less than a 1% probability that this relationship occurred by chance. Therefore, the study provides strong evidence that input/output prices are associated with maize yield through their influence on the effective use of weather information. This implies that farmers are more likely to benefit from weather information when agricultural inputs are affordable, and maize can be sold at higher prices. Therefore, policies aimed at increasing maize productivity should not only improve access to reliable weather information but should also ensure affordable agricultural inputs through subsidies or improved input markets, stabilised input prices, improved market access so farmers receive fair prices for their maize, and integrated weather information services with extension and input support programmes. The study by Hodjo *et al*., (2021) [35]. found that lower fertilizer prices and higher grain (maize and rice) prices have a positive effect on both the acreages planted and the eventual yield, indicating that favorable price conditions incentivize farmers to invest in essential inputs like fertilizer, which in turn boosts productivity. Conversely, higher fertilizer prices reduced fertilizer use, leading to low yields.

Soil fertility management

Soil fertility management was found to significantly influence the contribution of farmers' access to weather information to maize yield at the 5% level of significance, with a P-value of $P < 0.050$. The 5% level of significance ($p < 0.050$) indicates that there is less than a 5% probability that the observed relationship occurred by chance. Thus, there is sufficient statistical evidence to conclude that soil fertility management significantly influences the contribution of weather information accessibility to maize yield. This finding suggests that the effectiveness of weather information in improving maize yield depends partly on how well farmers manage soil fertility, such as applying the appropriate type and quantity of fertiliser, using organic manure or compost, practicing crop rotation or intercropping where appropriate, and conserving soil nutrients through proper land management. This implies that farmers who combine weather information with appropriate soil fertility management practices are more likely to achieve higher maize yields. However, access to weather forecasts alone may not substantially improve productivity unless farmers adopt complementary practices such as proper soil fertility management. MacCarthy *et al*., (2023) demonstrated that integrated soil fertility management (ISFM) options can increase farmers' maize yields and, importantly, provide greater yield stability under variable climate and rainfall conditions.

Table 4: Bivariate analysis of factors influencing smallholder maize farmers' access to weather information

Variables	Weather accessibility contributes to maize yield		Test Statistic
	Yes	No	
Usefulness of the information Yes No	297(79.2) 78(20.8)	25(6.0)	$X^2(1)=0.145$; $P=0.704$
Ability to understand and use Yes No	303(80.2) 72(19.8)	25(6.0)	$X^2(1)=11.718$; $P<0.001$
Availability of such information Yes No	259(69.0) 116(31.0)	25(6.0)	$X^2(1)=1.847$; $P=0.174$
Reliability of the information Yes No	227(61.0) 148(39.0)	25(6.0)	$X^2(1)=5.832$; $P=0.016$
Access to agricultural extension Yes No	236(62.9)139(37.1)	25(6.0)	$X^2(1)=1.732$; $P=0.188$
Farmer Based Organization (FBOs) Yes No	154(41.1) 221(58,9)	25(6.0)	$X^2(1)=1.664$; $P=0.197$
Access to credit Yes No	136(36.3) 239(63.7)	25(6.0)	$X^2(1)=1.384$; $P=0.239$
Input/output prices Yes No	215(57.3) 160(42.7)	25(6.0)	$X^2(1)=6.890$; $P=0.009$
Soil fertility management Yes No	238(63.5) 137(36.5)	25(6.0)	$X^2(1)=3.780$; $P=0.050$
Government policies Yes No	144(38.4) 231(61.6)	25(6.4)	$X^2(1)=0.908$; $P=0.341$
Availability of resources Yes No	166(44,3) 209(55.7)	25(6/0)	$X^2(1)=1.304$; $P=0.254$
Lack of technical know-how Yes No	213(56.8) 162(43.2)	25(6.0)	$X^2(1)=2.219$; $P=0.136$
Rainfall patterns Yes No	317(84.5) 58(15.5)	25(6.0)	$X^2(1)=0.281$; $P=0.641$
Temperature Yes No	274(73.1) 101(26.9)	25(6.0)	$X^2(1)=0.578$; $P=0.447$

Source: Field Survey (2026).

Following the bivariate analysis, the four explanatory variables that were significantly associated with weather information accessibility were included in the probit regression model. The probit regression model was estimated to determine the independent effect of each variable on farmers' accessibility to weather information while controlling for the influence of the other explanatory variables. This approach enabled the study to identify the significant determinants of weather information accessibility. The probit regression model estimated the effects of the significant explanatory variables identified in the preliminary bivariate analysis while accounting for the possible correlation between the two equations (Chireshe *et al*., 2025). The four independent variables include respondents' ability to understand and use weather information, reliability of weather information, input/output prices, and soil fertility management. The model is structured as follows: Yi= βo +β1 X1i+ β 2 X2+…………………… β n X n. Where;

Y = The dependent variable is the contribution of weather accessibility to maize yield.

X1………. Xn = independent variables as shown below; X1 = Ability to understand and use, X2 = Input/output prices, Yi= 1.671 - 0.574 X1+ 0.647 X2. Therefore; Weather accessibility = 1.671 - 0.574 (Ability to understand and use) + 0.647(Input/output prices).

Several studies used a bivariate probit model as a robustness check to confirm or validate findings from initial, simpler models such as bivariate analysis or binary logistic regression. This is standard practice in research to ensure results are not dependent on the specific assumptions of the initial method of analysis (Gong and Johnson, 2021) [32]. Analysis of the bivariate probit regression model revealed that respondents' ability to understand and use weather information and input/output prices were the only factors that influenced how access to weather information contributes to maize yield at a 5% level of significance for each variable in the study area.

Respondents' ability to understand and use weather information

Respondents' ability to understand and use weather information was found to negatively influence how access to weather information contributes to maize yield, with a coefficient of -0.574. This means that farmers who have difficulty interpreting or applying weather forecasts are less likely to benefit from weather information, and poor understanding reduces its effectiveness in improving maize productivity. This implies that farmers need to understand weather forecasts before they can use them effectively in making farm management decisions. Simply providing weather information does not guarantee higher yields if farmers cannot interpret or apply it correctly; therefore, extension officers need to train farmers to interpret rainfall forecasts, seasonal outlooks, temperature forecasts, and advisory messages. Again, the regression coefficient of -0.574 indicates that respondents' limited ability to understand and use weather information negatively influences the contribution of access to weather information to maize yield. This implies that as farmers have greater difficulty interpreting and applying weather information, the benefits of accessing weather information decline. Consequently, farmers with inadequate technical knowledge are less able to make informed decisions regarding planting dates, fertiliser application, pest management, and harvesting, resulting in lower maize productivity. The finding highlights the importance of strengthening farmers' capacity to interpret and utilise weather information through extension education, training, and simplified weather communication. The policy implication is that government agencies and agricultural organizations need to integrate weather information dissemination with farmer education, literacy programmes, and extension service delivery to improve farmers' ability to understand and use weather information effectively. This finding corroborates the work of Bert *et al*. (2006) [20], which shows that improved understanding and use of weather information positively influence maize yield by enabling better decision-making and climate adaptation. However, barriers to accessing and understanding weather information negatively affect maize yield. Also, extensive farming experience can moderate and significantly inhibit farmers' access to scientific forecasts because they put too much faith in their ability to predict weather using traditional methods alone, which in turn contributes to lower potential yields compared with those who combine local knowledge with scientific forecasts (Nocezo *et al*., 2024) [47].

Input/output prices

Input/output prices were found to have a positive influence on how access to weather information contributes to maize yield, with a coefficient of 0.647. This implies that, when a farmer's input/output prices increased by one, the likelihood of the farmer increasing his/her access to weather information was 0.647, holding all other variables constant. Studies show that better access to affordable inputs (like fertilizer, seeds) due to favourable prices/subsidies boosts maize yield by enabling farmers to use more, while higher output prices increase profitability, motivating investment in yield-boosting practices, though high input costs alone reduce usage and yield, proving a complex relationship where positive price incentives drive higher yield. Input subsidy programmes aim to lower costs, making fertilizers accessible and leading to more application and higher maize output, though the impact on market prices varies (Mvodo Meyo and Mbey Egoh, 2020) [43]. The policy implication is that since high input costs can limit farmers' ability to respond to weather information, expanding affordable credit schemes would enable farmers to purchase inputs at the appropriate time and fully utilise weather forecasts. Again, agricultural extension officers need to educate farmers on how to combine weather information with sound economic decisions regarding input purchases and crop marketing. This would improve the effectiveness of weather information in increasing productivity. Therefore, investments in rural infrastructure, storage facilities, and market linkages can reduce transaction costs and improve farmers' access to profitable markets, making the use of weather information more economically rewarding.

Table 5: Parameter Estimates of Probit Regression

Predictor Variables	B	Std. Error	Wald	Sig.
Intercept	1.671	0.2381	49.247	<0.001
Ability to understand and use weather information	-0.574	0.2754	4.338	<0.05
Input/output prices Reliability of the information Soil fertility management	0.647 0.182 0.290	0.2625 0.2792 0.2546	6.065 0.424 1.299	< 0.05 0.515 0.254

Source: Field Survey Data (2026)

Conclusion and recommendation

In conclusion, the results indicate that rainfall amount and distribution, temperature, wind speed and direction, onset and cessation of rains, seasonal forecast, weather warnings, and other types of weather information were types of weather information available to maize farmers, whereas radio, television, extension officers, FBOs, phone calls/WhatsApp, and the internet/weather app/Facebook were identified as the main sources of weather information for maize farmers in the northern region of Ghana.

Respondents' ability to understand and use weather information, reliability of weather information, input/output prices, and soil fertility management were significant determinants of how maize farmers' access to weather information contributes to maize yield in the study area. Specifically, respondents' ability to understand and use weather information and input/output prices were all significant at 1%, and reliability of weather information and soil fertility management were significant at the 5% level of significance.

The study recommends that government and agricultural extension organizations should prioritize disseminating rainfall forecasts, temperature patterns, and pest and disease alerts to maize farmers, as these are critical for their decision-making by leveraging mobile platforms, local radio stations, and social media platforms to increase farmers' accessibility to weather information. In addition, the Ministry of Agriculture should foster collaboration between government agencies, non-governmental organizations (NGOs), and the private sector to support older and illiterate farmers with training to improve their access to weather information.

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