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Access and Use of Seasonal Weather Forecasts for Maize Production in Zimbabwe: Perspectives of Farmers, Extension Officers and Policy Shapers

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ABSTRACT

In Zimbabwe, the production, dissemination and use of seasonal weather forecasts in maize production is a system that involves the flow of information from a production point to a final point for farmers, through dissemination channels such as agricultural extension officers and more experienced farmers and elders, in the case of indigenous seasonal weather forecasts. This paper examines the perspectives of maize farmers (the general public or the masses) alongside the views of agricultural extension officers, policy shapers and influencers (key informants or elites) regarding seasonal weather forecasts and their role in improving farmers' access to this information. The findings reveal a broad consensus that indigenous seasonal weather forecasts can complement modern forecasts, aiding farmers' adaptation to climate change mainly through selecting suitable crop varieties, scheduling planting dates and planning other agricultural activities. Both farmers and key informants agreed on the need to downscale and disseminate locality-specific seasonal weather forecasts and co-production involving the integration of indigenous seasonal forecasts with modern seasonal weather forecasts. However, many farmers feel marginalised, with limited access to localised and customised forecasts. Elites often underestimate this marginalisation, creating asymmetric information gaps. This asymmetry in information between farmers and elites highlights the need for more frequent interaction between the two groups, especially through co-production processes, to enhance access to seasonal weather forecasts and strengthen climate adaptation.

1 | Introduction

Most rural areas in Zimbabwe are extremely vulnerable to climate-related risks. In the short to medium term, interannual rainfall variability and recurrent droughts, hallmarks of climate variability, pose direct threats to food production (Manzvera et al. 2023; Munsaka et al. 2021; Mutandwa et al. 2019; Mutasa 2022; Nhundu et al. 2021). Over the longer term, climate change is expected to intensify the frequency and severity of rainfall variability and droughts, further compounding livelihood risks for smallholder farmers (Ayanlade et al. 2022; Mutandwa et al. 2019). Due to the increasing frequency and severity of droughts, maize production is projected to decline by up to 33% if significant investments in climate-smart agricultural technologies are not made (World Bank 2019). As such, identifying sustainable pathways to strengthen farmers' adaptation and resilience to climate change cannot be overemphasised (Defe et al. 2024; Manzvera et al. 2023).

Seasonal weather forecasts are valuable services that could significantly help to offset the negative effects of climate change in agricultural production by supporting farmers to make informed farming decisions (Chiputwa et al. 2022; Harvey et al. 2019; Tesfaye et al. 2023). However, the utilisation of

seasonal weather forecasts, especially among smallholder farmers who are most vulnerable to climate change, is limited in Zimbabwe (Grey 2019; Makuvaro et al. 2023). This is concerning since climate-related loss and damage are taking a significant toll on the country (Munsaka et al. 2021; Mutasa 2022; Nhundu et al. 2021). Aside from inadequate investments in the production of enhanced weather forecasts, weak dissemination systems and short lead times prevent farmers in Zimbabwe from accessing and using seasonal weather forecasts (Makuvaro et al. 2023; Meque et al. 2021).

Limited interactions among meteorologists, farmers and other stakeholders in the weather-forecasting value chain also remain a barrier to accessing, understanding and using seasonal weather forecasts, as has also been observed in countries such as South Africa (Ebhuoma 2022; Lumbroso et al. 2024). While Zimbabwe's National Climate Outlook Forum and other seasonal planning platforms offer some opportunities for engagement, these interactions are limited and occur mainly at the national level, leaving most smallholder farmers with minimal direct contact with meteorological experts. Although the weekly rainfall bulletin provides useful information to support farming decisions, the advisory content is often general, providing national and district-level analysis and does not adequately address the location-specific needs of farmers at the farm level.

It is, therefore, important to understand the views of different stakeholders, including farmers (the masses), on what needs to be done to strengthen stakeholder engagements and collaboration, to enhance access and use of seasonal weather forecasts to cushion agriculture and food systems from the effects of climate change. As such, this study presents a synthesis of various perspectives from a wide range of stakeholders in the seasonal weather forecast value chain. Apart from farmers, these stakeholders include policy shapers who are defined in this study as individuals or organisations that influence the formulation, direction and implementation of policies without necessarily holding formal decision-making power. They play a crucial role in shaping public policy through advocacy, research, thought leadership and stakeholder engagement. These policy shapers who help to influence the direction of policy change and other key stakeholders in the agriculture sector and weather forecast value chain can be referred to as elites. In this case, the elites are described as a small group of people having disproportionate levels of power in shaping policies and strategies that govern the delivery of weather and climate services, as well as acting as conduits and catalysts for the implementation of these strategies (Ayittey 2022; Höhler et al. 2023). For example, key informants from the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development are responsible not only for developing policies and strategies to improve the delivery of weather and climate services but also for disseminating forecasts to farmers. Throughout the remainder of this article, the words “elites”, “key informants” and “policy shapers” are used interchangeably to denote the same thing.

This study distinguishes itself from previous research in Zimbabwe by not only examining farmers' challenges in accessing seasonal weather forecasts but also exploring diverse stakeholder perspectives on strategies to improve forecast delivery and bolster climate change adaptation (Grey 2019; Meque et al. 2021; Mugiyo et al. 2023). By integrating the perspectives of both farmers and various stakeholders, this study contributes to the growing body of knowledge on how meteorologists, development practitioners, telecommunication companies and government agencies can strengthen the delivery of seasonal weather forecasts. This supports the broader call for a multistakeholder, co-production approach to enhance access, trust and the effective use of weather forecasts in farming decisions, especially given that smallholder agriculture in Zimbabwe is largely rainfed (André et al. 2023; Chiputwa et al. 2022; Lumbroso et al. 2024; Ofoegbu and New 2021).

To shape engagements among different stakeholders and hence foster sustainable demand-driven collaborations, this study addresses the following research questions:

a. what are the opinions and roles of farmers and other key stakeholders in relation to the access to seasonal weather forecasts and the uptake of anticipatory actions in Zimbabwe?
b. what are the similarities and contrasting views between the farmers and other key stakeholders in enhancing access to and use of seasonal weather forecasts in Zimbabwe?
c. what are the challenges and prospects for public–private partnerships in the delivery of seasonal weather forecasts to farmers in Zimbabwe?

Understanding the roles and opinions of different stakeholders is important from two key perspectives. Firstly, the study sheds light on the roles of various stakeholders in the production and dissemination of seasonal weather forecasts across the country. This is critical in providing policymakers with insights on effective strategies for promoting public–private partnerships and other multistakeholder collaborations towards the delivery of seasonal weather forecasts. This is also in line with the United Nations' Early Warning for All initiative, which aims to ensure that all people on the planet are protected by early warning systems by 2027 (Marchezini 2023). Second, understanding the perspectives of diverse stakeholders is crucial for designing co-production initiatives that are responsive to the needs of both farmers and supporting actors. This is key to ensuring the sustainability of such efforts in improving access to and use of seasonal weather forecasts for climate-informed farming decisions.

This article is organised into four key sections. Apart from the introduction, the second section presents the methods employed in this study to address the research questions and the theories that guided the study. The third section presents the main results and a discussion of the key findings. The conclusions and proposed recommendations are provided in the final section.

2 | Materials and Methods

2.1 | Study Area

The study was conducted in Mutare Rural, Chipinge, Chimanimani, Makoni and Buhera districts of Manicaland Province in Zimbabwe. The province is inhabited by people who follow the patriarchal inheritance system (Manzvera et al. 2024a; Manzvera and Anaman 2024). Like many other

African countries, the Zimbabwean societal system is patriarchal and tends to favour men over women in land ownership rights (Munemo et al. 2022). The predominant ethnic group in the area is the Shona, with the Manyika people, a subgroup of the larger Shona community, being the most prominent. While English serves as the official business language, primarily in urban areas, Shona is the main local language, with dialects such as Manyika and Ndau being the most widely spoken in the province (Manzvera et al. 2024a, 2024b; Manzvera and Anaman 2024). The major economic activity in the province is agriculture, with maize being the main staple crop among smallholder farmers (Manzvera and Anaman 2024; Manzvera et al. 2024b). Tobacco, timber, bananas, tea and coffee production are also key agricultural enterprises in the province. Mining also plays a key role in the province, with diamonds in the Marange area and gold in areas like Penhalonga of Mutare Rural district (Chipangura 2019). Tourism is a vital economic sector in Manicaland Province, with Nyanga, Chimanimani and the Vumba Mountains, along with Mutarazi and Nyagombe Falls, serving as major tourist attractions (Gohori and van der Merwe 2022).

2.2 | Theoretical Framework

This study is guided by political economy analysis, which emphasises the integration of various schools of thought in a blended form to analyse societal problems with an enhanced analytical lens (Manzvera and Anaman 2024). We first employ the neoclassical economics theory of information, especially the component that deals with market failures of information. Information from a neoclassical economics perspective is treated as a good or service that is exchanged between a producer and a consumer, for example, seasonal weather forecasts. The four major market failures related to information are (1) incomplete information, (2) asymmetric information, (3) adverse selection and (4) moral hazard (refer to Anaman 2014 for detailed explanations of these concepts). For the production, dissemination and use of seasonal weather forecasts, the most relevant information market failure problem is asymmetric information; this is the case whereby the producer and the consumer have different levels of information. This could apply to the situation where the disseminators of the information, such as agricultural extension officers (elites), have different levels of weather information from the types received by farmers (masses). The differences in information are generally ascribed to problems dealing with communication signals and the means of dissemination. For example, the use of the English language to disseminate information related to seasonal weather forecasts in Zimbabwe often leads to problems of interpretation by many farmers, given their limited command of the English language.

The second theory driving our analysis is the Standpoint political economy gender theory developed by a Canadian Sociologist, Dorothy Smith (Smith 1987, 1997). According to this theory, differences between the perceptions and realities of the masses and elites often come about through the lack of knowledge and information by the elites about the social development conditions faced by the masses. The Standpoint theory argues that deep-rooted hierarchical systems generate ignorance on the part of elites about the nature of social development related to marginalisation and social exclusion faced by the masses at the bottom of the social ladder. This leads to a lack of appreciation by the elites of the difficulties faced by marginalised and socially excluded people in accessing public goods and/or participating extensively in market-based activities. Thus, knowledge about how different people access public services, including weather forecasts, is not objective; rather, it is based on the social positions of various persons (Friesen and Goldstein 2022; Gurung 2020).

People at the top of social hierarchies can easily lose sight of reality and hence miss the critical challenges faced by the masses at the bottom of the pyramid while the masses at the bottom of social hierarchies (who are often ignored in policy formulation processes) have a unique standpoint that is a better starting point in defining sustainable ways of enhancing access and use of weather forecasts.

The dynamics of social hierarchies play a significant role in shaping policy outcomes and determining how different groups access public services, including access to weather forecasts. People at the top of social hierarchies—such as policymakers and other elites—often have the privilege of access to real-time data, information and decision-making tools. However, this privileged access can distance them from the lived realities of marginalised populations at the bottom of the social pyramid, leading to a disconnect between policies and the actual needs of the masses (Friesen and Goldstein 2022). This has often resulted in policies and strategies that overlook the nuanced and localised challenges faced by lower-income communities. For instance, elites may assume that digital weather-forecasting platforms are universally accessible, while in reality, people in rural areas often lack the technological infrastructure to receive such services (Falcescu et al. 2024; Gumucio et al. 2020). Moreover, without proper consultation and inclusion of the most affected populations, policy formulations can miss the practical barriers people face, like illiteracy, gender and disability disparities, further entrenching inequities (Falcescu et al. 2024). On the other hand, the masses at the bottom of social hierarchies possess a unique standpoint that is deeply grounded in their daily experiences (Smith 1987, 1997). These communities have firsthand knowledge of the socio-environmental challenges they face, such as recurrent droughts and limited access to weather forecasts. They are aware of the gaps in public service delivery, including access to timely weather forecasts, and can offer valuable insights into how these services should be tailored to meet their needs (Falcescu et al. 2024). Their perspectives are vital for developing sustainable, locally relevant solutions that improve access to and use of weather forecasts, thereby strengthening resilience to climate shocks.

A standpoint theory perspective, hence, suggests that those who are marginalised hold a more comprehensive view of reality due to their everyday struggles, giving them an advantage in identifying practical and sustainable solutions (Gurung 2020). By understanding their views and taking them into account directly in the policy formulation process, policies can be crafted that reflect their realities, leading to more inclusive and effective weather forecast delivery systems. For example, empowering extension agents and farmers to co-design weather forecasts ensures that the systems are more

accessible and effective (Chiputwa et al. 2022). Involving the farmers, who understand the challenges within their communities, can help in tailoring weather forecasts that factor in local infrastructure and communication methods. This approach not only makes policies more responsive but also strengthens resilience by equipping those most affected with the knowledge and tools to act on early warnings and forecasts. Recognising the critical insights of marginalised communities is essential for creating long-term, sustainable strategies for climate adaptation and disaster risk reduction. To comprehensively address the marginalisation issues surrounding access to weather forecasts, especially for farmers, it is critical to engage various stakeholders across the social spectrum. This includes not only the perspectives of farmers themselves, who are directly affected by climate and weather changes, but also those of elites and decision-makers who shape policies and provide the infrastructure for weather services. Combining these insights ensures that the solutions developed are both needs-driven and sustainable, promoting greater use of weather forecasts in agricultural decision-making and strengthening climate adaptation. This participatory approach is also aligned with the principles of bottom-up development, ensuring that those most affected by the issues are central to crafting the solutions.

2.3 | Data and Data Collection Methods

The data were collected through a mixed-method approach consisting of both qualitative and quantitative data collection techniques. For the qualitative data, 15 key informant interviews were conducted, while a household questionnaire survey was conducted to collect quantitative data from 502 farmers in the Manicaland province of Zimbabwe. The non-probability sampling approach was used to select the 15 key informants. Specifically, purposive sampling was employed to select the key informants for this study. The selection was based on the knowledge, dissemination and participation in the development of policies and strategies related to weather and climate services delivery in Zimbabwe. This allowed conducting the interviews with key informants with in-depth knowledge of the production and use of weather and climate services. A key informant guide consisting of both closed and open-ended questions was used to guide the interviews with key informants.

The in-depth interviews were conducted in December 2023 with diverse key stakeholders who could be described as policy shapers (help to influence the direction of policy change) in agriculture, weather and climate forecast services. These people were in the Ministry of Agriculture, Zimbabwe Meteorological Service Department (ZMSD), Agricultural extension agency (AGRITEX) under the Ministry of Agriculture, policy think tanks, Non-Governmental Organisations supporting climate change resilience and the Zimbabwe Farmers Union. A detailed description of these key informants without mentioning their names is given in the supplementary information (Description of stakeholders interviewed).

The quantitative data were collected using a structured questionnaire from 502 randomly selected maize farmers in the Manicaland province. The data were collected through a designed questionnaire deployed using the KoBo Collect software. A total of eight enumerators were trained to assist in administering the survey questionnaire to elicit farmers' information, their current level of access and willingness to pay for context-specific and co-produced seasonal weather forecast services rather than be without them. Face-to-face interviews with selected smallholder farmers were employed. This allowed enumerators to fully engage with farmers, probe responses and explain questions to respondents.

Employing a mixed-method design through integrating qualitative and quantitative data collection techniques allows triangulation and hence helps to provide a more holistic understanding of research issues being investigated than the usage of one technique alone (Molina-Azorín and López-Gamero 2016). Generally, integrating two different research techniques enables data enrichment as the techniques complement each other (Akimowicz et al. 2018; Hoyos and Riera 2013). The insights from qualitative data collection approaches provide an enhanced explanation of the observed statistics from quantitative data (Akimowicz et al. 2018). For example, the insights from key informants aid in the interpretation of people's perspectives, experiences and opinions on a certain subject under investigation (Wasti et al. 2022). Thus, integrating both household surveys and key informant interviews helped to triangulate the findings and explain the links found through household surveys. By integrating household surveys with key informant interviews, this study achieved effective triangulation, enriching both the scope and depth of the findings.

While many past studies have focused primarily on household surveys of individual farmers, often overlooking elite perspectives, this study bridges that gap by incorporating both. By engaging policy shapers and other key stakeholders, the research not only gathered critical insights but also validated emerging recommendations. This is particularly important, as these stakeholders play a vital role in determining national government funding and shaping the delivery of state-led seasonal weather and climate information services to farmers.

2.4 | Methods of Data Analysis

The descriptive statistics of mean and percentage distribution were used to analyse the socio-economic characteristics of farmers and their access to and use of seasonal weather forecasts. Thematic analysis was used to analyse the insights from key informants by selecting and picking out the main themes that emerged from their responses. The insights were grouped based on the identified themes. The data analysis process was done with the aid of Microsoft Excel and STATA computer software.

3 | Results

3.1 | Socio-Economic Characteristics of Farmers

The socio-economic characteristics of the 502 randomly selected maize farmers are summarised in Table 1. The majority of interviewed farmers (63%) were from female-headed

TABLE 1 | Socio-economic characteristics of farmers disaggregated by ethnicity.

Variable	Percentage	Ethnicity		
	All farmers	Ndau	Manyika	Difference
Religious preferences				
Subscribe to Traditional African Religions (1-yes, 0 otherwise)	14%	16%	13%	3%
Information and communication technology assets				
Mobile phone (1-yes, 0-no)	93%	96%	91%	5%**
Radio set (1-yes, 0-no)	68%	67%	69%	−2%
Television set (1-yes, 0-no)	27%	39%	24%	15%***
Social capital				
Access to public agricultural extension services (1-yes, 0-otherwise)	82%	70%	85%	−15%
Farming group membership (1-yes, 0-otherwise)	27%	50%	20%	30%***
Participation in agricultural policy development processes (1-yes, 0-otherwise)	7%	1%	8%	−7%***
Land ownership status				
Owning land (1-yes, 0-otherwise)	89%	98%	86%	12%***
Use of indigenous seasonal weather forecasts				
Use indigenous seasonal weather forecasts (1-yes, 0-otherwise)	58%	71%	54%	17%***
Use of modern seasonal weather forecasts				
Use modern weather forecasts in maize production (1-yes, 0-otherwise)	88%	87%	91%	−4%*
Use modern weather forecasts for non-farm activities (1-yes, 0-otherwise)	83%	81%	91%	−10%**
Willingness to pay decision and amount				
Willing to pay for modern seasonal weather forecasts (1-yes, 0-otherwise)	68%	42%	76%	−34%***
Education level	Mean			
Years of schooling completed (years)	9	10	9	1***
Age and income				
Age (years)	52	50	53	−3**
Household monthly income (US$)	75	83	73	10
Remoteness				
Distance to nearest district capital (kilometres)	39	42	27	15***
Experience				
Maize farming experience (years)	21	23	21	2
Land size				
Total landholding (hectares)	2.2	1.2	2.5	−1.3***
Farm equipment ownership				
Number of farm equipment	2	1	2	−1***

Source: Survey data, 2024.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

households, with an average age of 52 years. This aligns with the recent rural livelihoods assessment, which reports that most rural households are female-headed (54%), although the average household-head age of 46 years is slightly lower than that of this study's sample (Zimbabwe Livelihoods Assessment Committee (ZimLAC) 2025). Just over half of the respondents (51%) had attained secondary education, averaging 9 years of schooling. This is somewhat higher than the national rural figure, where 41% of household heads had secondary education (ZimLAC 2025).

Farmers reported an average monthly household income of US$75, which is below the national rural average of US$136 (ZimLAC 2025). This lower income may reflect agricultural losses linked to climate-related effects such as cyclones and droughts, which frequently affect Manicaland Province (Manzvera et al. 2025). These impacts are often more pronounced among female-headed households, who form a large proportion of the sample, which may explain the lower incomes relative to other rural areas in Zimbabwe. The majority (86%) identified as Christians, while the remaining 14% practiced Traditional African Religions. Among the farmers subscribing to Traditional African Religions, 10% of them also participated in some Christian activities and 1% in some Muslim activities. Thus, these farmers could be described as having mixed religious preferences (Manzvera and Anaman 2024; Tirivangasi and Nyahunda 2025). The predominance of Christian respondents (86%) is consistent with the 2022 Population and Housing Census, which recorded 85.3% of the population as Christian (Zimbabwe National Statistics Agency [ZIMSTAT] 2023). Religion plays a key role in farmers' choice of weather forecasts, as those practicing African Traditional Religions were observed to prefer co-producing seasonal forecasts and integrating modern forecasts from the Zimbabwe Meteorological Services Department with indigenous weather knowledge (Manzvera et al. 2025; Tirivangasi and Nyahunda 2025). Understanding these religious preferences is therefore important, as it can help tailor forecast delivery and co-production processes to ensure greater acceptance and use of climate information among diverse farmer groups.

All the 502 respondents belonged to the Shona broad ethnic group; 77% of them belonged to the Manyika tribe (subgroup), while the remaining 23% were from the Ndau tribe. Disaggregating the analysis by ethnicity (Table 1) revealed that a larger proportion of the Manyika members participated in agricultural policy formulation compared to the minority Ndau members. This limited participation among minority groups negatively affects climate literacy and access to weather forecast services, as it reduces understanding of the benefits of using weather forecasts for climate adaptation. Consistently, more Ndau members rely on indigenous seasonal forecasts, while Manyika members predominantly use modern forecasts for both maize production and social planning and are more willing to pay for them. This analysis underscores the need to strengthen social inclusion efforts to ensure marginalised groups, such as Ndau farmers, can benefit from improved delivery and use of weather forecasts (for detailed political economy analysis, refer to Manzvera and Anaman 2024).

3.2 | Access and Use of Modern Seasonal Weather Forecasts

Among the interviewed farmers, 92% accessed seasonal weather forecasts during the 2022/23 farming season. The majority of farmers received modern seasonal weather forecast information through radio (79%), agricultural extension officers (30%) and fellow farmers in the village (30%). Among those who had access to these forecasts, 88% utilised the information to implement anticipatory actions. The main anticipatory actions implemented by farmers based on seasonal weather forecasts were selection of suitable maize varieties (82%), scheduling planting (59%) and land preparation dates (39%). Farmers also used seasonal weather forecasts to plan various farming activities, including scheduling fertiliser application (3%), applying agrochemicals (1%) and determining harvesting dates (1%), among other tasks. Additionally, weather forecasts were utilised to adjust land allocation for maize production (15%) in anticipation of drought and to plan irrigation schedules (7%) to supplement rainfall and minimise agricultural losses caused by moisture stress (for a more detailed overview of anticipatory actions implemented, refer to Manzvera et al. 2024b).

Among the farmers interviewed, 68% expressed a willingness to pay for access to modern seasonal weather forecasts tailored to their own farm locations from the national weather agency (ZMSD), with an average willingness to pay (WTP) of US$1 per month (for more detailed WTP analysis, refer to Manzvera et al. 2024b). Such forecasts are contextually relevant, as they provide information that is directly aligned with farm-specific conditions and farmers' decision-making needs. Consistent with this finding, previous studies show that farmers prefer location-specific forecasts with a long lead time and are willing to pay for access to such services (Barrett et al. 2021; Bruno Soares 2017; Nyamekye et al. 2021).

3.3 | Challenges to Accessing and Using Modern Seasonal Weather Forecasts

The major challenges faced by farmers in accessing and using seasonal weather forecasts were the lack of internet access (68%), lack of knowledge to search the internet (64%) and language barrier because English is the major language of the internet not easily understood by the farmers (53%) (refer to Table 2 for more details).

3.4 | Access and Use of Indigenous Seasonal Weather Forecasts

The majority of farmers (58%) also used indigenous seasonal weather forecasts to guide maize farming decisions, including the selection of appropriate maize varieties during the 2022/23 farming season. The use of indigenous weather forecasts is a common practice among smallholder farmers in Zimbabwe. For instance, farmers in Chiredzi district used indigenous weather forecasts in 2021 to plan land preparation and select suitable crop varieties (Zvobgo et al. 2023) and earlier findings

TABLE 2 | Challenges to accessing and using seasonal weather forecasts.

Variable	Not considered an attribute at all	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
No internet access	2%	4%	5%	21%	24%	44%
Lack of knowledge to search the internet	2%	5%	6%	24%	22%	42%
Language (English) used not easily understood by farmers	16%	8%	6%	28%	23%	20%
Lack means to access (radio or television)	6%	9%	16%	32%	26%	11%
Poor mobile network	4%	11%	14%	25%	25%	12%
Limited access to AGRITEX	11%	23%	17%	25%	16%	9%

Source: Survey Data, 2024.

in Guruve district also reported their use for agricultural decision-making in 2016 (Gwenzi et al. 2016). Recent evidence shows that smallholder farmers increasingly combine indigenous forecasts with modern forecasts from the Zimbabwe Meteorological Services Department, highlighting their continued importance in farming decisions (Dube et al. 2024). The primary sources of indigenous seasonal forecasts were village elders (70%), followed by fellow farmers (14%). Similar trends have been observed in other African countries, such as Benin, where elders serve as the main source of indigenous weather forecasts (Amegnaglo et al. 2022).

The primary indicators for indigenous seasonal weather forecasts were the flowering of specific trees (51%), the behaviour of certain birds (33%) and high nighttime temperatures (21%) (for more analysis of indigenous seasonal weather forecast indicators refer to Manzvera et al. 2024a). These indicators are the most common indicators used to forecast the seasonal weather outlook before the onset of rain in many contexts (Amegnaglo et al. 2022; Gwenzi et al. 2016; Zvobgo et al. 2023). Farmers were asked to evaluate the attributes of indigenous seasonal weather forecasts, with many respondents agreeing that the forecasts were accurate (44%), reliable (38%) and easy to interpret (38%). These findings align with those of other studies, which indicate that many farmers in remote rural areas across Africa rely on indigenous seasonal forecasts due to their accessibility and ease of interpretation (Amegnaglo et al. 2022; Balehegn et al. 2019; Dube et al. 2024; Zvobgo et al. 2023). A comprehensive analysis of the access, use and economic benefits of indigenous seasonal weather forecasts in Zimbabwe was published in Manzvera et al. (2024a).

3.5 | Key Actors in the Weather and Climate Services Value Chain in the Agriculture Sector

Several actors in the weather and climate services value chain in the agricultural sector were identified (Table 3). These included the Zimbabwe Meteorological Service Department (ZMSD), which is the national agency responsible for the production and delivery of modern weather forecasts and early warning information. Apart from seasonal weather forecasts, the ZMSD also produces and disseminates 10-day weather forecasts, daily forecasts and instant forecasts (warning information) for extreme weather events. The agricultural extension officers (AGRITEX) were also identified as the key actors responsible for dissemination of modern weather forecasts to farmers mainly through face-to-face engagement with farmers, farmer meetings and the delivery of forecasts and other information through WhatsApp platforms.

The NGOs, such as Oxfam and the World Food Programme of the United Nations (WFP), were also identified as main players in disseminating weather forecasts to farmers mainly through WhatsApp platforms and farmer meetings. The key informants also indicated that the media plays a key role in disseminating weather forecasts to farmers. The main media houses identified were the Zimbabwe Broadcasting Corporation Television Station (ZBC TV), Radio Zimbabwe, Diamond FM Radio, Chimanimani FM Radio and National FM Radio. Village heads, elders and religious leaders were also identified as key actors in interpreting and disseminating indigenous weather forecasts to farmers.

3.6 | Elites' Views on the Access and Uses of Weather Forecasts Among Farmers

Most elites (70%) described the current access and use of modern seasonal weather forecasts by farmers as of moderate quality and spread. Radio, television, AGRITEX and non-governmental organisations were identified as the main channels for disseminating seasonal weather forecasts to farmers. The main challenges identified affecting access and use of weather forecasts were that the forecasts were not simplified or disseminated in the vernacular languages, poor network access and weak radio and television signals in many rural areas, and inadequate ownership of smartphones among farmers to access WhatsApp platforms. Other challenges included the lack of locality-specific weather forecasts and forecasts which were delivered within a short lead time for farmers to take meaningful action. The ZMSD officer also indicated that the lack of appropriate computing infrastructure (hardware and software infrastructure) to analyse and process climate data, poor density of meteorological stations and

TABLE 3 | Key actors in the weather and climate services value chain in the agriculture sector.

Actor	Role
Zimbabwe Meteorological Service Department	Production and dissemination of modern weather forecasts
Ministry of Lands, Agriculture, Fisheries, Water and Rural Development	Policy making, stakeholder engagement and investment facilitation
Ministry of Environment and Wildlife	Policy making, stakeholder engagement and investment facilitation
AGRITEX	Dissemination of modern weather forecasts to farmers.
Non-Governmental Organisations (NGOs) such as Oxfam, United Nations Development Programme (UNDP), Care Zimbabwe, World Food Programme of the United Nations (WFP)	Dissemination of modern weather forecasts to farmers and provide feedback to ZMSD.
Policy Think Tanks	Evidence generation and policy making
Media such as Zimbabwe National Television channel, National radio stations (Radio Zimbabwe, National FM, Star FM) and community radio stations (Diamond FM and Chimanimani FM)	Dissemination of modern weather forecasts to farmers
Village heads, religious leaders, elders in the villages and traditional weather forecasters	Interpretation and dissemination of indigenous weather forecasts
Farmers	Use the weather forecasts (indigenous and modern) in making farming decisions.

Source: Survey data, 2024.

inadequate skilled human manpower were three key challenges affecting weather forecasts production and delivery.

To bridge some of these challenges, several strategies were proposed. For instance, to strengthen access and use of seasonal weather forecasts, one of the key informants had this to say:

> *Given that in most communities the mobile phone network is poor and farmers rely on indigenous weather forecasts, there is a need for the ZMSD to co-produce weather forecasts with farmers. This will not only make weather forecasts interpretation easier among farmers, but it will allow for the integration of indigenous weather forecasts into the national weather forecasting system*,
>
> (Respondent 10-Chipinge district).

In emphasising the need for downscaled forecasts and long lead time for farmers to have more time to prepare for the season, one of the key informants in the Makoni district has this to say:

> *Currently, seasonal weather forecasts are not tied to farmer decision-making contexts, thus the ZMSD should downscale weather forecasts to the farm or village level. Downscaled or locality specific forecasts address farmers' needs, allowing farmers to use the forecasts to inform their agricultural decisions*,
>
> (Respondent 13-Makoni district).

In terms of lead time, most key informants stated that the present lead time for seasonal weather forecasts was less than 3 months. The relatively short period did not allow farmers to have enough time to prepare for the season. A common idea suggested by the elites was that the ZMSD should make efforts to disseminate seasonal weather forecasts with a longer lead time. Farmers specifically indicated a preference for a 6-month lead time, which would provide sufficient time to prepare and plan for the farming season (Manzvera et al. 2025). Furthermore, the key informants also suggested the need to use multiple dissemination channels, including digital tools such as mobile apps to disseminate seasonal weather forecasts to farmers and radio programmes on weather forecasts. Bundling with other services, such as the provision of actionable agronomic information, mainly when to plant and suitable varieties, was also suggested as a key aspect for consideration in disseminating seasonal weather forecasts.

The elites envisioned a similar future role of ZMSD through decentralisation of its services and the downscaling of weather forecasts, co-production of weather forecasts with communities, provision of weather forecasts with long lead times and increased collaboration with the private sector. The elites identified the selection of suitable crop varieties, planting drought-tolerant crops, practising conservation farming, scheduling land preparation and planting dates as the key actions implemented by farmers based on seasonal weather outlook.

3.7 | Elites' Views on the Challenges and Opportunities to Foster Public–Private Partnerships

The key informants unanimously identified the current legislation (Meteorological Services Act of 2003) as the main challenge hindering partnerships with private-sector actors in the

production and delivery of weather forecasts in Zimbabwe. This Act governs the operations, functions and administration of the Zimbabwe Meteorological Services Department. It was noted that the Meteorological Services Act currently regards the ZMSD as the sole producer of weather forecasts. The elites suggested the need to review the legal instrument and make provisions to allow partnerships with the private sector. Furthermore, the key informants suggested that such provisions should allow meteorological data sharing with different stakeholders and increase collaboration between the ZMSD and other government agencies and ministries. Private-sector players could establish weather stations and invest in advanced meteorological infrastructure in partnership with ZMSD. Farmers could also be provided with simple instruments, such as rain gauges, and trained to record and relay observations to ZMSD, thereby increasing data availability. Telecommunication companies could play a role in disseminating weather forecasts to farmers.

Most of the key informants (87%) agreed that after the Meteorological Services Act is revised, there is potential for public–private partnerships in the production and delivery of weather forecasts. The main suggested activities of private-sector actors in such collaborations are weather-forecasting infrastructure investments (such as automatic weather stations) and weather forecast dissemination to farmers. One of the key informants had this to say:

> *There are many areas in which the private sector could collaborate with ZMSD including investment in weather forecasting infrastructure and dissemination of weather forecasts. For example, the private sector actors could establish a call centre (help desk) to support the dissemination of weather forecasts to farmers*,
>
> (Respondent 3-Harare).

To recover the costs incurred by the private sector, two-thirds of the elites stated that once seasonal weather forecasts are downscaled to specific locations of farmers and are reliable enough to inform farming decisions, most farmers are willing to pay to receive the forecasts. As a result, it is possible to charge a premium for weather forecasts. Nonetheless, pricing segmentation should be used depending on the ability to pay, such as in a scenario, where subsistence farmers receive forecasts for free and commercial farmers pay for the services.

3.8 | Prospects to Integrate Indigenous Seasonal Weather Forecasts Outlined by the Elites

Apart from modern seasonal weather forecasts, most (93%) of the key informants agreed that farmers also used indigenous seasonal weather forecasts to inform farming decisions such as the selection of suitable crop varieties. The elderly, religious and traditional leaders were identified to be the people who mostly understood and interpreted the indigenous seasonal weather forecasts across all the study areas. Just like the findings from the quantitative data based on household surveys with farmers, the elites identified flowering or fruition of specific trees, the behaviour of birds, wind direction and high temperatures in specific months as main indicators used to predict the seasonal weather outlook derived from indigenous production of weather forecasts. A key informant in Mutare Rural indicated that:

> *High fruition of muzhanje and Boabob trees indicate that the coming season will be characterised by low rainfall and drought*,
>
> (Respondent 8- Mutare Rural).

Concerning high temperatures in specific months, one of the key informants in Chipinge district had this to say:

> *High temperatures especially at night in September and October indicate that the coming season will be characterised by heavy rainfalls*,
>
> (Respondent 8-Chipinge district).

Most (87%) of key informants also perceived that indigenous seasonal weather forecasts are accurate and reliable. An elite in Chimanimani district has this to say:

> *Indigenous seasonal weather forecasts are accurate, and farmers have utilised and trusted them for decades*,
>
> (Respondent 9- Chimanimani district).

About 87% of the key informants also agreed that it is possible to integrate the indigenous seasonal weather forecasts with modern forecasts. To achieve this, co-production of seasonal weather forecasts was suggested. In emphasising the need for co-production of weather forecasts, one of the key informants in Buhera district had this to say:

> *Co-production of weather forecasts allow integration of indigenous seasonal weather forecasting with modern forecasting system, and this could ensure trust and use of weather forecasts by farmers*,
>
> (Respondent 15- Buhera district).

These findings matched the insights generated through choice experiments, which suggested that farmers who utilised indigenous seasonal weather forecasts preferred the co-production attribute of seasonal weather forecasts (Manzvera et al. 2025).

3.9 | Comparison of the Views Among the Elites

There was a consensus among the elites that the current lead time for seasonal weather forecasts was too short, making them less effective in supporting farmers' decision-making. A common suggestion made was for the ZSMD to produce and disseminate seasonal weather forecasts with longer lead times, ideally 6 months before the onset of the rainy season. Achieving this requires substantial investment in advanced Numerical Weather Prediction (NWP) models, supported by adequate budget allocations from the national treasury for the acquisition and maintenance of modern meteorological equipment, including automatic weather stations, and the expansion of observation networks to improve data coverage. Additionally, investments

in high-performance hardware and software for data processing, capacity building for meteorological personnel, and reliable power supply are essential, as these factors currently constrain ZMSD's ability to generate accurate long-range climate forecasts (Meque et al. 2021). Integrating Artificial Intelligence and machine learning approaches, in collaboration with the Zimbabwe Centre for High-Performance Computing, could further enhance forecasting skill by improving model accuracy, optimising ensemble simulations and efficiently analysing large, multi-source climate datasets. Strengthening regional data sharing and collaboration with neighbouring meteorological services can also provide critical information on large-scale climate drivers, enhancing the reliability of 6-month-ahead forecasts.

The use of multiple dissemination channels, including digital tools such as mobile apps, to disseminate seasonal weather forecasts to farmers was a common idea suggested by the elites. The elites also had a consensual view of the future role of ZMSD through decentralisation of its services and the downscaling of weather forecasts, co-production of weather forecasts with communities and provision of seasonal weather forecasts with long lead time.

There was also a consensus among the elites over the need to review the Meteorological Services Act to stimulate public–private partnerships in the production and delivery of weather and climate services in Zimbabwe.

Nevertheless, the key informants disagreed on the current use of seasonal weather forecasts. Although most key informants rated the current access to and utilisation of seasonal weather forecasts as moderate, others rated it high or low. For example, a key informant from the Headquarters of the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development reported that access to and use of seasonal weather forecasts is moderate to high: high in resettlement areas and low in communal areas. Similarly, a key informant from the Directorate of Agricultural and Rural Development Advisory Services in Manicaland Province noted that access is high in Chipinge district and average in other districts. This reflected the disparities in access and use across districts. Key informants in Chipinge and Buhera districts reported higher access and use due to greater community engagement on climate change and weather forecast use through different initiatives being implemented in these districts compared to other districts. The WFP and Oxfam Zimbabwe are implementing the Participatory Integrated Climate Services for Agriculture (PISCA) and Climate Adaptation for Rural Livelihoods in Zimbabwe (CARL) programmes in the Chipinge and Buhera districts, respectively, to improve access and use of seasonal weather forecasts. Agricultural extension officers participate in these programmes to disseminate weather forecasts and provide advisory information to farmers, including guidance on selecting crop varieties based on the seasonal weather outlook. These and other initiatives are strengthening the use of seasonal weather forecasts in Chipinge and Buhera in contrast to other districts.

3.10 | Comparison of the Views of the Elites and the Sampled Farmers

One similar finding common to both the 15 elite persons and the 502 sampled farmers (masses) was the sources of dissemination of weather forecasts and information. There was a general agreement that State agencies such as ZMSD, AGRITEX, ZFU and non-governmental organisations were major players in this area in terms of the dissemination of modern seasonal weather forecasts and other types of weather information. National and community radio stations, particularly Radio Zimbabwe and Chimanimani FM, respectively, were also identified as the main sources of seasonal weather forecasts by both the elites and the masses.

Further, there was also agreement that traditional, religious leaders and elders in the villages were major sources of indigenous weather forecasts and information by both the elites and the masses. Both elites and the farmers identified the flowering or fruition of specific trees, the behaviour of birds, wind direction and high temperatures in specific months as the main indigenous indicators used to predict the seasonal weather outlook. There was also a consensus agreement that indigenous weather forecasts could be used in tandem with modern seasonal weather forecasts by farmers to schedule production and marketing activities.

Both the elites and the masses agreed that the lead times of the modern seasonal weather forecasts produced by ZMSD were too short and preferred longer lead times to allow farmers to properly schedule their production and marketing activities. Long lead times enable farmers to prepare for the season and adapt to climate change, while the short lead time of seasonal forecasts has been identified as a key barrier to timely and effective adaptation actions. Further, the elites and the masses had a general agreement on the key actions undertaken by farmers with seasonal weather forecasts. These activities included the selection of suitable crop varieties, planting drought-tolerant crops, practising conservation farming and scheduling land preparation and planting dates as the key actions.

However, while both elites and farmers agreed that indigenous seasonal forecasts and services were accurate, they differed on the ease of interpretation of these services. Accuracy here is based on subjective assessments of whether predicted events occurred rather than quantitative measurement. The sampled farmers (masses) generally found these indigenous forecasts easy to interpret and use for their production operations. However, the elites, who were mostly non-farmers, found the indigenous weather forecasts to be challenging to use in the context of the changing climate. This dichotomy of views among the two groups of people could reflect the inadequate comprehension of indigenous knowledge systems, embedded in local farming systems, by the elites as opposed to farmers. Awareness creation initiatives and the extensive documentation of indigenous seasonal weather forecast information, especially their indicators, could help to close this knowledge gap.

Another key difference between the views expressed by the elites and those indicated by the sampled farmers was related to the perceptions of marginalisation and social exclusion. A considerable number of farmers, especially those from the minority Ndau tribe, who constituted 23% of the sampled farmers, clearly expressed their status of marginalisation concerning the dissemination of weather and climate services, including policy

consultations related to the dissemination of these services in Zimbabwe. Yet none of the 15 interviewed elites expressed any open views on the marginalisation and social exclusion of groups concerning the dissemination of weather and climate services. This result could reflect the view that elites are not always in the best position to know and understand the vulnerable situations of the masses; this point validates the assertion derived from the Standpoint political economy theory.

This asymmetric information between the masses and elites, arising from hierarchical arrangements dealing with the dissemination of seasonal weather forecasts, suggests the need for more regular contacts between the two groups based on increased farmer-extension officer contacts and stakeholder workshops, which could incorporate discussion of relevant policy issues. Further, this finding supports the need for co-producing seasonal weather forecasts, offering a platform to integrate indigenous forecasting into national systems and enhance farmers' trust, use and anticipatory adaptation to climate change.

4 | Conclusion and Recommendations

This article presents the views of farmers and key informant interviews about their roles and strategies to enhance the delivery of seasonal weather forecasts to support decision-making and climate change adaptation in agriculture and food systems. The findings showed that although most farmers indicated that they accessed seasonal weather forecasts mainly through radio, the key informants reported that the current access and use of seasonal weather forecasts can be considered modest. This suggests an existing gap and a need to enhance the delivery of seasonal weather forecasts to reach all the farmers.

There was a general agreement between farmers and key informants that State agencies such as ZMSD, AGRITEX and NGOs, as well as the Zimbabwe Farmers Union, were the major players in disseminating modern seasonal weather forecasts to farmers. National and community radio stations, particularly Radio Zimbabwe and Chimanimani FM, respectively, were also identified as the main sources of seasonal weather forecasts by both key informants and the sampled farmers in the Manicaland province. Further, there was also agreement that traditional, religious leaders and elders in the villages were major sources of indigenous weather forecasts and information by both the key informants and the farmers. There was also a consensus agreement that indigenous weather forecasts could be used in tandem with modern seasonal weather forecasts by farmers to select suitable crop varieties and schedule land preparation and planting dates, among other activities.

The main challenges that were identified to affect access and use of seasonal weather forecasts include poor network access and weak radio or television signal in most rural areas, lack of smartphones among farmers to access WhatsApp and the English language used to disseminate the forecasts is not easily understood by most farmers. The ZMSD also identified three major challenges affecting weather forecast production and delivery: a lack of appropriate computing infrastructure to crunch and process climate data, a low density of meteorological stations and insufficient skilled human capital. Both the key informants and the farmers also agreed that the lead times of the modern seasonal weather forecasts produced by ZMSD were too short and preferred longer lead times to allow farmers to prepare effectively.

To address these challenges, key informants pointed out the need to downscale seasonal weather forecasts, co-produce with farmers to integrate with indigenous seasonal forecasts and disseminate the forecasts with a long lead time. This also aligns with the projected future role of ZMSD. In outlining the preferred future role of ZMSD, key informants envisioned decentralisation and downscaling of weather forecasts, co-production of weather forecasts with communities and more collaboration with the private sector.

To guarantee efficient engagement with the private sector, development partners and other non-state actors, the Meteorological Services Act of 2003 was identified as the key legal instrument requiring urgent review. Updating the Act would enable improved meteorological data exchange among stakeholders and allow private-sector players to establish weather stations and invest in advanced meteorological infrastructure in partnership with ZMSD. Such reforms would also strengthen existing collaborations with organisations such as Oxfam and WFP, who are already supporting the installation of automatic weather stations and encourage additional non-state actors to contribute to efforts aimed at enhancing early warning systems and weather forecast delivery. Beyond infrastructure investment, key informants also highlighted that civil society organisations, such as farmers' unions and the private sector, particularly telecommunication companies, could play an important role in communicating weather forecasts to farmers.

There is also a need for the government and development partners to bolster resources not only towards the delivery of enhanced seasonal weather forecasts but also to improve electricity supply and telephony infrastructure throughout Zimbabwe to reach the remotest areas of the country. This ensures that all farmers in rural areas have access to seasonal weather forecasts, in line with the United Nations' Early Warning for All initiative.

Given that this study focused only on maize farmers, future research could broaden the scope to include livestock farmers, horticultural producers and other sectors beyond agriculture, such as aviation, energy, mining, tourism and water, which also rely heavily on timely and accurate weather information. Further research work could also explore practical models for co-producing forecasts that blend indigenous knowledge with modern meteorological science, evaluating their accuracy, acceptance and influence on farm decision-making. Studies could also assess the effectiveness of private-sector engagement and public–private partnerships, including telecommunications companies, civil society organisations and development partners, in enhancing the downscaling, dissemination and farmer-targeted communication of weather forecasts. Additionally, future research could examine the wider economic impact of the Zimbabwe Meteorological Services Department using input–output analysis or other macroeconomic modelling approaches to demonstrate its economic value across the national economy and support evidence-based resource allocation for improved weather forecasts and early warning delivery.

Author Contributions

Conceptualisation: Joseph Manzvera and Kwabena Asomanin Anaman; data curation: Joseph Manzvera and Kwabena Asomanin Anaman; methodology: Joseph Manzvera and Kwabena Asomanin Anaman; data Analysis: Joseph Manzvera; supervision: Kwabena Asomanin Anaman, Akwasi Mensah-Bonsu, Alfred Barimah and Selma Karuaihe; validation: Kwabena Asomanin Anaman, Akwasi Mensah-Bonsu, Alfred Barimah and Selma Karuaihe; visualisation: Kwabena Asomanin Anaman, Akwasi Mensah-Bonsu and Alfred Barimah; writing original draft: Joseph Manzvera; writing – review and editing: Kwabena Asomanin Anaman, Akwasi Mensah-Bonsu, Alfred Barimah and Selma Karuaihe.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this study is available from the corresponding author upon reasonable request.

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