Bhutanese Farmers Perspectives on Climate Events and Agrometeorological Advisory Services

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ABSTRACT

Bhutan's agriculture sector is predominantly subsistence-based and highly vulnerable to extreme weather and climate events. As a result, Agrometeorological Advisory Services (AAS) have become increasingly important for helping farmers adapt to these challenges. In recognition of this, the 13th Five Year Plan of the Department of Agriculture prioritizes the development and delivery of effective AAS to build resilience among smallholder farmers. To assess the reliability, usefulness, and accessibility of AAS, a national survey was conducted. The findings show that while 48.1% of respondents were aware of AAS, only 45.7% of them actively used the information for making farming decisions. Awareness varied across Dzongkhags, with Punakha showing the highest awareness (90.6%), and 48.3% of those aware reported using the service. Farmers reported seven types of extreme climate events affecting their agriculture, with pests and diseases being the most common, mentioned by 77.6% of respondents. These events led to the highest reported crop loss of 204,966 kilograms. Cold waves and frost were the next most reported issues (18.7%). Awareness of AAS was highest among poultry farmers, and the service was rated as the most useful for cereal, vegetable, and fruit production. The most common sources of AAS were Bhutan Broadcasting Service (48.8%) and social media (23.4%). Among the services provided, the 24-hour and 3-day weather forecasts were considered the most useful, showing a strong demand for short-term forecasts. These findings will help guide the improvement and expansion of AAS to better support Bhutanese farmers in adapting to climate risks.

Keywords: *Agrometeorological Advisory Services, climate change adaptation, extreme weather events, smallholder farmers, agricultural resilience, Bhutan agriculture, weather forecast utilization.*

1 Introduction

The vulnerability and risks of the agricultural sector to weather and climate induced extreme events is well established. The increased frequency of extreme climate events which are driven by climate change increases the risk of food insecurity and adaptation needs of the agriculture sector (Hasegawa et al, 2021). Further, climate change induced weather patterns and disasters makes the agriculture sector highly vulnerable, threatening crop productivity and the overall

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sustainability of the sector (Zambrano-Medina et al. 2024). As the first strategy to minimize and protect agricultural communities against the wrath of extreme climate events through early warnings, the World Meteorological Organization (WMO) supports its members to develop and promote national agrometeorological and climatological services to help develop sustainable and economically viable agricultural systems (https://wmo.int/activities/agricultural-meteorology-and-food-security, nd). According to the WMO, agrometeorological advisory services help and prepare farmers to make informed decisions on different farming operations which can save them from inevitable losses. Walker (2024) has defined agrometeorological (agromet) service as the service that climate experts, using long term climate data and satellite images, provide advance information about the ensuing weather and climate to all stakeholders of the agricultural sector for making sensible farming decisions to avoid or reduce losses from weather and climate induced extreme events. Agrometeorology science can significantly support the adaptation of the agriculture sector to climate variability and climate change events (Salinger, Stigter & Das, 2000). Agrometeorology as a tool is now more robust, dynamic in responding to diverse needs, and reliable with the use of satellite-based weather and climate data monitoring systems and advancement of Information and Communication Technology (ICT) that supports rapid and concise data processing. Chattopadhyay (2018) has defined AAS as the agrometeorological and agroclimatology information which can be used by the farming communities to enhance and safeguard their agriculture-based livelihoods from the menace of weather and climate. For this study we have adopted this definition of AAS broadly referring to all the weather and climate related information and other crop advisory services disseminated to the farming communities as coping strategies to enhance their resilience to climate change impacts.

Bhutan's geographical location coupled with a mountainous topography exposes the country to frequent weather and climate hazards such as flash floods, Glacial Lake Outburst Flood (GLOF), landslides, cyclone induced storms and erratic rainfall affecting the lives and livelihoods of the people (NCHM, 2023). The Bhutanese agriculture is largely a unique smallholder mountain agricultural farming systems (Katwal and Bazille, 2020) that is highly dependent on the seasonal monsoon and the bear the brunt of fickle weather events (Katwal et al, 2015; Chogyal, Kumar and Bajgai, 2020). With only about 29% of the total agricultural land under the assured irrigation schemes (MoAL, 2023), both the small seasonal variations and extreme events can cause severe impacts to the farming communities. Further, Bhutan's economy hinges on climate-sensitive sectors like agriculture, livestock and forestry

contributing 14.67% and hydropower making another 13.40% of the GDP (NSB, 2023). The agriculture sector comprising livestock, fishery and forestry continues to remain an important source of revenues and employs 43% of the population (LFS, 2022). Recognizing the need for robust AAS, weather forecast services were started in 2007 under the then Ministry of Agriculture and Forest which is now further strengthened and upgraded to a more reliable satellite-based forecast. The agromet services is led and coordinated by the National Centre for Hydrology and Meteorology (NCHM), an autonomous agency of the Royal Government of Bhutan (Wangchuk et al, 2023).

The AAS plays a vital role as an early warning system for the smallholder farming communities precautioning them to make informed on-farm decisions against resulting inclement weather and extreme climate incidents. The Department of Agriculture (DoA) has prioritized the development and provision of robust AAS as one of its key priority areas to support climate smart agriculture and build resilience of the farmers in the current 13th Five Year Plan (FYP). The agromet services are in its formative stages as well as the awareness and utilization of the existing services by the target stakeholders are quite limited. To deepen the understanding of the status of agromet services and the perspectives of the farming communities who are the end users, a national study was undertaken with three main objectives. First to document the Bhutanese farmers perspective on climate events and its impact on the farming community; second to understand the status of the AAS, extent of use and usefulness of current AAs; and thirdly to draw lessons from farmers perspectives and experiences to further improve and strengthen the AAS. This research was implemented by the Agriculture Research and Innovation Division (ARID), DoA with fund support from World Bank (WB) as a part of the enhancement of Agro-Met Decision Support System (ADSS) for the DoA.

2 Materials and Method

The key methodology for this study was a national survey of farming households from five representative sample *Dzongkhags* (districts). A three-day training workshop was conducted to develop, pre-test, and finalize the data collection questionnaire, train and equip survey enumerators with the necessary skills for quality data collection, and identify representative Dzongkhags while determining the sample size. Furthermore, the workshop delved into sampling methods and designs, offering hands-on training to enhance participants' understanding in selecting representative samples. This component was seen to be very crucial for ensuring the validity and reliability of the data. The survey was conducted using a semi-

structured questionnaire developed in the Kobo toolbox application. It consisted of 12 modules designed to explore various aspects of Bhutanese farmers' perceptions, perspectives and experiences regarding climate events and other AAS. Data collection was carried out by enumerators using the Kobo collect application.

The survey covered five (25%) *Dzongkhags* namely Paro, Punakha, Wangduephodrang (Wangdue), Sarpang and Mongar and 11 (5%) *Gewogs* (blocks) from these *Dzongkhags* with a total respondent of 690 individuals. These locations were meticulously selected, ensuring a comprehensive representation of the agriculturally vibrant landscape and diverse agro-ecological zones (AEZ) of the country. The enumerators for this survey were Agriculture Extension Officers of the DoA posted in the *Gewogs*. The total sample size was 690 respondents from five *Dzongkhags* and 11 *Gewogs*. The AEZ size, *Dzongkhags*, *Gewogs* and number of respondents and other details are presented in Table 1.

Table 15:AEZ, Dzongkhags, Gewogs and details of respondents covered in the study

AEZ	**Dzongkhag**	**Gewogs**	**No of respondents**		
			Male	**Female**	**Total**
Warm Temperate (1200-1800 m asl)/Cool Temperate (2600 -3600 m asl)	Paro	Dopshari	14	44	58
		Loongnyi	21	36	57
		Sharpa	19	65	84
		Tsento	63	21	84
Warm temperate/Dry subtropical (1200-1800 m asl)	Punakha	Barp	13	19	32
Warm temperate/Dry subtropical (1200-1800 m asl)	Wangdue	Thedtsho	5	23	28
Wet subtropical (150-600 m asl)	Sarpang	Dekiling	52	35	87
		Gakidling	24	59	83
		Samtenling	44	20	64
	Total		320	370	690

3 Results and Discussion

The results and findings from this study are sequenced according to the three objectives of the study. The results are then used to infer the critical gaps in the current AAS as the end users' perspectives to further improve and strengthen the agromet services. There were 690 respondents of which 320 were male and 370 female (Table 1) to ensure an equal representation of gender-based perspective on climate events and agromet services.

3.1 Land Use information

Land holding size is an important factor that influences farmers' decisions on farming practices, crop selection and adoption of other farming operations. In Table 2 we present the distribution of land holdings across five sample *Dzongkhags* of Paro, Punakha, Wangdue, Sarpang, and Mongar. Across all the five Dzongkhags, the percentage of residents with large land holdings of 5 acres or more is few, with most residents falling into the land holding category of 0-2 or 2-5 acres. The national average land holding size is 2.22 acres (MoH, 2021). The size of holding reiterates that Bhutanese farmers qualify as smallholders who can be significantly affected by even small disruptions in their source of livelihoods. A high percentage of respondents fall under the category of having no land which can be explained by the fact that the respondents normally report as not having land if they have no legally registered land in their own name as the land is normally registered in the name of the head of the family (*Thram* holder). Alternatively, some respondents may possess only one category of land use. Most households in Pato fall into the category of land holding size of 0-2 acres with 71% possessing dryland and 61% wetland. In Punakha almost half of the respondents reported having no land which can be explained by the fact that the respondents were from Barp *Gewog* which is a peri-urban area with a high percentage of temporary residents who may not possess registered farmland in that *Gewog*. In Mongar, 77% of respondents own orchards followed by Sarpang with about 20%.

Table 2. Agriculture land information of the study sites

Dzongkhags	Category of Land Holdings	Dry Land (%)	Wet Land (%)	Orchard (%)
Paro (n=283)	No land	12	33	94
	0-2 acres	71	61	6
	2-5 acres	14	7	0
	5-10 acres	3	0	0
Punakha(n=32)	No land	47	34	94
	0-2 acres	53	53	6
	2-5 acres	0	13	0
	5-10 acres	0	0	0
Wangdue (n=28)	No land	18	0	100
	0-2 acres	82	64	0
	2-5 acres	0	29	0
	5-10 acres	0	0	0
	10 acres and above	1	0	0
Sarpang (n=234)	No land	0	50	79
	0-2 acres	66	40	18
	2-5 acres	30	9	2
	5-10 acres	4	1	1

	10 acres and above	0	0	0
Mongar (n=113)	10 acres and above	0	7	0
	0-2 acres	40	57	77
	2-5 acres	51	1	0
	5-10 acres	8	0	0

3.2 Crops and livestock farming in the study sites

The identification of prevalent crops and livestock was necessary to understand the use and effectiveness of AAS in relation to land use types, crops, livestock and other farming practices. While most farmers may not be formally educated, they are very intelligent and take prudent farming decisions. Through an extensive review of literature (Dessart, Barreiro-Hurlé, and Van Bavel, 2019), we have found that a careful understanding of the farmers' behavior which influences farmers decision making can lead to the development of more realistic and effective farming policies and interventions. In this study, we considered the farmers' choice of crops as an important indicator to understand the influence of climate events and its correlation to choice of crops and farming practices. In all the five *Dzongkhags,* cereals, vegetables and fruits were the most dominant crops in agriculture-based system. In the livestock-based system, cattle farming is the most prevalent in all the *Dzongkhags* (Table 3). The choice of diverse farming practices by farmers are the indicators of their strategic decision for a sustainable, integrated and climate resilient farming system. Obviously, climatic factors, land suitability, market and household needs would have significantly influenced the choice of these crops and livestock farming which is further examined in other sections.

Table 3. Dzongkhags, crops and livestock farming in the study area

Crops/Livestock	**Dzongkhag and Percentage of respondents by farming practices**				
	Paro	Punakha	Wangdue	Sarpang	Mongar
Cereals	22.90	33.80	23.50	19.10	21.20
Vegetables	24.80	27.50	24.30	24.70	21.40
Fruits	21.40	17.50	15.70	23.70	18.80
Poultry	0.60	1.30	0.90	7.00	6.30
Cattle	16.30	20.00	18.30	17.70	22.20
Piggery	0.20	NA*	NA	3.00	0.20
Forestry	0.1	NA	NA	0.40	0.20

3.3 Crops and land use types

Dryland agriculture and terraced wetland are the two dominant agriculture land uses system in Bhutan. Data was collected to know the popular crops cultivated by farmers according to the land use types.

3.3.1 Major crops cultivated in the dryland

The crops cultivated in the drylands included five cereals, 10 vegetables and one plantation crop (Table 4). In Paro the primary crops include chili, potato, green leaves, and Cole crops whereas in Punakha key crops were cole crops, chili, and maize. In Wangdue green leaves, chili, and Cole crops are dominant vegetables with maize and wheat as the two main cereals. Among all the *Dzongkhags* Sarpang has the maximum diversity as influenced by the favorable AEZ and growing season with the cultivation of a wide variety of cereals, vegetables and plantation crops. In Mongar maize, potato, chilli and green leaves are reported to be the major crops.

Table 4. Dzongkhag, crops and percentage of respondents growing crops in dryland

Crops	**Dzongkhag and Percentage of respondents cultivating the crops**				
	Paro	Punakha	Wangdue	Sarpang	Mongar
Paddy	0.60	NA	3.10	3.20	0.20
Maize	1.80	17.90	3.10	15.90	22.20
Wheat	8.40	NA	6.30	NA	6.40
Upland paddy	NA	NA	NA	NA	NA
Millet	0.70	NA	NA	3.30	NA
Potato	16.50	NA	NA	5.20	21.60
Winter Potato	NA	NA	NA	9.00	3.00
Chilli	19.40	28.20	31.30	15.70	18.20
Asparagus	5.20	2.60	NA	0.40	0.40
Carrot	7.80	NA	NA	0.60	0.80
Green Leaves	11.10	15.40	46.90	13.70	18.00
Cole Crops	10.40	35.90	9.40	14.00	9.00
Peas	4.00	NA	NA	2.30	0.20
Turnip	8.10	NA	NA	0.20	NA
Beetroot	5.80	NA	NA	NA	NA
Arecanut	0.10	NA	NA	16.40	NA

3.3.2 Major crops cultivated in the wetland

Under the wetland production systems, it is rational to find paddy as the dominant crop in all the Dzongkhags except for Sarpang which has 20.90% arecanut. Among the cereals maize and wheat are popular as they fit well in sequence after rice. Besides cereals, potatoes and different types of vegetables are also cultivated in the wetland (Table 5).

Table 5. Dzongkhag, crops and percentage of respondents growing crops in wetland

Crops	Dzongkhag and Percentage of respondents cultivating the crops				
	Paro	Punakha	Wangdue	Sarpang	Mongar
Paddy	53.10	56.00	42.90	16.70	88.50
Maize	0.50	6.00	1.60	16.10	1.90
Wheat	12.60	22.00	14.30	NA	NA
Millet	NA	NA	NA	1.50	NA
Potato	6.70	NA	1.60	4.50	3.80
Winter Potato	NA	NA	NA	7.90	NA
Chilli	14.60	NA	9.50	11.80	1.90
Asparagus	1.20	NA	NA	o.30	NA
Carrot	1.20	NA	4.80	0.60	NA
Green Leaves	3.00	2.00	19.00	6.70	1.90
Cole Crops	1.70	14.00	6.30	11.20	1.90
Peas	4.40	NA	NA	1.50	NA
Turnip	0.50	NA	NA	0.30	NA
Beetroot	0.50	NA	NA	NA	NA
Arecanut	NA	NA	NA	20.90	NA

3.3.3 Climate and its related events observed

The respondents reported seven different types of extreme climate events which have affected their crops and other agricultural enterprises. Among the seven different climate and its related events most respondents reported the occurrence of pests and disease followed by drought (Figure.1). The least observed climate events were cyclones and flood. In 2023, based on the frequency of occurrence, 77.6% of respondents said pests and disease while 18.7% mentioned cold wave and frost (Table 6). In general, Bhutanese agriculture sector is proven to be highly exposed to the impact of climate change triggering natural calamities including the emergence of new pests and diseases (MoAL, 2023). These observations are also in line with the findings

reported by Chogyel, Kumar & Bajgai (2020) who investigated the potential ramifications of extreme climate and weather events in Paro, Punakha, Wangdue and Sarpang *Dzongkhags* where farmers reported erratic monsoon rains, droughts and windstorms as the most common extreme events causing crop losses. In the Chitwan district of Nepal which has a similar socio-economic landscape like Bhutan, a study Bajracharya et al, (2023) have also recorded drought, flood, erratic rainfall, and hailstorms as the most commonly occurring extreme events perceived by farmers. Furthermore, the population dynamics of agricultural insect pest and diseases are influenced by climatic factors mainly temperature, rainfall and humidity and extreme climate events can enhance the incidence of pest and disease-causing significant production losses (Subedi, Poudel & Aryal, 2023). The emergence of new pests and diseases like Fall Armyworm in maize, incessant rainfall during rice harvest season in 2021 affecting 2500 acres of rice amounting to a production loss of 2,400 Mt and the outbreak of 13 different animal diseases at an epidemic scale are associated with climate change (MoAL, 2023). The findings and records from such studies further corroborate the farmers' observation of pests and diseases as an emerging extreme event triggered by climate change.

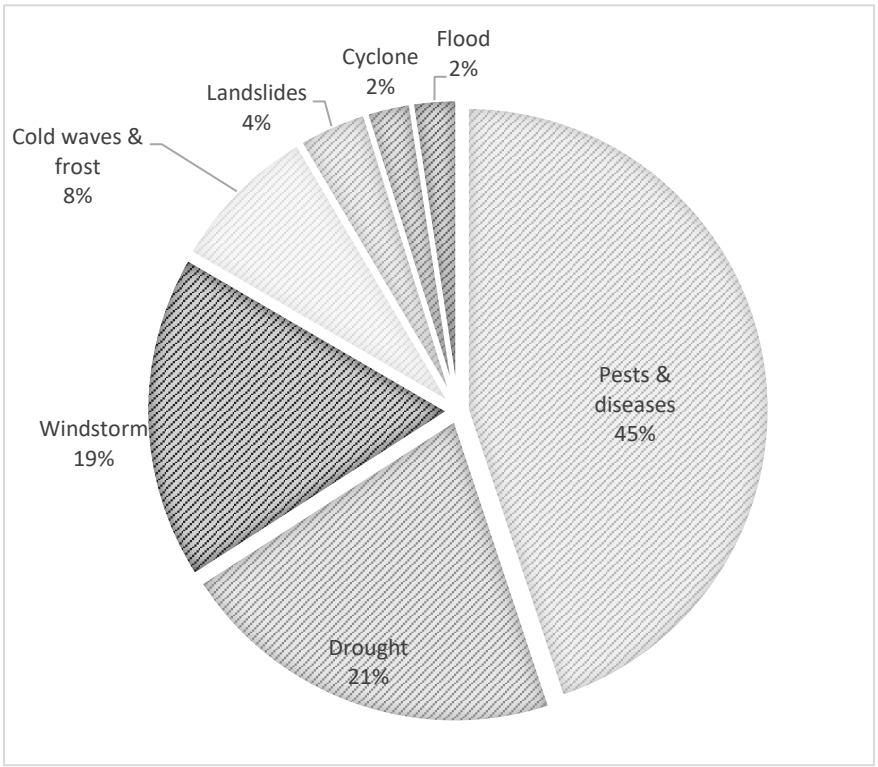

Figure 14: Climate/weather and related events experienced till 2022 by the respondents

Table 6. Frequency of pests & diseases, and cold wave & frost observed in 2023

Frequency of occurrence	Pests & diseases (%)	Cold wave & frost (%)
1-2 times in a year	77.6	18.7
3-4 times in a year	6.9	0.7
5-6 times in a year	1.3	0.1
More than 6 times in a year	0.3	0.6
Never	13.9	79.9

To estimate the crop losses respondents were first asked to recollect the extreme weather events that occurred in 2023 and provide their estimate of crop losses caused by the events. The respondents reported seven different weather and related events, namely pests and diseases, droughts, storms, landslides, floods and cyclones. Among these events, 55% of the respondents reported pests and diseases as the most frequent event causing the highest total production loss of 204,966 Kgs in all four categories of crops (Table 7). Drought was the second most observed event while cyclone was reported as the least observed event in 2023. Of the four types of crops, maximum loss was estimated for vegetables followed by fruits, cereals and spices (Table 7). This data indicates that a careful choice of the types of crops is an important coping strategy to reduce the impact of extreme events. The extreme weather events recorded by the meteorological stations of the NCHM in the five surveyed Dzongkhags further confirm the incidences of extreme events in the form of 24-hour rainfall, maximum temperature and minimum temperature (NCHM, 2024).

Table 7. Crops and estimated production loss due to climate/weather and related events in 2023

Climate Events	Respondent who reported the events (%)	Crops & Estimated Production lost (Kg)				
		Cereals	Vegetables	Fruits	Spices	Total (Kg)
Pest & Diseases	55	15708	30447	47421	490	94066
Droughts	23	22856	67476	3530	0	93862
Storms	15	2985	205	5870	0	9060
Landslides	5	80	500	2600	80	3260
Floods	1	3180	618	200	0	3998
Cyclones	1	100	620	0	0	720
Total	100	44909	99866	59621	570	204966

3.3.4 Agrometeorology Advisory Services (AAS)

The NCHM and DoA are striving to provide reliable real time agromet and crop advisory services to the farmers through national broadcasting and social media platforms. Farmers

comprise the last mile end users and the most vulnerable in the agricultural value chain. Vedeld et al, (2020) who compared weather and climate services in Norway and India have concluded that reliable and efficient AAS is essential to adapt and avert risks in agriculture sector. Such services which are targeted for the farming communities can be made more efficient, usable and integrated with local farming practices by leveraging the application of social media tools. Further, to facilitate Climate Smart Agriculture in India, the India Meteorological Department (IMO) disseminate the crop AAS and alerts through print, visual, radio and other IT based media tools such as short message service (SMS) and Interactive Voice Response Service (IVRS) to help farmers to take quick farming decisions that can prevent crop losses (Amith et al, 2022). To continuously improve and ensure that AAS is useful to the end users it is important to know their level of awareness. The awareness of the farmers on AAS varied significantly (Table 8). Overall, 48.1% of respondents were aware of the AAS but only 45.7% of them genuinely used it to make farming decisions. Punakha had the highest awareness at 90.6%, with 48.3% of those aware using the information. In contrast, Mongar had the lowest awareness at 13.3% and only 33.7% of those aware utilized the AAS. Farmers' feedback on the AAS should be taken as benchmark by the service providers to further improve and strengthen the AAS.

Table 8. Awareness and adoption of AAS

Dzongkhags	**Awareness Level (%)**		**Respondent who are aware and use the services (%)**	
	Yes	**No**	**Yes**	**No**
Punakha	90.6% (29)	9.4% (3)	48.3% (14)	51.7(15)
Wangdue	82.1% (23)	17.9% (5)	69.6% (16)	30.4% (7)
Paro	78.8% (223)	21.2% (60)	39% (87)	61% (136)
Sarpang	17.9% (42)	82.1% (192)	71.4% (30)	28.6% (12)
Mongar	13.3% (15)	86.7% (98)	33.7% (5)	66.7% (10)
Total	48.1% (332)	51.9% (358)	45.7% (152)	54.2% (180)

A binary logistic regression analysis (Table 9) was conducted to examine the factors influencing awareness of Agrometeorology Advisory Services. The results indicated that location and literacy were significant predictors. Individuals from Paro ($B = 3.246$, $p < 0.001$), Punakha ($B = 4.353$, $p < 0.001$), and Wangdue Phodrang ($B = 3.608$, $p < 0.001$) exhibited significantly higher levels of awareness compared to those from Mongar. Additionally, individuals who could read and write ($B = 0.784$, $p < 0.001$) were more than twice as likely to be aware of the services ($Exp(B) = 2.191$) compared to those who could not. However, gender

(B = -0.155, p = 0.5) and head of the family (B = 0.176, p = 0.412) did not significantly impact awareness levels. These findings suggest that geographic location and literacy are the primary factors influencing variations in awareness of Agrometeorology Advisory Services. Dzongkhags such as Paro, Punakha, and Wangdue Phodrang are relatively more developed, with better road connectivity, greater media reach, and early adoption of agrometeorological services. Consequently, differences in accessibility, outreach activities, and development infrastructure likely contribute to the disparity in awareness across regions. Interestingly, despite high awareness in Paro, Punakha and Wangdue, actual usage of the services tends to be lower. This may be attributed to a cultural tendency among farmers in these regions to rely heavily on peer practices, observing and emulating what fellow farmers do. This pattern aligns well with findings from the study conducted in the southern India where the farmers' initial exposure to agro-meteorological advisories often occurs through fellow farmers, underscoring the centrality of word-of-mouth dissemination (Venkatasubramanian, Tall, Hansen, & Aggarwal, 2014).

Table 9. Factors influencing awareness of Agrometeorology Advisory Services

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1a	Monggar			205.109	4	0	
	Paro	3.246	0.323	101.121	1	0	25.692
	Punakha	4.353	0.676	41.443	1	0	77.692
	Sarpang	0.22	0.337	0.426	1	0.514	1.246
	Wangdue Phodrang	3.608	0.579	38.886	1	0	36.89
	Gender	-0.155	0.229	0.454	1	0.5	0.857
	head_family	0.176	0.215	0.674	1	0.412	1.193
	Write and read	0.784	0.22	12.729	1	0	2.191
	Constant	-2.121	0.516	16.89	1	0	0.12

A Variable(s) entered step 1: dzongkhag, Gender, head family, Write and Read.

3.3.5 Sources for AAS

Rural communities require and rely on the most convenient source for their AAS needs. We investigated the popularity of the different sources that relay AAS to the farming communities in the five *Dzongkhags*. In all the five *Dzongkhags,* the Bhutan Broadcasting Service (BBS) television was identified as the most used source for AAS by 48.80% of respondents followed by social media (23.40%) (Figure. 2). This can be explained by the fact that BBS television broadcasts in the national language. With the wide use of mobile phones by rural communities, social media platforms through interactive voice messages are gaining popularity. The NCHM

website apparently was the least used source because most of the rural communities are not literate to access websites.

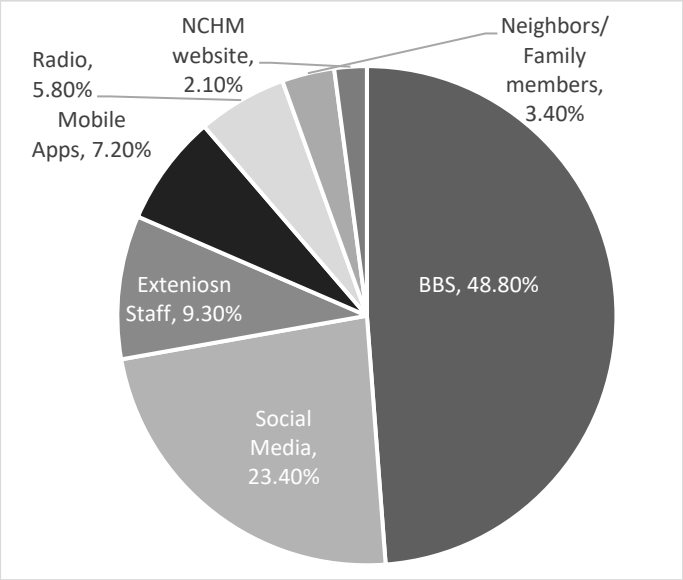

Figure 15: Sources of AAS

When the data on the different sources was disaggregated by Dzongkhags, BBS was still ranked as the most popular source except in Wangdue which ranked social media as the most popular (Table 11). After BBS and social media forums, *Gewog* Agriculture staff served as the next important source of AAS. In Mongar, neighbors and family members (45.5%) served as an important source for agromet information which could perhaps be facilitated by social media forums. It is very encouraging to note that there were no respondents in all five *Dzongkhags* who responded that they had no idea on the AAS. This is a very positive indicator of the usefulness, need and source of AAS. The least source was the NCHM website, which is understandable as our clients are the rural population.

Table 11: Dzongkhags and various sources of AAS

Dzongkhags	**Categories of Source and Respondents (%)**								
	Newspapers	**BBS**	**Social media**	**Extension staff**	**Radio**	**NCHM websites**	**Neighbors & family**	**Weather Apps**	**No idea**
Paro	0	62.8	27.7	4.4	0	2.2	1.5	1.5	0
Punakha	0	46.4	28.6	17.9	7.1	0	0	0	0
Wangdue	0	33.3	56.3	16.7	13.9	0	5.6	5.6	0
Sarpang	0	32.9	15.2	12.7	12.7	3.8	1.3	21.5	0
Mongar	0	45.5	9.1	0	0	0	45.5	0	0

3.3.6 Farmers' perception of the usability of AAS

One of the important AAS services is the weather forecasting for farmers to know in advance the ensuing weather conditions. Any weather forecast is perceived as the best if it is accurate and reliable which translates to the usability of the forecast. Respondents were asked to rate the four different frequencies of forecast currently provided through the AAS into four categories namely very useful, useful, not useful or neutral. The percentage of respondents rating the 24-Hour Forecast and Three day forecast as either very useful or useful was the highest (Figure.3). The rating trend of very useful or useful decreased as the frequency of forecast increased. There was a high percentage of respondents who remained neutral for three days, 10 days and monthly seasonal forecast indicating that these forecasts were not very effective as compared to 24 Hour forecast which had less than 8% respondents under the neutral category.

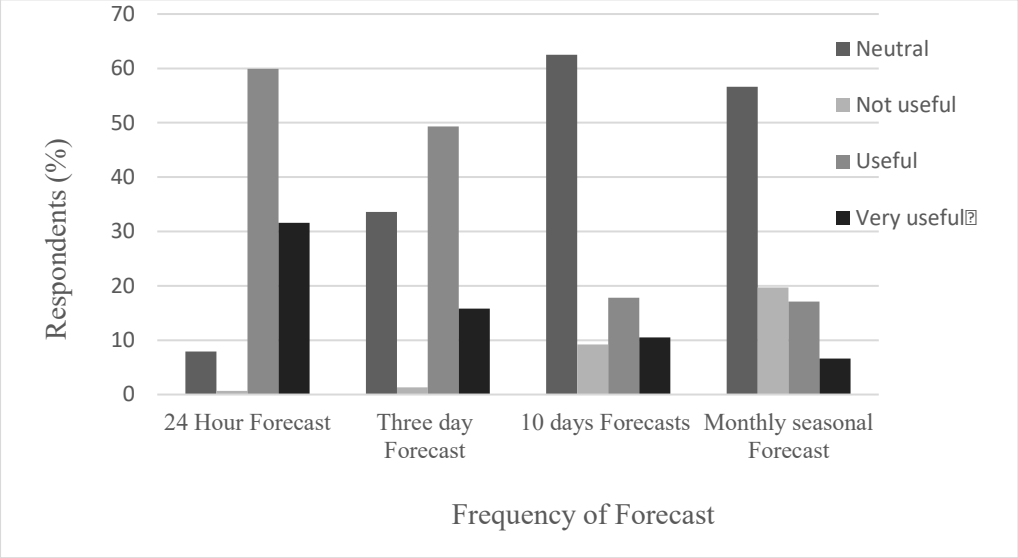

Figure 16. Rating of the usability of forecasting service by frequency of forecast

3.3.7 AAS use based on crops and farming steps

The most logical and widespread coping strategies adopted by subsistence farmers to avert risk from crop failures is the cultivation of diverse crops. Farmers use their experience and indigenous knowledge to select the crops. AAS requirements for crops vary depending on their agronomic needs and crop husbandry practices. We assessed the usefulness of AAS by categories of crops grown by the respondents. Most of the respondents perceived that AAS is useful in cereals (57.9%), vegetables (37.5%) and fruits (24.3%) (Figure. 4). The use of AAS

was rated the least for spices and Medicinal and Aromatic Plants (MAPs) due to the versatile nature and ability of these crops to tolerate climate extremes.

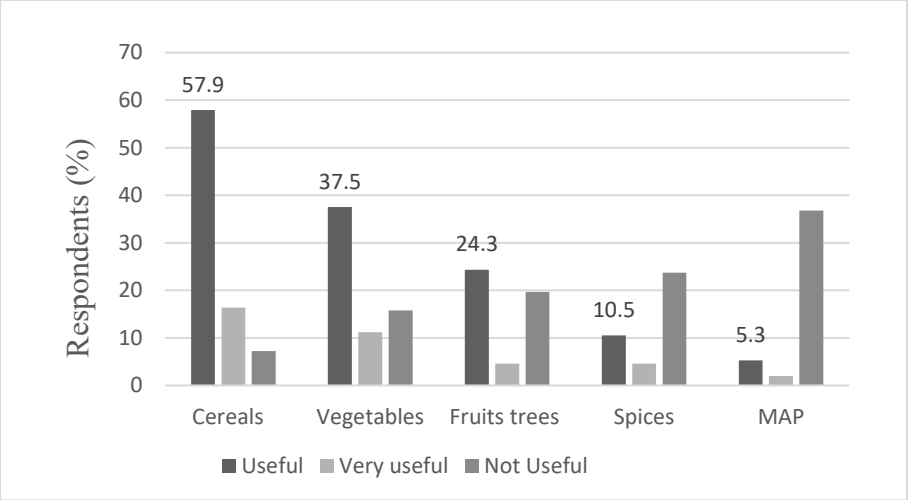

Figure 17: AAS use by crops

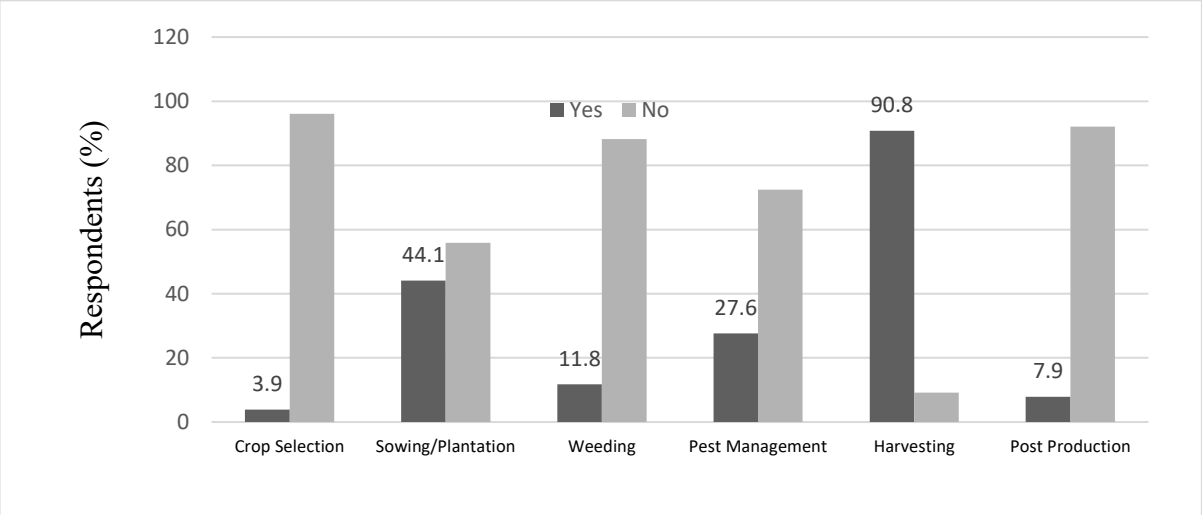

Figure 18. AAS use based on farming steps

The survey found that the use varied depending on the farming stages. According to the respondents AAS is predominantly used for decision making during harvesting (90.8%) followed by the sowing/plantation (44.1%). Farmers consider harvesting and sowing/plantation as the most critical farming steps where AAS can benefit them. At present AAS is the least used by farmers for crop selection (3.9%).

3.3.8 Suggestions to improve the AAS

The direct and most important beneficiaries of AAS are rural communities. To improve and strengthen these services, respondents were asked to provide suggestions based on their perceptions. The majority (43.5%) recommended enhancing the quality and accuracy of AAS. Additionally, 16.5% called for more detailed information, 14.3% suggested simplifying the content, 7% requested sector-specific advisories, and 18.7% had no specific suggestions (Figure. 6).

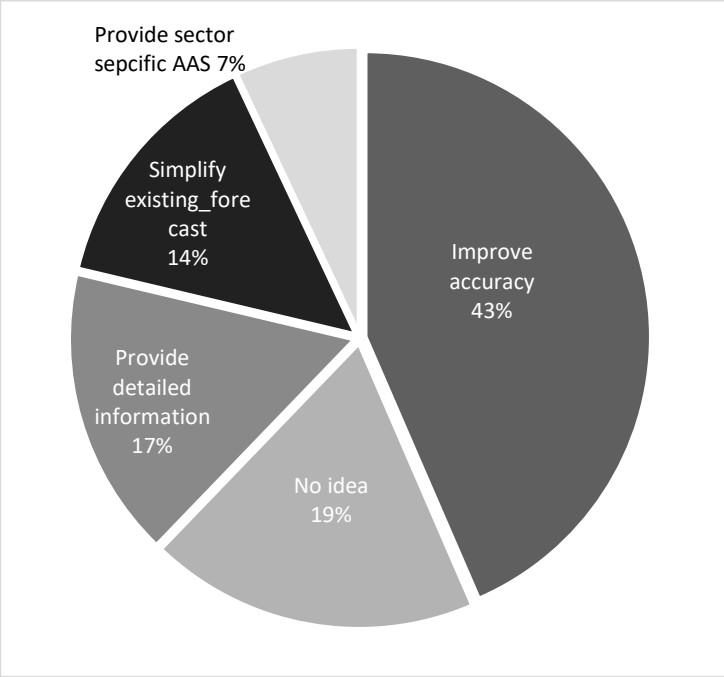

Figure 19: Suggestions for improving AAS

Findings from the binary logistic regression further highlight the importance of tailoring AAS delivery to specific user contexts. Awareness of AAS was significantly higher in Dzongkhags such as Paro, Punakha, and Wangdue Phodrang, likely due to better access to infrastructure, media, and extension services. Similarly, literacy was found to be a strong predictor of awareness, indicating that individuals who can read and write are more likely to understand and utilize the advisories.

According to WMO (2024), AAS can only achieve their intended positive impacts when they are delivered on time, in easily understandable language and format, and are specific to the local context. Therefore, improving AAS requires not only technical enhancements such as greater accuracy and detail, but also a focus on localized outreach strategies, simplified

communication for low-literacy users, and increased coverage in underserved Dzongkhags to ensure equitable access and adoption across rural Bhutan.

4 Conclusion

Bhutan’s mountainous terrain and fragile Himalayan landscape make it highly susceptible to extreme weather and climate events such as droughts, hailstorms, frost, flash floods, cyclones, and outbreaks of new pests and diseases affecting both crops and livestock. These events, regardless of their scale, have a disproportionate impact on smallholder subsistence farmers who have limited financial resources and adaptive capacity, making them especially vulnerable to climate shocks.

The country's complex topography creates diverse microenvironments even within short distances, which poses additional challenges in developing and disseminating uniform, timely, and reliable Agrometeorology Advisory Services (AAS). Despite these challenges, current initiatives by the National Center for Hydrology and Meteorology (NCHM) and the Department of Agriculture (DoA) to deliver AAS to last-mile users are showing promise. The study revealed that 48.1% of farmers were aware of the AAS, and 45.7% of them actively used it in their farming decisions—an encouraging indication of its relevance and potential.

However, the findings also expose significant gaps in awareness, access, and utilization of AAS across different Dzongkhags. Geographic disparities and literacy levels emerged as major factors influencing awareness, while gender and family roles had little effect. Moreover, the study underscores the need for short-term, localized forecasts that are more relevant to farmers' immediate decisions—particularly for harvesting and sowing—rather than generalized long-term advisories.

Farmers’ feedback calls for improved accuracy, simplified content, and more detailed, sector-specific advisories. As Bhutan's information and communication landscape evolves, there is a timely opportunity to leverage digital platforms and localized delivery mechanisms to enhance AAS outreach.

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6 Authors' contribution statement

Mr. Chimi Rinzin led the conceptualization of the research, developed the survey questionnaire, coordinated the field survey, and led the data analysis. Mr. Tirtha Bdr Katwal provided leadership in developing the conceptual framework, contributed significantly to the writing of the manuscript, and offered overall guidance throughout the research process. Mr. Tshering Wangchen, as the focal person for the Agrometeorology Project under the Department of Agriculture, played a key role in securing research funding, coordinating on-ground implementation, and contributing to research design and conceptualization. Mr. Ngawang supported the development of the survey questionnaire, assisted in coordinating the field survey, and contributed to the data analysis.

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