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Opportunities and barriers for using climate information services for resilient agriculture: Insights from the baseline study in Chitwan, Nepal

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ABSTRACT

Climate variability and change have affected the agriculture sector in Chitwan district, where farmers have confronted climate-related risks like drought, flood, erratic rain, and hailstorms. Close to two-thirds of farmers have reported that climate variability has largely affected the crop production on their farms. With climate risks and vulnerability projected to increase in the future, climate information services play a vital role in helping farmers build resilient livelihoods. About 67 percent of farmers have access to some form of climate information, which has largely been limited to the onset of rains. Different socioeconomic factors like age, education level, ownership of assets and contribution of farm income to overall household income significantly affect the functional access to and use of existing climate information services. In addition to this, the provision of the existing climate information services has been limited to the district or national level. There is an urgent need for improved access to reliable and easily available climate information and agro-advisory services at the local level.

Practical Implications

- Climate change has profoundly affected the farmers in Chitwan in terms of change in cropping patterns, largely due to variability in temperature and rainfall patterns. Farmers are now continuously confronted with climate-related risks like droughts, floods, erratic rain, and hailstorms. Close to two-thirds of respondent farmers (63.51%) reported that climate change has largely affected crop production on their farm. Addressing these effects through appropriate farm-level interventions supported by timely access to and use of accurate climate information to build resilience of small holder farmers is vital to ensure their food security.
- Our findings show that about 67 percent of the respondent farmers have access to some form of climate information, which has largely been limited to information on the onset of rain and temperature, with the advisory part of it lacking. The primary reason for this is the limited functional access to these services. Functional access to and use of existing climate information services is determined by various sociodemographic factors like age, education level, ownership of assets like mobile phones and contribution of farming to overall household income.
- The scope of the existing climate information and advisory services has been limited mostly to the national or district level at best. This calls into question the reliability, accuracy, and relatability of the information at the local level. Microclimate is a prominent factor, with local level forecasts and advisory services key to farmers' decision-making at the farm level. The provision of localized climate information relating to weather forecasts coupled with pertinent agro-meteorological advisory services is the need of the day.
- As improved access is essential for adoption and use of climate services, strengthening the capacity of local agencies to facilitate the generation and dissemination of advisories at the local level is vital. At the same time, strengthening institutional arrangements and governance – with public and private partnerships in developing and disseminating customized climate services looks to be a viable and sustainable option.

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Climate change is a defining issue that is a global phenomenon affecting everyone. Whether it be shifting weather patterns that affect food production or rising risks of catastrophic flooding, the impacts of climate change are unprecedented in scope and scale (UN, 2022). It is particularly damaging to the global food production potential, with wide-ranging impacts on the small-holder farmers of the world. It is estimated that over 500 million smallholder farms who produce more than 80 percent of the world's food that employ 750 million extremely poor farmers working in agriculture are vulnerable to the effects of climate change. Furthermore, estimates indicate that weather variability accounts for 20 to 80 percent of inter-annul variability in yields, with weather variability accounting for 5 to 10 percent loss of national agricultural production (FAO, 2019; Dobardzi et al., 2019).

At a national level, climate variability poses enormous pressure and costs on livelihoods of the people and the economy in Nepal (Sapkota and Rijal, 2016). Agriculture is still considered a mainstay of the country, with over 60 percent of the population relying on it, and this has far-reaching repercussions (MOALD, 2022). An example of this can be seen from the severe winter droughts in 2006 and 2009. It had a significant impact on agriculture, resulting in food deficits of 400,000 tons and subsequent increases in food prices by 117–300 percent in various locations (UNDP, 2013; Wang et al., 2013). During the 2009 drought, most monitoring stations received less than 50 percent of normal rainfall, 30 percent did not receive any precipitation, and temperatures were 1-20°C above average. This resulted in a 14.5 percent decrease in wheat and 17.3 percent decrease in barley production at the national level (Dixit, 2010).

Climate risks and vulnerability in Nepal are projected to increase in the future. It is projected that temperatures will increase between 1.3 and 3.8 °C by 2060 (MoPE, 2016). Variations in the weather patterns and hydrological regimes are also expected, with an incidence of wetter monsoon summers and dryer winters expected in the future (CCKP, 2021). This will undoubtedly have consequences for the agriculture sector moving forward.

In this context, climate information services play a vital role in assisting smallholder farmers to build resilient livelihoods by anticipating climate risks and taking preventive measures. Climate information that includes both short-term weather forecasts and longer-term climate change information coupled with the provision and contextualization of information and knowledge constitutes climate information services (Nkiaka et al., 2019; Singh et al., 2018; Vaughan and Dessai, 2014). An agronomic advice on farm management decision making with the provision of weather forecasts and seasonal climate information is the key to organizing agricultural activities (Arunkumar et al., 2015) to make the smallholder farmers resilient (Antwi-Agyei et al., 2021). This will aid to optimize farmers resources and reduce adverse impacts of weather-related hazards in agriculture (Jagadeesha et al., 2010). Therefore, it is the aim of this study to explore the climate services landscape in Chitwan, Nepal to observe the status and use of existing climate services and learn about opportunities and barriers that lie ahead for the successful provision of these services.

Study design and methods

Study area

Over the past few decades, Chitwan district has experienced drastic changes in the cropping systems from rice-wheat-maize to rice-vegetable-maize, and maize-millet in the face of changing climate. This has been largely due to the increase in variability in temperature and rainfall patterns (Paudel et al., 2014). The district is ranked as highly vulnerable as per the vulnerability index (VI) with the overall VI lying in the range of (0.601–0.786). In addition to this, the risks and impacts vary within the district because of altitudinal and climatic variations (Maharjan and Maharjan, 2020). Hence, the International Centre for Integrated Mountain Development (ICIMOD) in collaboration with the local stakeholders-Agriculture Knowledge Centre (AKC) and FORWARD Nepal selected four municipalities considering the diversity, accessibility, and majority area with prominent crops in the district as the study areas to assess the status of use of climate information services at a local level. Ratnanagar, Kalika, Khairahani and Madi municipalities were selected for this purpose (Fig. 1).

Research methods & data analysis tools

The study used a concurrent triangulation mixed methods research approach (a combination of quantitative and qualitative research elements) to assess the status of use of climate information services for evidence-based agriculture planning in the study areas. A quantitative data collection tool in the form of a household survey was used to collect information regarding the awareness, access and use of existing climate information services coupled with socioeconomic and agriculture-related data from the communities. The tool was specifically used to gather information relating to different determinants of access to, awareness of and use of existing climate information.

The sample size for the household survey was determined using Cochran's method (Cochran, 1977). The Cochran's formula has been applied for small population of a known size of 502 using the following formula:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

In the sample estimation formula, values of estimated proportion (0.4), confidence level (95%) and margin of error (0.05) were used. A probability proportional to size sampling technique was used to obtain the number of households to be surveyed in each ward, which were selected randomly. The sampling frame consisted of 502 farm households who had registered with the study database of the project. The farmers' database is expected to aid in providing agro-advisories as well as feedback to the operators of climate services once it is in place and operational. In total, about 211 registered farmers were interviewed (Table 1).

A qualitative research element that included the administration of focus group discussions (FGD) and key informant interviews (KII) were also conducted to triangulate and validate the quantitative data collected as well as gain further insights and details from the study areas. The focus group discussions were conducted with heterogeneous groups that included farmer cooperatives, individual farmers from the community, associations of producers and farmers, etc. These groups involved individuals from both genders, with women's participation particularly encouraged. A total of eight FGDs – one in each ward – were conducted in the study sites. The FGDs were conducted to learn about the farmers' understanding on climate change, its effects and possible local mitigation strategies as well as their perceptions on access and use of climate information services. Similarly, key informant interviews were conducted with representatives of local governments in the agriculture section of municipalities and the AKC. The key informants provided information on existing status of provision, utilization and dissemination of climate information services, sources of climate information, existing capacity of institutions and stakeholders, underlying gaps in climate information services. They were also asked about their experiences and knowledge on climate change risks and coping strategies used by them.

The research approach can be summarized in the form of Fig. 2 below:

The quantitative data analysis has been carried out in the statistical software (STATA) to obtain tabulations and perform regression analysis. A Heckprobit model was used to assess the determinants of access to, awareness of and use of existing climate information. This model was applied as a farmers' decision to use the climate information involves a two-step process that involves awareness of and access to climate information, and then utilization in farm decisions. In the two-step

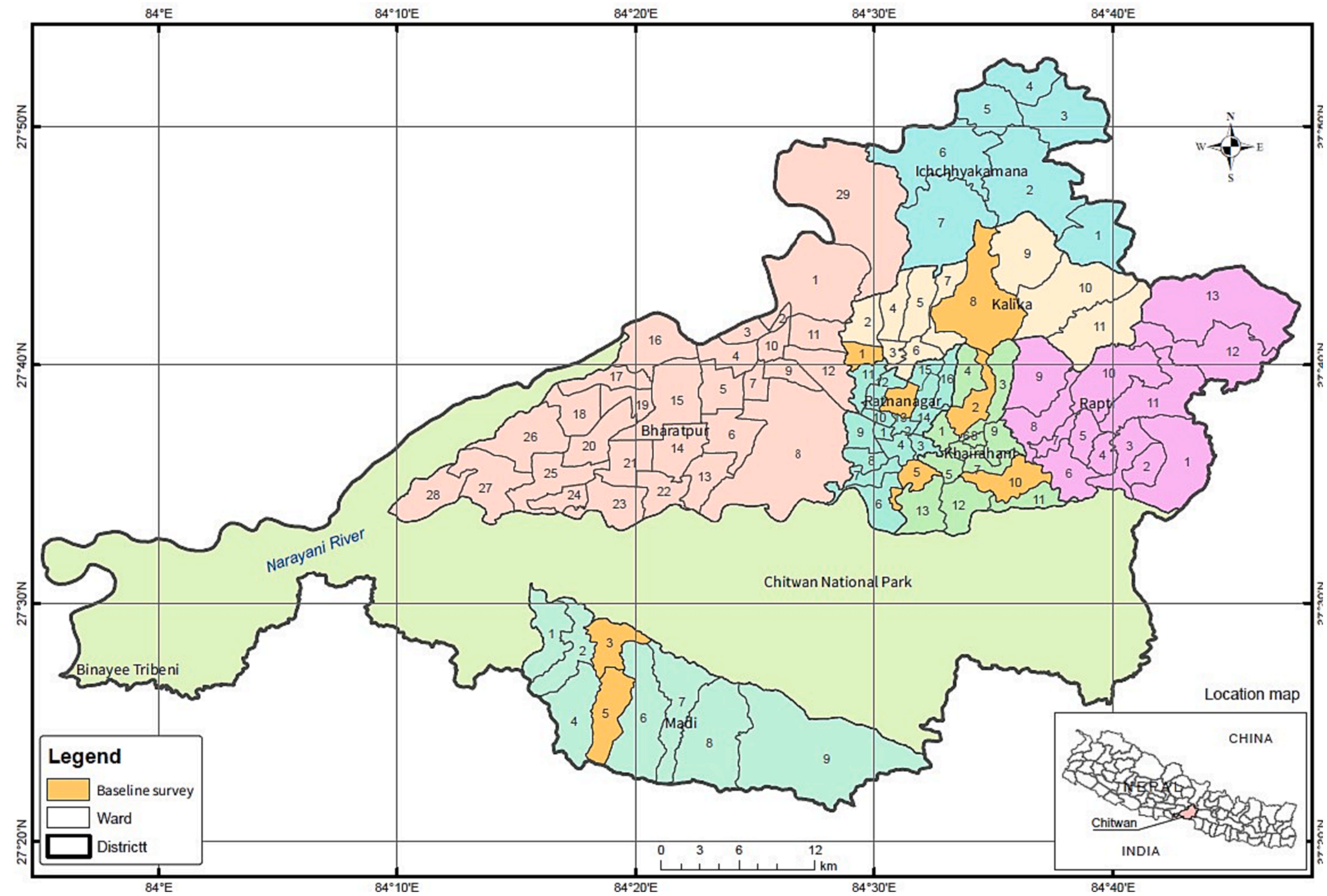

Fig. 1. Location of study area.

Table 1
Number of sampled households and sampling frame.

Study area	Sampling frame (No. HHs)	Sample size (No. HHs)
Kalika-1	53	23
Kalika-8	69	36
Khairahani-2	60	21
Khairahani-10	74	47
Madi-3	68	34
Madi-5	57	11
Ratnanagar-5	58	15
Ratnanagar-13	63	24
Total	502	211

process, use of climate information is a sub-sample of the first (awareness and access to climate information). As the sub-sample is most likely to be non-random which creates a sample selection bias, a heckprobit model (a modification of Heckman two-step model) is used to correct this selectivity bias. (Van de Ven and Van Praag, 1981).

The model specifications can be described as below adopted from Muema et al. (2018)):

$Y2 = \beta X_i + \beta_\lambda \alpha_i + \varepsilon_{1i}$ Main Equation

$Y1 = \alpha Z_i + \varepsilon_{2i}$ Selection Equation

$Y2 = \beta X_i + \varepsilon_{1i}$Latent Equation

Here, ε_1 and $\varepsilon_2 \sim$ N[0,1]; Corr[$\varepsilon_1 \varepsilon_2$] = ρ.

The main equation is the second stage with the inverse mills ratio as an additional explanatory variable to solve for the selectivity bias. Y2 (use of climate information) was deemed meaningful if Y1 (awareness and access to climate information) = 1. β and α are vector of coefficients for the independent variables with X_i and Z_i representing the exogenous variables that are mostly socioeconomic variables of interest. Y1 (awareness of and access to existing climate information) looks to measure if the farmers are aware of any type of climate information relating to forecasts that is presently available (in the form of indigenous knowledge, short-term forecasts, etc.) with access to climate information capturing if it (mostly relating to forecasts) is accessible to the farmers. A new variable in the form of combination of awareness and access to climate information was constructed based on the logic that effective accessibility involved both access to and awareness of the existence climate information in line with various other studies (Fay Buckland and Campbell, 2021; Weaver and Shannon, 1963). Similarly, Y2 (use of climate information) seeks to capture if the farmers are using climate information for farm level decisions.

Using these methods and tools, the paper is looking to answer the following research questions: i) what is the farmers' perception of climate risk, change, and impact on agriculture? ii) what factors determine the farmers' awareness of, access to and use of climate information for farming decisions? iii) what are the barriers to evidence-based decision making in resilient agriculture? iv) what opportunities exist for increased access to, adoption of, and use of climate services?

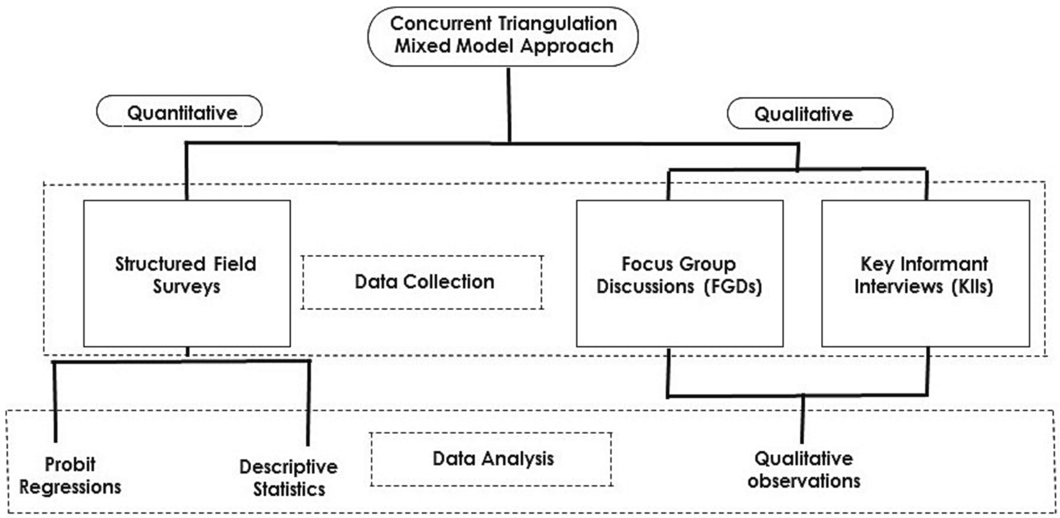

Fig. 2. Research Framework.

Results and discussion

Farmers' perception of climate risk, change and its impact on agriculture at local level

Farmers in the study area are confronted with several climatic risks. Drought, erratic rainfall, and hailstorms have been considered the major climate risks that plague the farmers. Flood risks, however, have been considered a major climate risk only in Madi. Similarly, an increase in erratic rainfall patterns leading to drought episodes has become a common problem in the region. Most of the respondent farmers reported drought (36.49%) as the first prioritized climate risk, followed by erratic rainfall (33.18%), hailstorms (17.06%), and floods (4.27%). An increase in temperature and a severe winter was considered as major climatic risks by 2.84% and 5.21% of the total respondents.

The farmers' perceptions can be corroborated from the precipitation data obtained from Department of Hydrology and Meteorology (DHM) in Nepal as there have been fluctuations in the precipitation levels over the years. The rainfall data from three meteorological stations in Chitwan (Bharatpur, Jhuwani, and Rampur) over the period of 1989–2019 (Fig. 3) show that it deviated highly ($\sigma = 432.78$ mm) and has observed a decreasing trend of 2.9 mm per year. The average annual mean, maximum and minimum temperatures in Chitwan district of 24.4 °C, 30.88 °C, and 17.8 °C have been observed respectively over this period. The observed annual mean temperature ($\sigma = 0.54$ °C) ranges from 22.18 °C (2012) to 25.12 °C (2019), the annual maximum temperature ($\sigma = 0.37$ °C) ranges from 30.15 °C (2015) to 31.78 °C (1994), and the annual minimum temperature ($\sigma = 0.91$ °C) ranges from 13.91 °C (2012) to 19.12 °C (1998).

Climate variability and change have affected the agriculture sector. Close to two-thirds of respondents (63.51%) reported that climate change has largely affected crop production on their farm, while 33.65% of the total respondents had experienced a moderate effect of climate change on crop production. Small proportion of the total respondents (2.37%) reported that they were experiencing a slight effect of climate change on crop production, while 0.47% of the total respondents did not know about any visible effect of climate change on crop production.

The majority of farmers reported decreased productivity, increased disease and pest incidence, rising irrigation costs, post-harvest losses, and crop quality decline. The farmers have been witnessing the most productivity declines in spring season rice, main season rice, potato, and chili, with a response rate of close to one-third of respondents reporting this in the study areas. About one-fifth of the farmers opined that there had been a decline in the productivity of tomato and banana. Around a

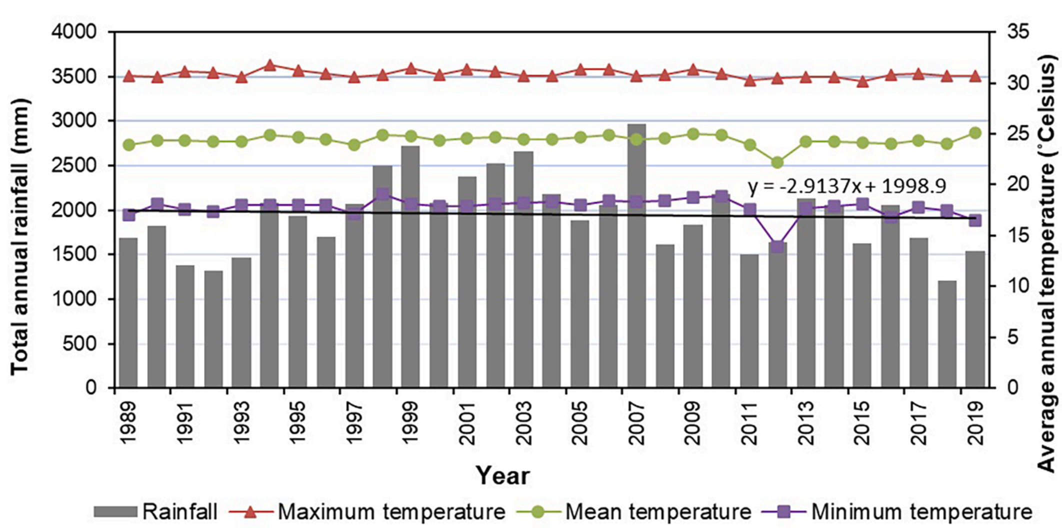

Fig. 3. Annual Rainfall and temperature in Chitwan district (1989–2019).

quarter of the farmers have also reported post-harvest losses in chili, spring rice, and main season rice. Pest infestations had also been reported in main season rice, spring rice, chili, and banana, with over 40 percent of farmers reporting this phenomenon. Accordingly, the quality of the produce has also seen a decline, mainly for tomato, potato, and spring rice, as reported by farmers.

Status of availability, and access to existing climate information services

Climate information and advisory services have been limited mostly to the national or district level at best. In Nepal, the Agricultural Management Information System (AMIS) is the first attempt at bringing experts from multidisciplinary teams to jointly generate agriculture-related information and disseminate climate information to support farmers (Timilsina et al., 2019). In its current form, this system is highly centralized and based in the capital city (Kathmandu), involving experts who deal with large and highly variable agriculture conditions across Nepal. The availability of climate services through a local institution varies in different wards of the municipalities in Chitwan. In ward no. 3 of Madi, only general information on rainfall, temperature, and wind velocity is available through the radio station – Madi FM. Contrary to this, no services are available in ward no. 5 of the municipality through any local institution. The situation is similar in Ratnanagar, where only general information is available in ward no. 13, and ward no. 5 lacks any type of service related to climate. The availability of climate information in Khairahani comes in the form of the provision of weather information through the NARC weather TV program and applications such as Smart Krishi and Krishi Guru. However, no local institution is actively engaged to provide climate information cum advisory services. Apart from the forecast of extreme events via the local radio in ward 8 of Kalika Municipality, no local institution is actively making any type of climate information or advisory available.

Results show that about 67% of the respondent farmers have access to climate information in the municipalities of the study area (Table 2). It is observed that Kalika reported better access to climate information among the municipalities, with about 76% of the respondents having access to climate information. Similarly, more than 50% of the respondents claimed to have access to climate information in the rest of the study region. Of the farmer respondents having access to at least some form of climate information, the majority (about 97%) indicated that they received information on rainfall – specifically the notifications regarding the onset of rain (Table 2). About 56% of the respondents had access to information on the start of the rainy season, and 35% received information on the daily precipitation/temperature information.

The access to information regarding the distribution of rainfall, amount of rainfall, risk of dry spells, and number of days with/without rainfall is relatively less, with only 1.77%, 8.89%, 0.98%, and 5.37% receiving these forecasts respectively.

Table 2
Specific climate information accessed by smallholder farmers (% response).

	(% out of those who have access to at least some form of climate information)			
Municipality	Extreme events	Onset of rain	Rain Next 2–3 days	Access to at least some form of climate information
Kalika Municipality	15.56	97.78	51.11	76.27
Khairahani Municipality	21.28	97.87	38.3	69.12
Madi Municipality	46.15	92.31	46.15	57.78
Ratnanagar Municipality	26.92	100	46.15	66.67
Overall	27.48	96.99	45.43	67.46

Note: The specific climate information consists of extreme events, onset of rain and rain next 2–3 days that are multiple choice options. The percentages have been calculated out of those that have access to at least some form of climate information.

Climate information tends to be limited to forecasts of rain and temperature, with the advisory part of it lacking. Focus group discussions with the farmers show that there are instances where there are a small proportion of progressive farmers in Khairahani and Kalika municipalities who are using mobile applications for agro-advisory. The primary reason for this is the limited access to and awareness of these services. For example, Khairahani Municipality is home to the Institute of Agriculture and Animal Science (IAAS), and the proximity to this campus means that the farmers are aware and can access the information. Apart from these instances, there is a dearth of appropriate and well-designed climate information services that advise farmers in farm planning.

In terms of dissemination of climate information at different levels, the findings show that the instances of dissemination of information have mostly been at the national or district level, with very few instances where the provision has been at the municipality or ward level. Most farmers have access to national or district level climate forecasts via national level mass media. Only 3 percent of farmers reported receiving climate information at the municipality level. It is therefore clear from this that there is a gap in the provision of information at the local level, showing that the farmers do not have access to site-specific climate information. It is also key to note that close to one-third of respondents were not aware of where the information on short-term forecasts originated. Hence, localized climate information is needed as many studies like Lugen et al. (2019); Nyadzi et al. (2018); Josephert et al. (2019) that were done in Africa have shown that the farmers benefited from the provision of localized information on climate services. Moreover, the Kenya Meteorological Department (KMD)'s program shows that the households accessing decentralized local level advisory and seasonal forecasts in Kitui County experienced marginally higher productive income levels compared to those receiving national level forecasts (Barrett et al., 2021).

At the same time, the survey responses also show that various dissemination channels and media are used when accessing climate-related information. A large proportion of the respondents use television (84%) followed by mobile phones (75%) and radio (57%) among other mediums (Table 6). If we look into individual mediums of receiving climate information, we find that certain mediums work better in some municipalities more than others in terms of the prevalence of the use of the medium. For instance, the use of radio for receiving climate information is more prevalent in Madi, with 73 percent of the respondents using it. This is also the case due to the high illiteracy rate in the area. The use of television and mobile phones is more prominent in other municipalities like Ratnanagar, Khairahani, and Kalika (Table 3).

Determinants of awareness of, access to and use of existing climate information for farm decisions

A large proportion of total respondent farmers (73%) were aware of the existing basic climate information and forecasts, while close to 68% of the total respondents had access to this information. Awareness of and access to climate information were combined to assess the functional access (as knowledge of existence of information without effectual means to access would not be functional) which ended up being only about 60% of the total respondents. The factors that determine the awareness of and access to climate information and subsequently the use of it for farm level decisions were analyzed using the heckprobit regression model. The variables used for the analysis and its descriptions are listed below: (See Table 4)

The heckprobit results show that farmers with secondary education and above, mobile owners and higher households' size were associated with an increased likelihood of being aware and having access to climate information. Though statistically insignificant, radio owners were more likely to be aware of and have access to climate information.

Table 3
Medium for access to climate information (% response).

Municipality	Radio	TV	Mobile phone (Phone call/SMS/App)	Computer (social media or internet)	Newspaper/magazine	Govt. extension agent	Farmer Fellow
Kalika	50.85	88.14	74.58	35.59	1.69	0.00	3.39
Khairahani	47.06	92.65	79.41	42.65	1.47	0.00	2.94
Madi	73.33	64.44	62.22	0.00	0.00	2.22	22.22
Ratnanagar	58.97	89.74	84.62	25.64	0.00	0.00	0.00
Overall (%)	57.55	83.74	75.21	25.97	0.79	0.56	7.14

Table 4
Variable list and descriptions.

Variables	Description
Gender	Gender of the respondent (Male = 1; Female = 0)
Age	Age of the respondent
Secondary school and above	Respondents with the educational qualification of secondary school and above = 1; rest = 0
Total family size	Total household members count
Land area for cultivation	Total land area available for cultivation
Radio	Access/ownership of radio
Mobile	Access/ownership of mobile
Television	Access/ownership of television
Household monthly income	Monthly income of the household
Farm contribution to income	% of agricultural farm contribution to the household income
Ownland	Status of land (1 = Ownland; 0 = Other)

Subsequently, the determinants of usage in farming decision making for those who were aware of and had access to climate information were analyzed. We find that older respondent farmers were less likely to use the climate information. Conversely, the households that had a larger household size and share of contribution from agricultural farming towards their household income were more likely to use the climate information for farm level decision making. These findings are consistent with many previous studies that investigate the socioeconomic determinants of functional access and use of climate information. (Muema et al., 2018; Fay Buckland and Campbell, 2021; Ncoyini et al., 2022) (See Table 5).

Table 5
Marginal effects of awareness of and access to; use of climate information.

Dependent Variable	Selection Equation (Awareness of and access to CIS)			Outcome equation (Use of CIS)		
	dy/dx	Std. Err.	P>|z|	dy/dx	Std. Err.	P>|z|
Gender (Male = 1; Female = 0)	0.041	0.078	0.598	−0.056	0.076	0.461
Age of respondent	−0.004	0.003	0.205	−0.007**	0.003	0.024
Secondary school and above	0.143*	0.082	0.083	0.063	0.080	0.425
Land area for cultivation				0.003	0.003	0.287
Status of land (1 = Ownland; 0-Other)	0.049	0.126	0.698			
Access/ ownership of radio	0.114	0.071	0.108	0.058	0.073	0.420
Access/ ownership of television	−0.203	0.126	0.109			
Access/ ownership of mobile	0.302***	0.097	0.002	0.078	0.139	0.574
Farm contribution to income	0.0001	0.001	0.913	0.003**	0.001	0.016
Total family size	0.041**	0.018	0.023	0.039**	0.016	0.017
Household monthly income				0.044	0.036	0.224

Notes: Number of observations 211, Censored observations 81, Uncensored observations 130, Log likelihood = -169, Wald chi2(9) = 23.63, Prob > chi2 = 0.0049. LR test of independent equations (rho = 0): chi2(1) = 4.04, Prob > chi2 = 0.0445.
*, **, *** significance at α = 0.10, 0.05 and 0.01 respectively.

Adoption and use of climate information by smallholder farmers

About 60% of the farmers in the study region were quite proactive in seeking climate information through different channels. This varies among the municipalities; 73% of farmers from Khairahani actively sought this information as compared with Madi, where only 37% of the farmers actively sought the information.

About 42% of the respondent farmers opined that they use existing climate information services for farm level decision-making, though it varies among different wards. This indicates that there is an active demand from the farmers in the region for climate information services that aid in farm-level decision-making. (Table 6). For instance, ward 1 in Kalika (82%) leads the way in the use of climate information, while ward 2 in Khairahani (19%) is the lowest in using the information. In addition to this, there is also a proportion of farmers in most wards where they think the climate information is not relevant. Ward no. 8 in Kalika (22%) has the higher proportion of farmers who do not think the climate information is relevant.

Specifically, the current forecasts have contributed to farm level decisions in terms of adjusting farming practices for about 40 percent of the farmers. The farming practices adopted have mostly been in the form of early land preparation and planting with a few farmers focusing on introducing new as well as early maturing varieties of crops.

The survey responses show that the smallholder farmers in the region need climate information on the amount, distribution, and number of days of rainfall, and the risk of dry spells. Only a small proportion of farmers reported receiving such relevant information. This shows that the current climate information content does not cover the needed information sought after by farmers for farm-level decision-making purposes. Farmers require this information to make critical decisions on the type of crops to plant for different seasons (Antwi-Agyei et al., 2021). Similarly, the number of days of rain and dry spells are crucial for making decisions regarding when to plant, disease management, and harvesting times (Coulibaly et al., 2015). As this information holds a considerable influence on crop production, access to it is vital for farmers to make farm-level decisions.

Farmers are unable to utilize climate information to take farm level decisions due to limited capacity to do so, as only about 40% of them are able to make changes with the use of information through farm level decision-making. It is observed that there isn't any institution that has initiated the provision of climate information with pertinent advisory services in the region. Moreover, the observations from the field show that there is a poor understanding and knowledge among the staff in the agricultural department in the municipality offices regarding the

Table 6
Adoption of climate information services in the farm management decisions (% response).

Study area	Yes (adoption of climate information services in the farm decisions)	No (non-adoption of climate information services in the farm decisions)	Not relevant climate information
Kalika Municipality-1	82.61	17.39	0.00
Kalika Municipality-8	36.11	41.67	22.22
Khairahani Municipality-10	46.81	51.06	2.13
Khairahani Municipality-2	19.05	61.90	19.05
Madi Municipality-3	38.24	44.12	17.65
Madi Municipality-5	45.45	45.45	9.09
Ratnanagar Municipality-13	29.17	62.50	8.33
Ratnanagar Municipality-5	46.67	33.33	20.00
Overall (n = 211)	42.65	45.50	11.85

climate information services and associated agro-advisory. This avenue remains untapped and has the potential to benefit the farmers in a hands-on approach through capacity building of both the farmers and the government bodies.

Barriers in evidence-based decision making for resilient Agriculture

A successful uptake of climate information by smallholder farmers is constrained by a lot of factors that need to be considered when designing appropriate climate information and advisory services geared towards mitigating climate risks. Primarily, these constraints surface because of a mismatch between the requirements of the end users (smallholder farmers) and the modality of provision of services or lack thereof. Results from the survey point to several key barriers that hinder the uptake by farmers. These include non-provision of advisory services to go with the climate information, inaccurate and too general information, trust, difficulties in understanding the information and the limitation of agricultural resources at disposal.

Around half of the farmers responded that they had not received any form of advisory service. Similarly, about 40% of the farmers opined that the climate service information provided was too general. This puts the relevancy and applicability of the information in doubt. Moreover, close to one fifth of the farmers thought that the information provided was too general, coupled with no advisory service. This is quite pertinent as group discussions from the field point to the lack of appropriate climate information and agro-advisory relevant to the locality. One in five farmers also pointed out that the information that was provided was not accurate. At the same time, the same proportion of farmers pointed out limited agricultural resources as the constraining factor in the uptake, with 6% of farmers considering the information too complicated to understand and 3% not trusting the information provided.

In terms of the provision of climate information services, the findings have shown that there is little or no institutional platform at the district and municipality level in the study sites to deliver client-oriented climate information services and associated agro-advisory. While the Agriculture Knowledge Center (AKC) - the only mandated government mechanism in the agriculture center at the local level has not endorsed any full-fledged policy and program specific to climate information services in Chitwan, it has been providing agro-advisory services to farmers regarding improved cultivation practices. These services have been deemed ineffective as they are based on general recommendations and advisories. Apart from Madi Municipality, where initiatives have been taken towards provision, other municipalities have no programs and/or platforms (as seen in Table 7). Indeed, there is a poor understanding among staff members regarding climate information and related advisory services.

The stakeholder consultations revealed that there were technological barriers in terms of access to the latest technology and network, language barriers in the form of lack of communicability due to communications not being in the local dialect or language, and information barriers in the form of lack of information access and delay in relaying of information.

Opportunities for improvement in climate information services

More than half of the farmers have received some form of climate information. This has been largely limited to the onset of rain, with very little information being provided relating to the distribution of rainfall, amount of rainfall, risk of dry spells, and number of days with/without rain. The timely provision of locally relevant climate information goes a long way toward preparing and adapting farmers to cope with and face climate risks. Moreover, the provision of existing climate information and advisory services has been limited to the district or national level, with very little penetration at the local level. Microclimate is a prominent factor that affects the forecasts and is vital to consider while designing and/or considering local level climate information forecasts and advisory services. Hence, there is a scope for site-specific and local-level climate information and advisory services which are lacking and

Table 7
Status of delivery of climate information services.

Institution	Status of the delivery of climate information services
Agriculture Section (Ratnanagar Municipality)	• At present, it does not have any kind of institutional platform/staff/ infrastructure to deliver client-oriented climate information services and associated agro-advisory • No facility of data archiving, public database, or out-sourcing facility • Poor understanding and knowledge of climate information services in the staff
Agriculture Section (Khairahani Municipality)	• No programs and platforms for provisioning climate information services and related agro-advisory services to farmers. • Poor understanding and knowledge of climate information services and CIS-based agro-advisory services. • Availability of IT officers who can be trained to upload weather-related information on the website
Agriculture Section (Kalika Municipality)	• No programs and platforms for provisioning climate information services and related agro-advisory services to farmers. • Limited understanding of climate information services among the staffs
Agriculture Section (Madi Municipality)	• Initiatives are taken to develop an official website which will also integrate weather information for the benefit of farmers. • An archiving system is under development. • Staff are using weather-related information from external sources for agro-advisory services. • Staff seek capacity building and support in terms of climate information services and agro-advisory

remain a work in progress. The provision of localized climate information relating to weather forecasts coupled with pertinent agro-meteorological advisory services is the need of the day.

There is an urgent need for user-tailored services that are accurate, reliable, and easily available. To successfully implement the provision of localized climate information with agro-met advisory services, there is a need to work closely with the local institutions like the Agriculture Knowledge Center (AKC) and local municipalities in Chitwan. Involvement of the local institutions in this process enables the sustainability of the interventions beyond the project durations and involvement. Improvement of the service design and delivery of climate information services to meet the needs of farmers – such as impact-based forecasts and location-specific mid-long range weather forecasts at a local scale – along with local level advisories – is needed.

Improved functional access to climate services is essential for adoption and use of the services, for which strengthening the capacity of local agencies to facilitate in generating and disseminating advisories to the local level is vital. At the same time, strengthening of institutional arrangements and governance – particularly public and private partnerships in developing and disseminating customized hydrometeorological as well as agrometeorological services – is required for sustainable provision.

Conclusion and way forward

With the increase in climate variability and change in the agriculture sector in Chitwan, the farmers are confronted with many climate-related risks like drought, flood, erratic rainfall, and hailstorms. The farmers are aware of climate risks and their impacts on agriculture and livelihoods. They perceive drought and erratic rainfall as the most prominent climate risks that they have been facing with hailstorms and flooding coming after that. A significant number of farmers reported that climate variability has largely affected the crop production on their farms. The perceived impacts on agriculture have been in the form of productivity decreases, post-harvest losses, increased incidence of disease and pests, rises in irrigation costs, and a decline in the quality of different crop products.

The majority of farmers are aware of the existing climate information and services provision to aid in combating the climatic risks. However, usage of this information has been limited to only about 40 percent. While awareness of and access to climate information are largely determined by education and access/ownership of information receiving devices (mobile and radio), use of climate information eventually depended upon the significance of the contribution of the farm-level income towards the household income and the number of household members in the family. In addition to these considerations, there are several barriers that resist the take-up of the climate information for resilient agriculture. Primarily, there is a mismatch between the requirements of the end users (small holder farmers) and the modality of provision of services or lack of it. Other barriers include centralized nature of the generation of agriculture-related information and dissemination of climate information to support farmers, non-provision of advisory services to go with climate information, inaccurate and general information provision, difficult to understand information, limitation of agricultural resources at disposal.

There are many opportunities for learnings from this study in Chitwan that can be used to inform policy and actions relating to climate information services in Nepal. Firstly, there is an urgent need for better information and services delivery for farmers in the region. This can be addressed through policy formulation and actions enabling more decentralized provision of climate information and advisory services for better take-up of the information for decision-making. An improved collaborations between central, provincial, and local level of Department of Hydrology and Meteorology (DHM) and Agriculture Knowledge Centers (AKCs) would go a long way in achieving this. Second, there is a need for provision of locally relevant and reliable climate information for wider accessibility among small holder farmers. Provisions in the policy encouraging public–private partnership for generation and wide dissemination of climate information and advisory is needed as public provision is limited due to resource limitations (e.g., human resources, funding, etc.). This would also ensure that the climate information and advisory generated and disseminated are reliable and of adequate quality. Third, there is a need for customized climate advisory services and capacity enhancement of users of agromet advisory services for provision at the local level. Analysis of the determinants of functional access and usage of existing climate information services can aid in designing relevant capacity enhancement and customized advisory packages for a better uptake. Access to climate information and advisory can be made effective through dissemination using mobile as pointed out by the study findings.

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CRediT authorship contribution statement

Sugat Bajracharya: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Lalu Maya Kadel:** Conceptualization, Validation, Writing – review & editing. **Ujjal Tiwari:** Investigation, Formal analysis, Writing – review & editing. **Ganesh Bhattarai:** Conceptualization, Writing – review & editing. **Himalaya Subedi:** Conceptualization. **Min Bahadur Pun:** Conceptualization. **Mandira Singh Shrestha:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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References

Antwi-Agyei, P., Dougill, A.J., Abaidoo, R.C., 2021. Opportunities and barriers for using climate information for building resilient agricultural systems in Sudan savannah agro-ecological zone of north-eastern Ghana. Clim. Serv. 22, 100226 https://doi.org/10.1016/j.cliser.2021.100226.

Arunkumar, N., Solaimalai, A., Jawahar, D., Veeraputhiran, R., Rao, V.U.M., 2015. Economic use of Agro Meteorological Advisory Bulletins (Aabs) at farmer's holding for chilli in Southern Agroclimatic Zone of Tamil Nadu. Int. J. Agric. Sci. 7 (14), 879–882.

Barrett, S., Ndegwa, W., Maggio, G., 2021. The value of local climate and weather information: an economic valuation of the decentralised meteorological provision in Kenya. Clim. Dev. 13, 173–188. https://doi.org/10.1080/17565529.2020.1745739.

Climate Change Knowledge Portal (CCKP), 2021. Nepal Country Profile. accessed 3 January 2021. https://climateknowledgeportal.worldbank.org/country/nepal/impacts-agriculture/.

Cochran, W.G., 1977. Sampling Techniques, 3rd Edition. John Wiley.

Coulibaly, J.Y., Mango, J., Swamila, M., Tall, A., Kaur, H., Hansen, J., 2015. What Climate Services Do Farmers and Pastoralists Need in Tanzania? CCAFS Work. Pap.

Dixit, 2010. Climate change in Nepal: Impacts and adaptive strategies. accessed 21 October 2022. https://www.wri.org/our-work/project/world-resources-report/climate-change-nepal-impacts-and-adaptive-strategies/.
Dobardzi, S., Dengel, C., Gomes, A.M., Hansen, J., Bernardi, M., Fujisawa, M., Heureux, A.M., Kanamaru, H., Neretin, L., Rojas, O., Intsiful, J., Barnwal, A., Iqbal, F., Kull, D., Bogdanova, A.M., Fara, K., Pergolini, G., Aich, V., Alexieva, A., Baddour, O., Delju, A., De Coning, E., Devillier, R., Eggleston, S., Gallo, I., Harou, A., Hechler, P., Hovsepyan, A., Jepsen, L.A., Moufouma Okia, W., Msemo, N., Parrish, P., Richter, C., Riishojgaard, L.P., Rixen, M., Ruti, P., Santamaria, L., Stefanski, R., Watkins, J., Wright, W., 2019. 2019 State of Climate Services: Agriculture and Food Security. World Meteorological Organization (WMO), Geneva, Switzerland.
FAO, 2019. Handbook on Climate Information for Farming Communities – What Farmers Need and What is Available. Rome. 184 pp. Licence: CC BY-NC-SA 3.0 IGO.
Fay Buckland, S., Campbell, D., 2021. An assessment of factors influencing awareness, access and use of agro-climate services among farmers in Clarendon, Jamaica. Geoforum 126, 171–191. https://doi.org/10.1016/j.geoforum.2021.07.032.
Jagadeesha, N., Ravindrababu, B.T., Pankaja, H.K., Rajegowda, M.B., 2010. Adoption of agromet advisory services (AAS) for improving livelihood of rural farmers. Int. J. Agric. Sci. 6 (2), 584–586.
Josephert, A., Cholo, W., Mulinya, C., Ong'anyi, P., 2019. Access and use of seasonal climate forecasts information on maize crop production in Vihiga County. Kenya. III, 2454–6186.
Lugen, M., Diaz, J., Sanfo, S., Salack, S., 2019. Using Climate Information and Services to Strengthen Resilience in Agriculture: The APTE-21 Project in Burkina Faso. 10.13140/RG.2.2.27501.03044.
Maharjan, S.K., Maharjan, K.L., 2020. Exploring perceptions and influences of local stakeholders on climate change adaptation in Central and Western Tarai, Nepal. Clim. Dev. 12, 575–589. https://doi.org/10.1080/17565529.2019.1664377.
Ministry of Agriculture and Livestock Development (MOALD), 2022. Agriculture Sector. accessed 20 Jan 2022. https://nepal.gov.np:8443/NationalPortal/view-page?id=44.
MoPE, 2016. Intended Nationally Determined Contributions. Ministry of Population and Environment (MoPE), Government of Nepal, Kathmandu, Nepal.
Muema, E., Mburu, J., Coulibaly, J., Mutune, J., 2018. Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya. Heliyon 4 (11), e00889. https://doi.org/10.1016/j.heliyon.2018.e00889.
Ncoyini, Z., Savage, M.J., Strydom, S., 2022. Limited access and use of climate information by small-scale sugarcane farmers in South Africa: A case study. Clim. Serv. 26, 100285 https://doi.org/10.1016/j.cliser.2022.100285.
Nkiaka, E., Taylor, A., Dougill, A.J., Antwi-Agyei, P., Fournier, N., Bosire, E.N., Warnaars, T., 2019. Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa. Environ. Res. Lett. 14, 123003 https://doi.org/10.1088/1748-9326/ab4dfe.
Nyadzi, E., Nyamekye, A.B., Werners, S.E., Biesbroek, R.G., Dewulf, A., Slobbe, E.V., Long, H.P., Termeer, C.J.A.M., Ludwig, F., 2018. Diagnosing the potential of hydro-climatic information services to support rice farming in northern Ghana. NJAS Wageningen J. Life Sci. 86–87, 51–63. https://doi.org/10.1016/j.njas.2018.07.002.
Paudel, B., Acharya, B.S., Ghimire, R., Dahal, K.R., Bista, P., 2014. Adapting agriculture to climate change and variability in Chitwan: long-term trends and farmers' perceptions. Agric. Res. 3, 165–174. https://doi.org/10.1007/s40003-014-0103-0.
Sapkota, R., Rijal, K., 2016. Climate Change and its Impact in Nepal. PhD Dissertation. Institute of Science and Technology, Tribhuvan University, Katmandu, pp. 9–11.
Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., Zaroug, M., Kituyi, E., 2018. The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. Clim. Dev. 10, 389–405. https://doi.org/10.1080/17565529.2017.1318744.
Timilsina, A.P., Shrestha, A., Gautam, A.K., Gaire, A., Malla, G., Paudel, B.P., Rimal, R., Upadhyay, K.P., Bhandari, H.L., 2019. A practice of agro-met advisory service in Nepal. J. Biosci. Agric. Res. 21 (02), 1778.
UN, 2022. Climate change. accessed 2 Jan 2022. https://www.un.org/en/global-issues/climate-change.
Undp, 2013. Country Report: Climate Risk Management for Agriculture in Nepal. accessed 9 December 2020. https://www.geonode-gfdrrlab.org/documents/842/download.
Van de Ven, W.P.M.M., Van Praag, B.M.S., 1981. The demand for deductibles in private health insurance: A probit model with sample selection. J. Econ. 17 (2), 229–252. https://doi.org/10.1016/0304-4076(81)90028-2.
Vaughan, C., Dessai, S., 2014. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim. Chang. 5, 587–603. https://doi.org/10.1002/wcc.290.
Wang, S., Yoon, J., Gillies, R.R., Cho, C., 2013. What caused the winter drought in western Nepal during recent years? J. Clim. 26, 8241–8256. https://doi.org/10.1175/JCLI-D-12-00800.1.
Weaver, W., Shannon, C.E., 1963. The Mathematical Theory of Communication. University of Illinois Press.