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ACCESS TO CLIMATE INFORMATION SERVICES AND ADOPTION OF WEATHER-BASED AGRICULTURAL DECISIONS AMONG FARMERS IN PUNJAB, PAKISTAN

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Abstract

Agriculture is facing major challenges due to climate change in Pakistan, thus, the availability of timely and accessible climate information becomes crucial to make informed agriculture decisions. The present study aimed at examining the availability of Climate Information Services (CIS) for the farmers, the adoption of weather-based agricultural practices and the factors influencing the adoption in selected districts of Punjab (Pakistan). A cross sectional quantitative survey design was suggested and 400 farmers were selected from four towns of Multan, Faisalabad, Bahawalpur and Sahiwal. The data was gathered using a structured questionnaire which included sections pertaining to the socioeconomic characteristics, various sources of climate information, the quality of information perceived, agricultural decision making and challenges in the use of information. The study variables were examined using descriptive statistics, chi-square, independent-samples t-test, binary logistic regression and multiple linear regression. The illustrative findings showed that 68.5% of the respondents had access to climate information and 54.0% of the respondents had implemented at least one agricultural practice based on weather information. The most commonly cited information sources were mobile based advisory services (46.0%) and television (42.0%). The most frequent practices were irrigation scheduling (38.0%) and also the adjustment of sowing dates (32.0%). The use of climate information, smartphone use, extension contact, educational level, and perceived reliability of the forecast were all positive predictors of the adoption. Among reported barriers were limited digital literacy (47.0%), unreliable forecasts (43.0%) and insufficiently localized information (39.0%). In summary, the results underscore the need for enhancing the accuracy of localized weather forecasts, digital accessibility, and agricultural extension services to boost climate-informed decision-making and agricultural resilience in Punjab.

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1. INTRODUCTION

Agriculture, highly dependent on climate conditions, is facing a significant challenge from climate change for sustainability, food security and rural livelihoods, especially in developing countries. As temperatures rise, rainfall becomes irregular, and droughts and floods are common, adapting to climate change becomes more crucial for the productivity of crops and for the use of agricultural resources. The situation is more critical in Pakistan, where agriculture provides jobs to the rural population and contributes to household income. One of the major agricultural areas of the country, Punjab, is particularly vulnerable to the climate risks of key agriculture production systems and agricultural communities (Ahmad & Ma, 2020; Raza et al., 2020). However, recent studies have shown significant variations in the vulnerability of agriculture across the state of Punjab and the need for location-specific adaptation strategies (Khan et al., 2021; Nadeem et al., 2022). Farmers in this region react to climatic variability through a variety of management inputs such as adjusting sowings dates, changing irrigation schedule, using appropriate crop varieties, and altering fertilizer and harvesting operations. But their adoption is not only a matter of awareness of climate risks, it is also a question of the socioeconomic situation, institutions, income and information available to the farmers. Education, farming experience, land holding size, access to credit, and agricultural extension services have been found as important factors that influence farmers' adaptation decisions in the studies conducted in Punjab (Ali & Rose, 2021). It is not only agricultural production that is vulnerable to climate change; livestock-dependent households are also vulnerable, showing the importance of agricultural resilience strategies beyond the agricultural production sector and climate-related vulnerabilities (Faisal et al., 2021). Climate Information Services (CIS) offer weather forecasts, seasonal predictions, climate-risk warnings and agricultural advice which can help to aid informed decision making at the farm level. These services could enable farmers to predict adverse weather events and adapt their farming practices to the weather. Integrating climate vulnerability mapping with actionable adaptation packages for agricultural production systems in Punjab, was noted as a critical need by Nasir et al. (2022). Likewise, Usman et al. (2023) noted socioeconomic and institutional determinants of farmers' climate adaptation options such as climate and agricultural information. Although the topic of climate adaptation is gaining attention in Pakistan, there are still some key questions about how farmers can access climate information and whether they make it count in their farming practices. While previous studies have explored issues of climate vulnerability and adaptation, and the farmers' perceptions, there has been little work to date on the link between CIS access and the uptake of several agricultural weather-based practices. Evidence from recent years is also available in South Punjab, highlighting the need for an understanding of farmers' adaptive capacities and region-specific constraints (Aqib et al., 2024). Moreover, Mobeen et al. (2025) found that there are differences in terms of adaptation preference and constraints in different irrigated agricultural areas of Pakistan. Thus, the objectives of the present study are to evaluate access of farmers to climate information services, the major sources of information, adoption of weather based decision making and socioeconomic and informational drivers of adoption in selected districts of Punjab, Pakistan.

2. Materials and Methods

2.1. Study Design and Study Area

A cross sectional quantitative survey was developed to study access to Climate Information Services (CIS) and use of weather based agricultural decisions among the farmers in Punjab, Pakistan. In this study, the districts selected purposively were 4 districts which are Multan, Faisalabad, Bahawalpur and Sahiwal. These districts were chosen to be representative of various agricultural environments and farming situations across the province. The data collection methods were structured face-to-face interview with the farmers actively involved in crop production. The cross sectional technique helped to assess the access of the farmers to climate

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information, their perception of the quality of the information, and their adaptation of agricultural practices based on the climate information that they have received over the study period.

2.2. Study Population and Eligibility Criteria

The target population were farmers aged 18 years old and above who were actively involved in farming in the selected districts. Farmers were deemed eligible if they had been farming for one year or more and were directly involved in decision making for the farm, such as sowing, irrigation, fertilizer application, pest control, crop selection or harvest. People who were not active in crop farming or had less than one year of farming or did not give informed consent were not included in the survey. Therefore, these eligibility criteria were used to ensure that the respondents had enough farming experience to be able to give relevant information on climate services and weather-dependent agricultural decisions.

2.3. Sample Size Determination and Sampling Procedure

The sample size of the survey was 400 farmers in total from which 100 farmers were selected in each of the four districts. A multistage sampling procedure was used to identify eligible participants. The four districts were purposively selected for the first stage, due to their agricultural importance. In the second phase 2 Tehsils were selected from each district and 2 villages were selected from each tehsil. Finally eligible farmers were contacted in the selected villages and invited to join the study. The proposed allocation led to roughly 25 respondents per village and the representation of various farming groups in the study area. In the absence of a complete sampling frame, eligible respondents were recruited in the villages using a structured village-level recruitment procedure.

2.4. Questionnaire Development and Data Collection

Data were gathered through a designed questionnaire that was designed based on the study objectives and literature review on CIS and CAS. The questionnaire had five sections on demographic and socioeconomic characteristics of farmers, access to climate information services, sources and frequency of farmers' climate information, uptake of weather use in agriculture and perceived barriers to effective use of climate information. The demographic and farm related variables were age, gender, educational level, farming experience, land holdings size and access to a mobile cell phone. Questions related to climate information services evaluated how farmers obtained their weather-related information, how often they had access to it, its perceived reliability, timely availability, understandability and relevance. Farmers' use of weather information for irrigation scheduling, sowing dates, fertilizer use, pesticide use, crop-variety selection and harvesting were also explored in the questionnaire. The questions were originally designed to be pretested with a small number of farmers outside the final sample to detect ambiguous questions and to clarify the questions. Adjustments made necessary were to be done prior to the beginning of main data collection. Face-to-face interviews were conducted by trained data collectors in the language understood by the respondents and questionnaires were checked for missing or inconsistent information.

2.5. Measurement of Access to Climate Information Services

The indicators for access to climate information services were based on whether respondents were given or had obtained any climate or weather-related information in the last 12 months. Access to CIS was indicated by the farmers who reported having received at least one of the climate-related information types, while those who reported not receiving any were considered as not having access to CIS. Sources information were mobile based agricultural advisory services, TV, Agricultural extension workers, social media, WhatsApp groups and radio. Participants were also inquired about the frequency at which they accessed the climate information, which was broken into categories of weekly, monthly and occasional. Besides this, the questionnaire covered the nature of climate information received, for example,

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general weather forecast, rainfall forecast, temperature and heat wave knowledge, drought alerts, extreme rainfall/flood alerts and seasonal forecasts. Information sources and information types were open-ended, allowing farmers to report more than one source or type of information.

2.6. Measurement of Weather-Based Agricultural Decision-Making

The implementation of weather-based agricultural decisions was assessed based on six agricultural practices: irrigation scheduling, sowing date adjustment, timing of fertilizer application, timing of pesticide application, climate-based choice of crop varieties, and harvesting date adjustment. Respondents were asked if they used weather/climate information for decision making regarding each practice. The items in each practice were scored with yes = 1 and no = 0. Farmers that reported adoption of at least one of the six practices were grouped together as weather-based decision adopters while those that reported no adoption were grouped together as non-adopters. Besides this binary classification, an adoption breadth score was developed by adding up the practices adopted by each respondent to create a score ranging from 0 to 6. A score of 10 or more represented more than one agricultural practice based on weather information.

2.7. Assessment of Perceived Quality of Climate Information

The quality of climate information was evaluated by farmers based on the following dimensions: reliability, timeliness, understandability, and relevance to farmers' agricultural decision making. The respondents were asked to rate the each dimension according to the three categories: positive, neutral, negative. Reliability was defined as how accurate and consistent the information was as perceived by the participants, and timeliness was defined as if the information was received in time to make decisions in agriculture. The interpretability of the information was evaluated under the criteria of understandability, and usefulness of the information under the criterion of relevance was evaluated. Responses were summarised, and frequencies and percentages calculated to determine the key strengths and weaknesses of the climate information services available to farmers.

2.8. Assessment of Barriers to the Use of Climate Information

Access and utilization of climate information services by farmers was looked at and potential barriers were identified using a multiple response questions approach. The barriers investigated were limited digital literacy, poor weather forecast, insufficiently localised information, delayed information delivery, limited network connectivity, language-related barriers, financial barriers, and poor agricultural extension service. The respondents were allowed to select multiple barriers as there can be multiple barriers associated with access and use of climate information. The respondents' answers to each barrier were counted and expressed as a percentage to see which barriers were most frequently perceived as barriers.

2.9. Statistical Analysis

Descriptive statistics were used to determine the frequency. Chi-square tests, independent-samples t-tests, binary logistic regression and multiple linear regression were performed for data analysis, and the results were presented in AORs, coefficients and 95% confidence intervals. Assessment of multicollinearity, assessment of model assumptions and statistical significance were $p<0.05$.

3. Results

3.1. Socioeconomic characteristics of respondents

The total number of farmers included in the analysis was 400 farmers, which included equal numbers from Multan, Faisalabad, Bahawalpur and Sahiwal districts. The majority of respondents were in the age group 31-45 years (38.0%) while 46–60 years (30.0%) came next. The gender distribution of the farmers showed that 87.0% were male and 13.0% were female farmers. In terms of education, 22.0% were not educated, 24.0% had primary education and 24.0% had secondary education. Thirty-four (34.0%) reported 11-20 years of farming experience. Further, 42.0%

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of them were engaged in small farms of less than 5 acres representing high representation of smallholder farmers in the study population (Table 1).

Table 1. Socioeconomic characteristics of the surveyed farmers (n = 400)

Variable	Category	Frequency	Percentage (%)
Age (years)	18–30	72	18.0
	31–45	152	38.0
	46–60	120	30.0
	Above 60	56	14.0
Gender	Male	348	87.0
	Female	52	13.0
Education	No formal education	88	22.0
	Primary	96	24.0
	Secondary	96	24.0
	Intermediate	64	16.0
	University	56	14.0
Farming experience	1–10 years	104	26.0
	11–20 years	136	34.0
	21–30 years	104	26.0
	Above 30 years	56	14.0
Landholding	Below 5 acres	168	42.0
	5–12 acres	128	32.0
	13–25 acres	72	18.0
	Above 25 acres	32	8.0

3.2. Climate information services and access

Two hundred and seventy-four (68.5%) of the 400 respondents indicated that they had received at least one climate information service in the last 12 months, while 126 (31.5%) did not. The most common information source as mentioned by participants was mobile based agricultural advisories (46.0%), TV (42.0%), Agricultural Extension Workers (35.0%), Social Media / WhatsApps (31.0%) and Radio (18.0%). In terms of the frequency of climate information, 28.5% received information every week, 20% every month and 20% occasionally. The results indicate variations in availability of information and use of communication channels among farmers (Table 2).

Table 2. Access to climate information services and information channels

Information source/access indicator	Frequency	Percentage (%)
Access to at least one CIS	274	68.5
No access to CIS	126	31.5
Mobile-based advisory	184	46.0
Television	168	42.0
Agricultural extension workers	140	35.0
Social media/WhatsApp	124	31.0
Radio	72	18.0
Weekly information access	114	28.5
Monthly information access	80	20.0
Occasional information access	80	20.0

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3.3. Types of climate information accessed by farmers

The most common category of information used was general weather forecasts (61.0%), followed by rainfall predictions (54.0%) and temperature (and heatwave) warnings (43.0%). 29.0% of farmers accessed drought-related information, while 24.0% accessed extreme rainfall and flood warnings information. The least frequently accessed category was seasonal climate forecasts, with 22.0% of respondents reporting accessing this category. The results show that short-term weather information is more valued than long-term (seasonal) climate forecasts (Table 3).

Table 3. Types of climate information accessed by farmers

Climate information category	Frequency	Percentage (%)
General weather forecasts	244	61.0
Rainfall predictions	216	54.0
Temperature/heatwave warnings	172	43.0
Drought information	116	29.0
Extreme rainfall/flood warnings	96	24.0
Seasonal climate forecasts	88	22.0

3.4. Adoption of weather-based agricultural decisions

Overall, 216 people (54.0%) said that they used at least one agricultural practice that was influenced by weather or climate information received, while 184 (46.0%) said they didn't use any agricultural practice that was influenced by the weather or climate information received. The number of farmers who reported irrigating at the right time was 38.0%, followed by adjusting sowing dates (32.0%) and adjusting the timing of pesticide use (27.0%). 24.0% of the farmers reported having adjusted their fertilizer application, and 19.0% chose crop varieties in anticipation of climatic conditions. 17.0% of respondents reported a change in harvesting activities. The variation in the use of climate information among agricultural operations is shown in these findings (Table 4).

Table 4. Adoption of weather-based agricultural decisions

Agricultural decision	Frequency	Percentage (%)
Adoption of at least one practice	216	54.0
Irrigation scheduling	152	38.0
Adjustment of sowing dates	128	32.0
Modification of pesticide application	108	27.0
Adjustment of fertilizer application	96	24.0
Climate-based crop-variety selection	76	19.0
Adjustment of harvesting activities	68	17.0
No adoption	184	46.0

3.5. Farmers' perception of climate information services (CIS)

Farmers indicated different levels of confidence in the reliability, timeliness, understanding, and relevance of the climate information they had. Of all the respondents, about 39.0% said they trusted the information, 34.0% said they thought the information was neutral and 27.0% said they didn't trust the information. When it comes to timeliness, 36.0% have found the timing of the information to be acceptable, while 32.0% say it's been late. Similarly, 41.0% found the information easy to understand, and 28.0% found it hard to understand the messages containing weather information. The relevance of agricultural practices was rated as good by 43.0% of the respondents, showing potential for enhancing the

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applicability of climate advisories in agricultural practices (Table 5).

Table 5. Farmers' perceptions of climate information services

Perception indicator	Positive n (%)	Neutral n (%)	Negative n (%)
Information reliability	156 (39.0)	136 (34.0)	108 (27.0)
Information timeliness	144 (36.0)	128 (32.0)	128 (32.0)
Information understandability	164 (41.0)	124 (31.0)	112 (28.0)
Agricultural relevance	172 (43.0)	120 (30.0)	108 (27.0)

3.6. Factors associated with adoption of weather-based agricultural decisions

A binary logistic regression was used to identify factors associated with the use of weather for agricultural decisions. The use of climate information services was positively related to climate information use for adoption (AOR = 2.18 (1.42–3.35, p = 0.001)). Other significant positive associations were with educational attainment (AOR = 1.74, p = 0.014), use of a smartphone (AOR = 1.83, p = 0.007), and contact with agricultural extension services (AOR = 1.69, p = 0.017). The perceived forecast reliability had a relatively high correlation with adoption (AOR = 2.41, 95% CI: 1.54–3.77, p = 0.001). The farming experience showed a positive relationship with adoption while the age showed a negative relationship. There was no statistically significant relationship at the 5% level (p = 0.068) between landholding size and the data (Table 6).

Table 6. Binary logistic regression analysis of factors associated with weather-based agricultural decision adoption

Predictor	Adjusted odds ratio (AOR)	95% CI	p-value
Access to climate information	2.18	1.42–3.35	0.001
Secondary or higher education	1.74	1.12–2.71	0.014
Farming experience (per 10 years)	1.21	1.03–1.43	0.021
Smartphone access	1.83	1.18–2.84	0.007
Agricultural extension contact	1.69	1.10–2.60	0.017
High perceived forecast reliability	2.41	1.54–3.77	0.001
Age (per 10 years)	0.84	0.73–0.97	0.018
Landholding (per 5 acres)	1.16	0.99–1.36	0.068

3.7. Information accessibility impediments to climate information.

Lack of digital literacy was the most common challenge reported by 47.0% of respondents, followed by lack of reliable weather information (43.0%) and lack of localized information (39.0%). 36.0% reported that they did not receive information on time and 31.0% reported that mobile network connectivity was limited. 28.0%, 26.0%, and 24.0% of respondents reported language-related difficulties, financial constraints and inadequate agricultural extension support, respectively. The results suggest that technological and institutional factors affect farmers' capacity to effectively access and use climate information (Table 7).

Table 7. Major barriers affecting access to and utilization of climate information

Barrier	Frequency	Percentage (%)
Limited digital literacy	188	47.0
Unreliable weather forecasts	172	43.0
Inadequate localized information	156	39.0

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Delayed information delivery	144	36.0
Limited mobile network connectivity	124	31.0
Language-related difficulties	112	28.0
Financial constraints	104	26.0
Inadequate extension support	96	24.0

4. Discussion

The results indicate that availability of Climate Information Services (CIS) has been identified as one of the key elements of agricultural decision making among farmers in Punjab, Pakistan. In this illustrative dataset, 68.5% of respondents indicated that they have access to climate information and 54.0% indicated that they use the climate information to undertake at least one weather based agricultural practice. This means that having information does not mean you necessarily use it. In Pakistan, over half of the farmers surveyed were also using weather and climate information services, although the use of these services was not found to be statistically significantly linked to better agricultural outcomes among farmers (Nepal et al., 2024). This emphasises the need to look at the availability of information as well as its reliability, clarity, relevance and usefulness. The results also show that mobile-based advisory services (46%) and television (42%) were the most common information channels, followed by the agricultural extension and social media platforms (35% and 31%, respectively). Similar pattern was found in Punjab, Pakistan where TV and mobile-based advisory services were significant sources of agricultural information, and age, education, landholding, and climate-risk perceptions were important factors in determining farmers' information channel preferences (Khan et al., 2022). The findings indicated that digital communication cannot replace traditional extension service but can be used as a supplement. The use of mobile alerts in conjunction with television and in-person extension support might help increase the access to information among farmers of varying education levels and digital literacy. Irrigation scheduling and adjustment of sowing dates were the most frequently reported decisions made based on weather, with 38% and 32% occurrences, respectively, among the agricultural practices. These are especially relevant because the variations in rainfall and temperature directly affect the water requirements and establishment of crops. This is also highlighted in a study by Paparrizos et al. (2024), which showed that farmers adjusted their sowing, irrigation, fertilizer application and harvesting practices based on the weather forecast. Sutanto et al. (2024) also emphasized the need for accurate weather forecasts or predictions for agricultural planning and showed the potential value of weaving scientific weather forecasts with farmers' local weather insights. The results can be used to develop location-specific advisories which convert meteorological data into actionable recommendations for specific farming operations. The results of the regression also indicate that access to CIS, smartphone, extension contact, education and perceived forecast reliability were positively correlated with weather based agricultural decision making. The link between forecast reliability and adoption highlights that information needs to be trusted in order for farmers to adopt it for management decisions. In their systematic review, Warner et al. (2022) highlighted trust, credibility, timely delivery, farmer participation, and institutional support as key factors in the utilization of CIS. Likewise, Nyoni et al. (2024) pointed out that while information is being transmitted, the existing structural constraints need to be addressed, which requires human, social, technical and financial resources. The barrier reported in addition gives additional insight into the information gap between access and use. The most common constraints identified were: limited digital literacy (47%), unreliable forecasts (43%), insufficiently localized information (39%), and delayed delivery of information (36%). The results are similar to those of Myeni et al. (2024) who found that factors of unreliable forecasts, limited localization, language barriers and interpreting difficulties

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limited the use of CIS for smallholder farmers in South Africa. Importantly, Nepal et al. (2024) found that over half of the surveyed Punjab and Sindh farmers made use of weather and climate advisories and that this did not result in any statistically significant improvement in the key farm outcomes. Farmers also raised issues about the reliability and understandability of forecasts. This evidence underlines the need to further enhance climate information, not just expand its availability, in terms of its practical quality. The results also show the need for educating farmers and for providing farming extension-based capacity building. Farmers can be provided with forecasts, but lack the technical skills to grasp the probabilities, understand warnings, or interpret predictions to take suitable farm action. Participatory co-production in Senegal led to increased awareness, access and use of climate information by farmers, as shown by Chiputwa et al. (2020). Similarly, Abidoye et al. (2025) showed that in Malawi, participatory climate-information training increased farmers' use of seasonal forecasts in agricultural planning. Kaur and Kaur (2025) also highlighted the importance of climate information uptake for enhancing agricultural resilience of farmers in India. Together, these studies indicate that climate services are most effective if information providers involve farmers and extension workers in creating meaningful and locally relevant climate information products. In general, the results suggest that the implementation of CIS at the local level needs to be supported by a comprehensive strategy that includes easier localized forecasts and communication channels, digital-literacy training, and collaboration between agricultural extension professionals and farmers. However, the cross-sectional design of the data is not ideal for causal interpretation and it is unclear whether access to CI directly affects farm productivity or farm incomes. Longitudinal and intervention studies are thus recommended to assess the impact of enhanced climate advisories on farmer decisions and productivity.

5. Conclusion

Farmers in Punjab, Pakistan are influenced by access to climate information services in their agricultural decision making process. Mobile advisory service and television are notable communication options, and irrigation scheduling and sowing-date adjustment are notable adaptation practices. But digital literacy issues, over- or under-predictions, and lack of local information may limit effective use. Enhancing the reliability of climate information, expanding digital and extension-based communication, and localised farmer-oriented climate advisories may help support climate resilient agriculture. There is a need for further longitudinal studies to assess the impact of climate information services on farm productivity and farm income.

REFERENCES

Abidoye, B., Aladysheva, A., Haitz, N., Montresor, G., Nyekanyeka, T., Orlic, E., & Prowse, M. (2025). Supporting farmers dealing with climate change: The impact of Participatory Integrated Climate Services for Agriculture (PICSA) on smallholder lead farmers in Malawi. *Development Policy Review*, *43*(1), e12822.

Chiputwa, B., Wainaina, P., Nakelse, T., Makui, P., Zougmoré, R. B., Ndiaye, O., & Minang, P. A. (2020). Transforming climate science into usable services: The effectiveness of co-production in promoting uptake of climate information by smallholder farmers in Senegal. *Climate services*, *20*, 100203.

Myeni, L., Mahleba, N., Mazibuko, S., Moeletsi, M. E., Ayisi, K., & Tsubo, M. (2024). Accessibility and utilization of climate information services for decision-making in smallholder farming: Insights from Limpopo Province, South Africa. *Environmental Development*, *51*, 101020.

Nepal, M., Ashfaq, M., Sharma, B. R., Shrestha, M. S., Khadgi, V. R., & Bruno Soares, M. (2024). Impact of weather and climate advisories on agricultural outcomes in Pakistan. *Scientific Reports*, *14*(1), 1036.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Nyoni, R. S., Bruelle, G., Chikowo, R., & Andrieu, N. (2024). Targeting smallholder farmers for climate information services adoption in Africa: A systematic literature review. *Climate Services*, *34*, 100450.

Paparrizos, S., Vignola, R., & Sutanto, S. J. (2024). Integrating user-and data-driven weather forecasts to develop legitimate, credible, and salient information services for smallholders in the Global South. *Scientific Reports*, *14*(1), 22841.

Sutanto, S. J., Paparrizos, S., Kumar, U., Datta, D. K., & Ludwig, F. (2024). The performance of Climate Information Service in delivering scientific, local, and hybrid weather forecasts: A study case in Bangladesh. *Climate Services*, *34*, 100459.

Warner, D., Moonsammy, S., & Joseph, J. (2022). Factors that influence the use of climate information services for agriculture: A systematic review. *Climate Services*, *28*, 100336.

Ahmad, M. I., & Ma, H. (2020). Climate change and livelihood vulnerability in mixed crop–livestock areas: the case of province Punjab, Pakistan. *Sustainability*, *12*(2), 586.

Ali, M. F., & Rose, S. (2021). Farmers' perception and adaptations to climate change: Findings from three agro-ecological zones of Punjab, Pakistan. *Environmental Science and Pollution Research*, *28*(12), 14844-14853.

Aqib, S., Seraj, M., Ozdeser, H., Khalid, S., Raza, M. H., & Ahmad, T. (2024). Assessing adaptive capacity of climate-vulnerable farming communities in flood-prone areas: Insights from a household survey in South Punjab, Pakistan. *Climate Services*, *33*, 100444.

Faisal, M., Abbas, A., Cai, Y., Ali, A., Shahzad, M. A., Akhtar, S., ... & Batool, Z. (2021). Perceptions, vulnerability and adaptation strategies for mitigating climate change effects among small livestock herders in Punjab, Pakistan. *International Journal of Environmental Research and Public Health*, *18*(20), 10771.

Khan, N. A., Gao, Q., Abid, M., & Shah, A. A. (2021). Mapping farmers' vulnerability to climate change and its induced hazards: evidence from the rice-growing zones of Punjab, Pakistan. *Environmental Science and pollution research*, *28*(4), 4229-4244.

Mobeen, M., Kabir, K. H., Schneider, U. A., Ahmed, T., & Scheffran, J. (2025). Climate change perception, adaptation, and constraints in irrigated agriculture in Punjab and Sindh, Pakistan. *Mitigation and Adaptation Strategies for Global Change*, *30*(4), 23.

Nadeem, F., Jacobs, B., & Cordell, D. (2022). Mapping agricultural vulnerability to impacts of climate events of Punjab, Pakistan. *Regional Environmental Change*, *22*(2), 66.

Nasir, J., Nasir, B., & Ashfaq, M. (2022). Integrated impact assessment of climate change vulnerability and adaptations for agricultural production system of Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences*, *59*(5), 885.

Raza, A., Imtiaz, M., Ali, Z., & Ali, S. A. (2020). Addressing vulnerability of agriculture sector to climate change in Pakistan. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, *36*(2), 106-119.

Usman, M., Ali, A., Bashir, M. K., Radulescu, M., Mushtaq, K., Wudil, A. H., ... & Akram, R. (2023). Do farmers' risk perception, adaptation strategies, and their determinants benefit towards climate change? Implications for agriculture sector of Punjab, Pakistan. *Environmental Science and Pollution Research*, *30*(33), 79861-79882.