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FARMERS' CLIMATE CHANGE AWARENESS AND ADAPTIVE READINESS IN PUNJAB, PAKISTAN: A COMPREHENSIVE REVIEW OF KNOWLEDGE, PERCEPTIONS, AND DIGITAL COMMUNICATION PATHWAYS

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Abstract

The impact of climate change on agricultural productivity and food security is unprecedented in South Asia, especially in the province of Punjab in Pakistan, where climate change is affecting smallholder farmers. This extensive literature review brings together the existing evidence on awareness, readiness of farmers to adapt to climate change, and institutional and digital channels that empower or hinder adaptation in Punjab. Findings indicate that around 71% of the farmers in Punjab are aware of the changes in rainfall and temperature due to climate change, but such awareness does not necessarily imply adaptation action. Awareness must be translated into effective adaptation, which relies on several interdependent factors: socioeconomic factors (education, farming experience, credit access), institutional support systems (climate risk management trainings and digital agriculture extension services), and digital communication infrastructure (mobile phones, Internet-based advisory services). Gender differences can markedly influence technology adoption and access to information, with women having more barriers to the use of mobile extension services. Limited digital literacy, lack of extension infrastructure, and a significant digital divide in rural areas are some of the barriers to adaptation. The review points to an integrated policy approach for knowledge enhancement, institutional capacity building, gender-inclusive communication channels, and strategic investments in digital infrastructure as crucial to support climate-resilient agricultural systems. This approach includes farmer-centered indigenous knowledge and experience, context-specific extension approaches, and climate risk management trainings and personalized climate digital advisory services, providing avenues for sustainable adaptation. The findings highlight the need for a multi-sectoral approach to information access, institutional arrangements, technology adoption, and equity concerns to support effective climate change adaptation in Punjab, and that farmer voices and their experiences must be at the heart of the design and implementation of sustainable agricultural futures.

Keywords: Climate Change Awareness, Adaptive Capacity, Agricultural Extension Services, Digital Agriculture Communication, Smallholder Farmer Adaptation

1. Introduction and

1.1 Context

The impacts of climate change on agriculture are unprecedented and especially severe in South Asian developing nations, where agriculture is a key source of income. The agriculture sector in Pakistan is heavily vulnerable as a result of rising temperatures, unpredictable rainfall and increased instances of extreme weather events. (Usman et al., 2023) Smallholder farmers in

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Punjab, the agricultural hub of Pakistan and a major contributor to food security across the country, are facing growing climate risks to their productivity, livelihoods, and food security. This study found that 70.8% of farmers in Punjab are aware of climate change because of the changes in rainfall, temperature, length of growing season, and sea level rise during winter and summer seasons. Awareness, however, is not enough without understanding on adaptation pathways and the ability to access extension services, though. Institutional arrangements, including climate risk management trainings and digital agriculture extension communication services, mediate the link between accurate climate risk perception, planning, and implementation of adaptation. Awareness of farmers' changing climate and their preparedness to adapt is therefore critical to developing specific interventions to improve their resilience and maintain agricultural productivity in the region.

1.2 Research Problem

The effects of climate change have become a significant challenge to the agricultural production, food security, and livelihoods of developing countries, especially in climate-sensitive areas like Punjab, Pakistan. Increasing variability in rainfall, rising temperatures, water scarcity, decreasing soil fertility, pest infestation, and shifting cropping seasons are direct impacts of climate change on farmers in Punjab, impacting agricultural sustainability and economic stability of farmers (Usman et al., 2023; Mustafa et al., 2023). Many farmers are aware of climate change, but this awareness does not guarantee effective adaptation behavior or a resilient agriculture.

Previous research has shown that education, institutional assistance, access to extension services, digital communication, socioeconomic status, and access to climate-related information all have a significant impact on farmers' adaptive readiness (Mahmood et al., 2021; Mahmood et al., 2020). But knowledge about climate change and adaptation opportunities are not equally available to farming communities, especially among smallholder and resource-constrained farmers. Even though significant strides have been made in providing farmers with reliable climate information and adaptive technologies, there are still several challenges impeding their ability to access these resources, including limited digital literacy, weak agriculture extension systems, poor internet connectivity, financial constraints, and gender inequalities (Khatri et al., 2024; Ngigi & Muange, 2022).

Although there has been a growing body of research related to climate smart agriculture and adaptation, the literature is still split across different themes including climate awareness, adaptation practices, agricultural extension through the use of ICTs, and institutional support systems. The interaction between the awareness of farmers about climate change, their adaptive readiness, and the digital communication pathways in the context of agriculture in Punjab, Pakistan, is explored in a limited way through a comprehensive synthesis. In addition, the importance of digital agricultural communication systems and the gender-responsive approaches to information dissemination in enhancing the capacity of farmers to adapt to climate change has been neglected.

Hence, it is essential to conduct a comprehensive review to compile the existing evidence on awareness of farmers, perception, adaptation preparedness, institutional support mechanisms and digital communication channels with respect to climate change in Punjab, Pakistan. This synthesis is crucial to uncovering knowledge gaps, policy vulnerabilities, and actionable solutions to enhance climate resilience and sustainable agriculture.

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1.3 Significance of the Study

This research is important as the literature is synthesized on the farmers' awareness of climate change, readiness to adapt, and digital communication channels in the context of agriculture in Punjab, Pakistan. The importance of understanding farmers' perceptions of climate risks and responses to them has grown even more critical as climate change poses a growing threat to the productivity and food security of farmers.

This study adds to the literature by synthesizing data on climate change perception studies, agricultural adaptation research, digital extension services, and institutional support mechanisms in an analytical overview. This review offers a more comprehensive understanding of the relationship between collective factors (awareness, socioeconomic factors, institutional arrangements, and digital communication systems) and farmers' adaptive behavior as compared to previous studies that examined only individual dimensions of climate adaptation.

This review's findings are relevant to policymakers, agricultural extension departments, development organisations, and climate adaptation planners, as they identify a number of challenges that will hinder adaptation effectiveness, such as weak extension systems, digital inequality, limited farmer education, and gender gaps in access to information. The study also highlights the increasing relevance of Information and Communication Technologies (ICTs), mobile advisory services and digital agriculture platforms to support climate-smart agricultural practices and farmer resilience (Khan et al., 2019; Khatri et al., 2024).

The study also offers practical implications for enhancing climate communication strategies, the capabilities of agricultural extension systems, gender-sensitive dissemination pathways, and digital infrastructure in rural areas. The synthesis can help inform the work on developing evidence-based interventions to build adaptive capacity, sustain the agricultural sector, and decrease climate vulnerability for farmers in Punjab.

The study is academically significant in terms of identifying the key research gap and future research priorities of the areas of climate awareness, adaptation behaviours of farmers, digital extension services, and climate-smart agriculture. It is also a basis for future empirical, comparative, and policy-oriented research on agriculture in Pakistan and other climate-sensitive agricultural areas.

1.4 Objectives of the Study

The purpose of the Study is to:

1. To assess farmers' awareness and perception of Climate Change in Punjab, Pakistan.
2. To understand the key adaptation measures farmers took to climate risks.
3. To explore the institutional support, agricultural extension services, and farmers' adaptive readiness.
4. To measure the effect of digital communication pathways on farmers' awareness and adaptation to climate change.
5. To determine the main challenges, knowledge gaps, and policy needs regarding farmers' adaptation to climate change.

1.5 Research Questions

1. What is the level of awareness among Punjab (Pakistan) farmers regarding climate change and its effects on agriculture?
2. What are some of the adaptation strategies that are widely used by farmers in adapting to climate change?

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3. What impact do institutional support systems and extension services have on the adaptive readiness of farmers?
4. How does the digital communication pathway contribute to the awareness of and adaptation to climate change?
5. What are the constraints and gaps in knowledge that hinder farmers' adaptation to climate change in Punjab, Pakistan?

1.6 Methodology

The present study was conducted using the comprehensive literature review method to synthesize the available literature on farmers' awareness, readiness to adapt, and digital communication channels in Punjab, Pakistan. The study was non-empirical, and the review was conducted using published academic literature focusing on climate change perception, agricultural adaptation, digital extension services, ICT-based extension services, and farmer capacity building.

Academic databases and search engines like Google Scholar, ScienceDirect, SpringerLink, MDPI, Frontiers, PLOS ONE, Taylor & Francis, and other peer-reviewed journals were used to identify the literature. The search terms used were various combinations of words like climate change awareness among farmers, perception of farmers on climate change, adaptation in agriculture in Punjab, Pakistan, digital agriculture extension services, ICT in agricultural extension, climate smart agriculture, farmer adaptive capacity, mobile extension and mobile advisory services, gender and climate information services.

The studies were included if they addressed the awareness and perception of farmers about climate change, their adaptation behavior, agricultural extension, digital communication, or climate-smart agriculture, and if they were relevant to Pakistan, South Asia, or similar smallholder farming conditions and offered evidence relevant to the understanding of knowledge, perception, communication, or adaptation pathways. Studies were not included if they did not address agriculture, were not relevant to climate change adaptation, or if they were only about non-farming populations or did not contribute to the aims of the review.

The literature used was thematically analyzed. The evidence that was extracted was summarized into broad themes: farmer perceptions and awareness of climate change, the factors that constrain farmers' adaptive capacity, adaptation strategies, institutional support systems, digital communication pathways, gender-related barriers, knowledge gaps, and policy implications. Studies from Punjab, Pakistan were specifically taken into account and International studies were employed to complement comparative discussion when there was insufficient local evidence.

Because of the variation in design, geography, methods and measured outcomes of the studies included in this review, statistical meta-analysis was not applied. Rather, a narrative and thematic synthesis was performed to look for patterns, contradictions, and gaps in the literature. The approach was appropriate, as it aimed to establish a general picture of the factors that influence farmers' awareness of climate change and their readiness to adapt to it, rather than estimating the impact of a specific intervention.

2. Climate Change Awareness and Farmer Perceptions

2.1 Levels and Patterns of Climate Change Awareness

The level of awareness among the farmers of Punjab is different with respect to impacts of climate change (Mustafa et al., 2023). Most people feel there is more rain, more temperature fluctuations, but a large proportion don't realize some key changes. For example, 48% of the

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farmers did not notice any decrease in winter rainfall, and 31.2% did not notice any change in summer rainfall. The perception gaps indicate that farmers' capacity to correctly perceive changes in climate remains a challenge even in the face of climate change, but is dependent on several socio-economic and institutional factors.

Climatic variations are influenced by the awareness of farmers, which is determined by the environmental communication networks including socioeconomic, institutional and geographic ones. Farmers of rice-wheat and cotton-wheat cropping systems face various climate risks such as weed problems, rise in crop diseases and pest, shift in cropping system, soil fertility loss, and higher frequency of irrigation. Such risks directly impact farmers' choices of adaptation strategies.

2.2 Factors Influencing Climate Change Perceptions

Education (odds ratio 1.16), farming experience (1.07), distance to markets (2.83 for non-agricultural income), agricultural credit (0.29), and extension services (3.87) are key factors that influence climate change awareness in Punjab. The foregoing shows that awareness is not a uniform characteristic of the farmer population, with important equity implications. Farmers who are better resourced and more capable are more likely to feel safer and have better ability to withstand negative climate effects. (Sohail et al., 2022)

The linkage between perception and adaptation is not linear, that is, the perception of climate change does not always correspond to the actual data, and the differences between perceived and observed climate change can affect adaptation intentions (Ricart et al., 2022). In similar agricultural settings, positive relationships have been found between climate change awareness, climate change vulnerability, and adaptation practices, indicating that climate change awareness is indeed a first step towards adaptation.

3. Agricultural Adaptation Strategies and Farmer Readiness

3.1 Common Adaptation Practices

To meet the threats of climate change, the farmers of Punjab have been using various adaptation measures such as crop variety management and selection, soil and irrigation water management, diversification of agricultural production systems and livelihoods, fertilizer management, and the use of new technology. Farmers have turned their attention towards changing of variety and type of crop, planting date adjustments, tree plantation, increase in fertilizers or change in type of fertilizer, soil and water conservation, and off-farm diversification activities.

Adoption of climate-resistant crops and mobile communication-based advisory services are highly significant positive farmers' adaptation decisions. Agricultural diversification in general and especially in climate-vulnerable areas such as Punjab brings environmental and economic advantages, but the advantages are highly dependent on the successful implementation and the support system for the farmers.

3.2 Determinants of Adaptive Capacity

Numerous factors influencing the adoption of adaptation strategies: age, education, number of family members, off-farm income, access to credit, knowledge about weather forecasting, land acreage, farming experience, ownership of tube well and agricultural extension services. Farmers' cooperative meetings, off-farm income sources, and education are important factors in determining adaptive behaviour (Mahmood et al., 2021). All these influence the adaptive capacity as defined by (Qaisrani et al., 2018), which is an important factor determining the reaction of households to climate change exposure and sensitivity.

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Importantly, (Kiani et al., 2021) found that while diversification practices brought benefits in terms of income (around Rs 95,260 or US $635 per year for adopters), non-adopters suffered losses of Rs 115,750 if they had not diversified from traditional practices. This underscores that adaptive readiness requires both the willingness to behave adaptively as well as access to resources that are needed for adaptation to happen. The fatalistic attitude has a negative impact on the likelihood of adaptation, and access to the input market and the presence of a tractor have a positive impact on the ability of farmers to take action.

4. Institutional Arrangements and Digital Communication Pathways

4.1 Role of Institutional Support Systems

The impact of formal institutional arrangements, such as Climate Risk Management (CRM) trainings and Digital Agriculture Extension Communication (DAEC) services, is highly significant at all stages of adaptation, from perception to planning to implementation (Mahmood et al., 2021). Agricultural extension services are essential to the adaptation of smallholder farmers, but are limited by lack of transport infrastructure for extension agents, lack of extension materials, a high extension agent-to-farmer ratio, and limited extension funding. (Antwi-Agyei & Stringer, 2021)

Climate-specific extension services and training on climate-resilient crop varieties greatly improve the uptake of adaptation measures by farmers. (Mahmood et al., 2020) The reliable information available on the weather parameters, the advanced agricultural inputs, and the agricultural advices, allows the farmer to develop an effective adaptation strategy that reduces the effects of climate change.

4.2 Digital Communication and Technology Pathways

The use of Information and Communication Technologies (ICT) is changing the way agricultural extension services work, offering timely, place-specific, and economical solutions. Advancements in mobile phones, internet platforms, Geographic Information Systems (GIS) and new technologies such as Artificial Intelligence (AI) have improved the ability of farmers to access timely information regarding weather, pest, market and best practices. Mobile phone ownership was high among farmers, and was reported by 91.2% of farmers in Punjab, while 87.20% used private sector advisory staff and agricultural extension services. Easy connection to stakeholders and updated information about stakeholders were considered to be important advantages (mean satisfaction scores of 4.63 and 4.72 respectively).

Gender differences may be observed in the adoption of mobile phone technologies as men had better financial resources and control over the income of their households as compared to women, and women were able to access services via their husbands' devices. Radio and social groups were the preferred channels for information access for wives while extension officers, print media, television, and local leaders were the preferred channels of information access for husbands, indicating the need for gender-specific methods of information dissemination.

Spatial targeting of ICT-based weather and agro-advisory services based on agricultural vulnerability zones has the greatest impact. (Gangopadhyay et al., 2019) The adoption of recommended practices by farmers and outreach to more farmers than that of the traditional government extension services is significantly higher in the case of video mediated extension services, which also help farmers to better understand the knowledge. (Abate et al., 2022)

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5. Knowledge Gaps and Implementation Barriers

5.1 Information Access Constraints

However, with the advancement of ICTs, there are still some challenges in the process of widespread adoption such as a huge digital divide where the rural communities lack access to smartphones and internet connectivity and electricity supply. (Khatri et al., 2024) These challenges are amplified by gender and socioeconomic differences, as women and marginalized groups tend to be denied access to the benefits of ICTs. Farmers' access to extension services is still a big problem, and the role of public extension services is still very limited in disseminating agricultural knowledge to many farming communities, where farmers rely on other sources of information (Popoola et al., 2020).

The major technologies being used in Africa are text and voice messaging via mobile phones and radios as channels for information dissemination (Ayim et al., 2022). But, the adoption is still limited due to inadequate technological infrastructure, inadequate policies, and low digital literacy of the smallholder farmers.

5.2 Capacity Building and Training Needs

Extension agents need to build their technical skills, knowledge of climate smart agricultural practices, soil moisture conservation techniques, and information communication technologies. (Antwi-Agyei & Stringer, 2021) Mobile phone-based agricultural services are unsuccessful at meeting their goals if the service providers do not take farmers' literacy, skills, cultural contexts and their actual information needs into account. (Emeana et al., 2020) To achieve success, it is important to design services that involve the user, analyse local contexts, understand the farmer's environment and have long-term sustainability through data-driven maintenance.

Physical, social, human, financial, natural and institutional capital along with social responsibility awareness and digital advisory services have been effective in encouraging the adoption of climate-smart agriculture. It is concluded that personalized digital extension service plays a significant association with input intensity, production diversity, productivity of crops, and farm income, which indicates the need for location-specific and customized information in extension services.

6. Synthesis and Policy Implications

6.1 Integrated Framework for Enhancement

A multi-facet approach is needed for farmers' awareness and adaptive preparedness to climate change in Punjab, which encompasses knowledge, perception and digital communication channels. Though current research practice tends to assess farmer perceptions, it rarely fully adopts their contribution to the discourse of adaptation, calling for more qualitative and farmer-centered research.

Adaptation strategies need to be context-specific and regionally specific, and the balance of ‘top-down' and ‘bottom-up' approaches need to be well balanced (Grigorieva et al., 2023). Biodiversity based and climate-smart agriculture approaches, in the context of robust local ecological modernization initiatives, can provide pathways to enhancing incomes sustainably and alleviating food insecurity. Digital technologies have the potential to transform agricultural extension systems and facilitate the dissemination of information at reduced cost, to groups of farmers that have not been well served by extension systems. (Mapiye et al., 2021)

6.2 Recommendations for Policy and Practice

Reliable climate risk management trainings and digital agriculture extension communication services should be given due importance as crucial elements of enhancing adaptive capacity.

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To ensure sustainable food production and livelihood security in the context of changing climate, the investments in education, especially in improving the literacy and numeracy of farmers, need to be complemented with government efforts to provide extension services that cater for climate change. (Mahmood et al., 2020)

Strategies are needed to invest in rural connectivity, affordable technology, and capacity development programmes, with policies that encourage public-private partnerships and farmer-centric participatory approaches, for long-term success (Khatri et al., 2024). Agricultural workshops and training have a positive impact on farm productivity, but the outcomes are dependent on the quality of the training; the suitability of the trainings for local conditions; the willingness of farmers to implement new methods; and the support provided after the training. (Kalogiannidis & Syndoukas, 2024)

To scale climate services for farmer adaptation, mutually reinforcing supply-side and demand-side capacity constraints must be tackled by: (1) transforming the way forecasts are generated and disseminated; (2) leveraging merged gridded observational data as a basis for products; (3) opening up access to climate information; (4) mobilizing staff in existing agricultural extension systems; (5) collectively evaluating tools for communicating with farming communities; and (6) establishing service frameworks at national level.

Gender responsive pathways for dissemination of climate information services should be identified and disseminated through pathways which meet the unique needs and preferences of each gender group, ensuring equitable access to climate adaptation information and opportunities.

6.3 Research and Implementation Priorities

Future climate change studies in Punjab and South Asian region needs to give more specific attention to the understanding of existing gender inequality across intersecting gender axes instead of emphasising only on binary gender inequalities. Improved farmer involvement in research design and implementation, and the incorporation of indigenous knowledge systems and scientific approaches can contribute to better effectiveness of adaptation to climate change. Although the significance of indigenous knowledge for climate adaptation has been firmly established, geographic research is still unevenly distributed and rather general, indicating the need for more region-specific research. (Petzold et al., 2020)

Digital technologies have transformative potential for the agriculture sector in Sub-Saharan Africa and South Asia, and can have a positive impact on market access, decision-making capacity, farm incomes, and livelihoods. Yet, the challenge of surmounting obstacles like limited access to the internet and low digital literacy is essential, and will necessitate a concerted effort from technological development to infrastructure building to human capacity development.

Conclusion

Awareness and preparedness of farmers to climate change in Punjab, Pakistan is an important precursor to maintaining agricultural productivity and food security under the increasing climatic change. Farmers have high levels of awareness of climate change and take a wide variety of actions to adapt, but there are gaps between awareness and action. Adaptive capacity can be significantly improved through the design of support systems for institutions, notably the integration of climate risk management trainings with digital agriculture extension communication services, (Usman et al., 2023) and through the use of ICTs (Khatri et al., 2024). It takes a whole-of-system approach to tackle knowledge gaps, institutional constraints, gender

disparities, and digital access inequities, and to ensure farmer voices and experience are at the heart of adaptation planning and implementation. Extension services, digital systems and farmer capacity building, along with supportive policies and sufficient funding, can provide opportunities for the development of climate-smart agricultural systems which can improve both productivity and livelihood security for farmers of Punjab.

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