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Conceptual Paper

A Conceptual Framework on Climate Change Sensitivity and Technology Adoption Among Farmers

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Abstract: This conceptual paper investigates how economic, political, cultural, and institutional responses to climate change influence farmers' use of adaptive technologies. Drawing on interdisciplinary theories and contextual literature, it proposes an integrative framework in which these sensitivities act as interconnected factors that either promote or impede innovation. Economic sensitivity determines farmers' financial capacity and their willingness to invest in climate-related risk-mitigation technologies. Political sensitivity refers to the role of policies, governance, and resource allocation in creating enabling environments for trust and adoption. Cultural sensitivity emphasises the impact of local knowledge, traditions, and collective practices on farmers' perceptions of technological change, demonstrating that technologies that align with established norms are more likely to be adopted. Institutional sensitivity focusses on the role of research organisations, agricultural extension services, and financing mechanisms in providing the knowledge and support required for successful adoption. The paper contends that climate-smart agricultural systems necessitate adaptive strategies that combine technological solutions with socially grounded and context-specific methods. This paper addresses a gap in prior research, which has typically treated these sensitivities separately, by proposing an integrative framework. By situating adoption decisions within these interconnected sensitivities, the framework improves understanding of how social, economic, and institutional dimensions interact to shape farmers' reactions. It also provides useful insights for developing inclusive policies and practices that boost resilience and enable long-term agricultural transformation.

Keywords: Climate change sensitivity; technology adoption; farmers; climate adaptation; adaptive capacity

Introduction

Climate variability manifested in rapid changes has forced a number of sectors to reassess their strategies for ensuring resilience. Due to their direct dependence on natural resources and prevailing weather patterns, the agricultural sector is at an increased exposure from climatic extremes. Farmers, especially smallholders, are vulnerable due to economic, political, cultural, and institutional sensitivities. While previous studies have examined these dimensions separately, this paper addresses the gap by offering an integrated conceptual framework that demonstrates how they collectively shape adaptation and technology adoption. Furthermore, these sensitivities do more than just impact farmers' financial health. They also slow down their adoption of

new technologies designed to help buffer against the impacts of climate change. Consequently, understanding the effect of climate change sensitivity on farmers' technology adoption is becoming increasingly salient in both academic and policy debates (Marshall et al., 2010; Adger et al., 2013a; Fenton et al., 2007). Despite ongoing efforts, climate change continues to disrupt food systems and hinder technology adoption through erratic weather, poor disaster planning, and reduced yields, highlighting the need for resilient, context-aware strategies (Boboye & Dorasamy, 2025; Dyke et al., 2020; Lasisi et al., 2025).

Quantifying farmers' economic well-being is an important first step in determining their readiness to adopt new technologies. For example, economic well-being refers to an individual's or family's ability to maintain financial stability and manage potential future risks, as evidenced by considerations for emergency savings and retirement over time savings behaviour (Brou & Zeigler-Hill 2020; Graham 2011). Economic security, for example, is a critical component of well-being that is directly related to farmers' and their families' ability to withstand climate shocks such as droughts or floods in torrential downpours. Economic or financial factors influence when a farmer can afford to use new technologies (Wilmarth 2021; Osberg 2020). According to Harvey et al. (2018), farmers are more likely to adopt technological solutions that increase productivity and reduce future risks after suffering significant economic losses as a result of climate extremes.

Climate-friendly technology aids adaptation efforts, while perceived benefits, simplicity, and compatibility with existing farming practices influence farmer adoption (Davis, 1989; Rogers, 2003). Farmers' cost-benefit ratios also have a strong influence on adoption processes, particularly given their economic vulnerability to climate change (Hassan & Nhemachena, 2008). Furthermore, political factors such as government incentives and agricultural policy stability influence farmers' decisions to adopt technology (Wu et al., 2022).

Political sensitivity to climate change refers to how quickly the government responds to the realisation that it is under threat. Farmers gain trust in new technologies when they believe politicians or the government are more responsive and politically savvy. Governments promote agricultural innovations and provide support mechanisms such as subsidies or grants to encourage farmers to use adaptation technologies that will allow them to adapt their systems for climate resilience (Adger et al., 2013b; Gemenne et al., 2014). Farmers will be hesitant to adopt new technologies if political systems are unstable or unresponsive due to ambiguity and a lack of trust (Crentsil et al., 2020; Zakaria et al., 2020).

Aside from economic and political sensitivities, climate change's cultural sensitivity would imply an understanding of how weather affects social relations, traditional behaviour, and farming methods. Farmers in areas with strong cultural ties to traditional farming practices, on the other hand, may be reluctant to adopt new technologies that contradict established techniques (Shen et al., 2023; Antonelli, 2023). On the one hand, farmers may be more likely to adopt technologies that complement or enhance conventional practices (Makate 2020).

Finally, institutional awareness of climate change highlights organisations and institutions as key promoters of technology adoption. Institutions such as agricultural extension services and research organisations play critical roles in transferring skills by fostering innovation and providing the necessary resources for technology adoption (Danso-Abbeam et al., 2018). Farmers' trust in these institutions influences their willingness to adopt new technologies (Fan et al., 2023).

This paper provides a conceptual framework of how sensitivities across economic, political, cultural, and institutional dimensions shape technology adoption and influence societal responses to the growing challenges of climate change. It emphasises the importance of increasing farmer awareness and accounting for these interconnected sensitivities in order to successfully implement climate-smart agriculture in rural communities. Rather than using empirical data or systematic analysis, the study develops its framework through an interpretive review of academic literature and theoretical perspectives on technology adoption.

Conceptual Framing and Approach

This paper employs a narrative literature review, drawing interpretively from interdisciplinary sources, to build a conceptual framework. This narrative approach enhances both clarity and transparency by acknowledging that the paper does not synthesise empirical findings systematically but develops theory

through conceptual reasoning. Rather than synthesising empirical findings or using a structured review protocol, it creates a theoretical framework to understand how farmers' sensitivity to climate change influences their adoption of adaptive technologies in four critical domains: economic, political, cultural, and institutional. This decision reflects the growing recognition that technology adoption in agriculture cannot be fully understood using isolated variables alone, but rather requires an integrated perspective that connects climate risks to the larger social, political, and institutional contexts in which farmers operate (Adger et al., 2013a; Ostrom, 2010).

The conceptual approach combines theories and evidence from various disciplines, drawing on findings from climate adaptation research, rural development, and innovation diffusion. It uses interpretive reasoning to investigate how environmental pressures interact with social systems and behavioural responses, with a focus on the decision-making processes that occur in the face of climate uncertainty. This enables the paper to move beyond descriptive accounts of farmer behaviour and propose a coherent explanatory framework for comprehending adoption dynamics. By framing the inquiry around sensitivities, the approach emphasises the importance of lived experiences, perceived risks, and resource constraints, which are frequently overlooked in strictly empirical analyses (Marshall et al., 2010; Fenton et al., 2007).

Importantly, this conceptual framework recognises that farmers' adaptive decisions are influenced not only by direct environmental impacts, but also by multiple social, political, and institutional factors. Economic pressures may limit investment capacity, political environments influence trust and policy stability, cultural practices shape technology perceptions, and institutional arrangements determine access to resources and knowledge. These domains are interconnected rather than independent, which means that a change in one dimension, such as an enabling subsidy policy or improved institutional support, can have a cascading effect on farmers' technology adoption behaviours (Gemenne et al., 2014; Rizzo et al., 2024).

By focussing on these intersections, the framework contributes to a multi-scale understanding of climate adaptation. It integrates farmers' technological decisions into larger governance systems and socio-cultural contexts, moving beyond single-factor explanations. This approach also promotes the development of context-sensitive strategies that take into account heterogeneity within farming communities, such as differences in resource access, social norms, and institutional support structures. Such integrative conceptual work is essential for developing policies that are not only technically sound, but also socially inclusive and responsive to local realities (Crate & Nuttall, 2016; Adade Williams et al., 2020).

The goals of this framework are threefold: to consolidate theoretical perspectives, to guide future empirical research, and to inform policy and practice. By articulating the connections between economic, political, cultural, and institutional sensitivities, the study lays the groundwork for developing adaptive interventions that reflect farmers' lived experiences and strengthen resilience on multiple levels. The conceptual framework thus adds to broader discussions about climate-smart agriculture by demonstrating that effective adaptation strategies must combine technological innovation with socially grounded, context-specific pathways.

Defining Climate Change Sensitivity

According to Marshall et al. (2010) and Fenton et al. (2007), sensitivity to climate change refers to how human social systems adapt to climate change, with a particular emphasis on economic, political, cultural, and institutional dimensions. Marshall et al. (2007) defined sensitivity as the degree to which a system is affected or triggered by climate change, with systems that rely on sensitive natural resources being more sensitive. This sensitivity implies that the economic cost of climate exposure may rise or fall depending on how some of these social factors balance or interact with one another. This emphasises the importance of incorporating local communities and their vulnerabilities into climate adaptation plans, as well as tailoring responses to specific local needs and conditions.

Each sensitivity dimension has a different impact on climate adaptation. Economic sensitivity evaluates climate change's effects on income, employment opportunities, and adaptation costs (IPCC, 2007; Stern, 2007). Political sensitivity refers to the public's perception of political actions on climate change, including political willingness and decision-making influences on adaptation policies (Adger et al., 2013b;

Barnett & Adger, 2007). Cultural sensitivity entails understanding the effects of climate change on cultures, traditions, and social relations while taking into account indigenous peoples' adaptation knowledge systems (Adger et al., 2013a; Crate & Nuttall, 2016). Finally, institutional sensitivity assesses how well institutions perceive climate change problems and address their solutions, with institutions responsible for policy implementation, resource control, and adaptation advocacy (Biermann et al., 2009; Ostrom et al., 2010).

The Impact of Climate Change Sensitivity on Technology Adoption

Economic, political, cultural, and institutional sensitivities must be thoroughly understood in order to encourage farmers to adopt technologies during times of climatic stress. These sensitivity domains have a unique impact on farmers' readiness to adopt new technologies, emphasising the importance of addressing their sensitivities holistically. Recognising such factors allows policymakers, researchers, and practitioners to develop better solutions to assist farmers in adopting technologies that can help improve their resilience to climate change.

1. The Impact of Economic Sensitivity to Climate Change on Technology Adoption

Economic sensitivity to climate change measures how climate extremes affect farmers' financial well-being and income, as well as the overall economic landscape. When climate variability puts a strain on farmers' finances through crop failures caused by droughts, floods, or heat waves, they are forced to look for ways to adapt. Economic measures that motivate or demotivate respondents can have a significant impact on their willingness to adopt new technologies (Figure 1).

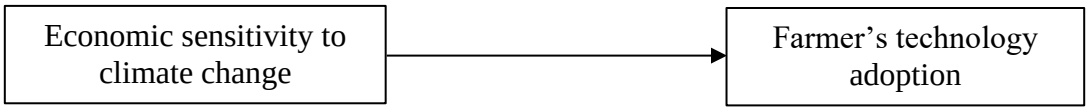

Figure 1. Climate change’s economic sensitivity affects farmers' technology adoption

First, the economic impact of climate extremes drives farmers to use technology to reduce the likelihood and severity of future disasters in order to increase returns. For example, Harvey et al. (2018) discovered that farmers who have experienced significant revenue losses due to unfavourable weather are more likely to purchase technologies that can help them produce more crops or manage risks more effectively. Furthermore, it was reported that there are ways to reduce vulnerability to such losses, such as the use of drought-tolerant crops, efficient water management techniques, and effective weather prediction systems (Khatun et al., 2021; Frimpong et al., 2023; Wodaju et al., 2023; Aishwarya & Kumar, 2024).

As a result, a farmer's economic sensitivity may influence his or her decision to adopt technology. For example, during times of economic stress, farmers may be willing to adopt technologies with short-term returns or those that require an initial investment (Hassan & Nhemachena, 2008). The presence of incentives and funds to support technology implementation, such as subsidies or grants, may also improve their readiness to adopt new technologies (Barbosa, 2024; Wu et al., 2022).

This aspect of economic sensitivity is also related to the realised return on investment for technology adoption. Farmers who expect to benefit more from adopting new technologies are more likely to invest in them, especially if they have recently suffered losses due to climate change (Wang et al., 2019; Rizzo et al., 2024; Asante et al., 2024). As a result, the potential economic returns from new technologies play a critical role in increasing farmers' propensity to innovate.

2. The Impact of Political Sensitivity to Climate Change on Technology Adoption

The acceptability of policies and regulations, as well as how farmers engage with the country's political action, is critical in the context of climate change. Political factors can have a significant impact on farmers' willingness to accept new technologies because government actions or inaction can either facilitate or impede the adoption process (Figure 2).

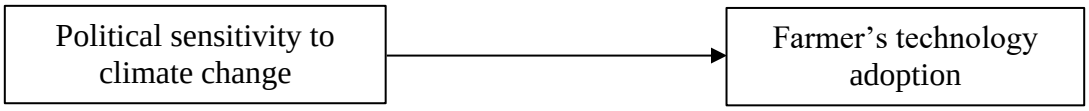

Figure 2. Climate change's political sensitivity affects farmers' technology adoption

Governments' adoption of technology is heavily influenced by policies and regulations. For example, favourable institutional factors, such as subsidies for climate-smart technologies or funding for agricultural extension and innovation, can boost farmers' motivation to innovate (Hebsale Mallappa & Pathak, 2023; Belmin et al., 2023). On the one hand, political instability or unfavourable policy changes can create uncertainty, making farmers hesitant to purchase new technologies (Aisen & Veiga, 2013; Bertin et al., 2016; Abadie & Gardeazabal, 2003).

Political sensitivity also influences farmers' confidence and readiness to adopt technologies. Farmers are more likely to adopt new technologies if they believe the government is doing enough to combat climate change and support agricultural technological advancement (Zakaria et al., 2020; Tanure et al., 2024). Farmers who have a negative perception of their political leadership and feel unsupported may be more resistant to new technologies (Crentsil et al., 2020; Han et al., 2022).

Furthermore, political sensitivity influences farmers' risk perceptions and willingness to adopt new technologies. Farmers are more likely to understand that technology can help them deal with climate risks when political leaders emphasise the need for climate change action and provide direction and resources (Hebsale Mallappa & Pathak, 2023; Lamichhane et al., 2022; Ma & Rahut, 2024). On the other hand, political risk or ambiguity can slow technology adoption (Wu et al., 2023; Harik et al., 2023; Chavas & Nauges, 2020).

3. The Impact of Cultural Sensitivity to Climate Change on Technology Adoption

Cultural sensitivity entails understanding how climate variables affect people's social interactions, beliefs, and practices. Cultural factors can have a significant impact on farmers' readiness to embrace new technologies because the technologies may alter culture and/or beliefs in some way (Figure 3).

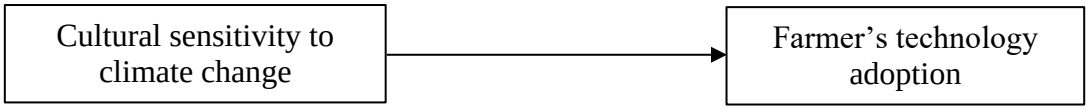

Figure 3. climate change's economic sensitivity affects farmers' technology adoption

Cultural sensitivity can also influence farmers' attitudes towards and use of new technologies. There may be cultural barriers to change in societies where traditional forms of farming are practised, and people may be hesitant to change or embrace new technologies that differ from conventional ones (Shen et al., 2023; Duong et al., 2019). For example, technologies that require farmers to change some aspect of their farming practices may be rejected if they appear to conflict with farmers' beliefs or knowledge systems (Mohan et al., 2021; Antonelli, 2023).

Furthermore, cultural sensitivity can foster technology adoption by ensuring that newly introduced technologies support or enhance cultural values. This means that farmers are more likely to adopt technologies that complement or improve on traditional practices (Denashurya et al., 2023; Palis, 2006). People may easily adopt technologies that incorporate local knowledge and practices, as well as cultural beliefs (Adade Williams et al., 2020; Makate, 2020; Peddi et al., 2023).

Furthermore, cultural sensitivity can influence the delivery and advertising of technology. In tightly knit cultures, community-based methods of technology diffusion, such as demonstrations or peer learning, have been shown to be more effective than individualistic methods (Dutta, 2007; Bader et al., 2023; McElfish et al., 2017). It is critical to involve local leaders and incorporate cultural practices into the design and implementation of technology interventions in order to increase acceptance and utilisation (Questa et al., 2020; Alderwick et al., 2021).

4. The Impact of Institutional Sensitivity to Climate Change on Technology Adoption

Institutional sensitivity refers to farmers' ability to identify and interact with various institutions, such as research organisations, extension services, and co-operatives, in the context of climate change. The efficiency and friendliness of these institutions can significantly influence a farmer's willingness to innovate (Figure 4).

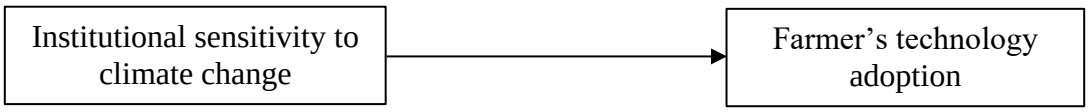

Figure 4. climate change's institutional sensitivity affects farmers' technology adoption

Institutions are important in the adoption of technology because they provide the necessary resources, information, and support. For example, a tie and dye farming service that offers training and advisory services will help farmers understand and apply new technologies (Makate, 2020; Danso-Abbeam et al., 2018; Gebremariam et al., 2023). Research, development, and dissemination of new technologies may increase farmers' trust in these technologies (Schut et al., 2016; Danso-Abbeam et al., 2018; Kapgen & Roudart, 2023).

Institutional sensitivity also influences farmers' perceptions of the credibility of technology providers. Such a positive perception increases the likelihood that farmers will adopt the institutions' promoted technologies (Fan et al., 2023; Somanje et al., 2021; Bontsa et al., 2023). However, where farmers have had negative experiences or believe institutions are flawed or unfair, their willingness to innovate may be reduced (Cafer & Rikoon, 2018; Crentsil, 2020; Rizzo et al., 2024).

In addition, institutional sensitivity influences the resources and support available for technological implementation. Financial institutions that offer loans or grants for technologies can increase farmers' ability to invest in new technologies (Geng et al., 2024; Xie et al., 2024). The assessment of these institutional mechanisms in terms of their ability to meet farmer needs and challenges has a significant impact on farmers' willingness to adopt new technology.

Conceptual Framework: Sensitivities Shaping Farmers' Technology Adoption

This paper proposes a conceptual framework (Figure 5) to explain how four interconnected sensitivities, namely economic, political, cultural, and institutional, influence farmers' decisions to implement adaptive technologies in response to climate change. Rather than viewing these sensitivities as separate factors, the framework sees them as mutually reinforcing dimensions that shape adaptive capacity collectively. Each sensitivity has a distinct impact on farmers' decision-making, either facilitating or impeding their ability to adopt new technologies under climate stress (Marshall et al., 2010; Adger et al., 2013a).

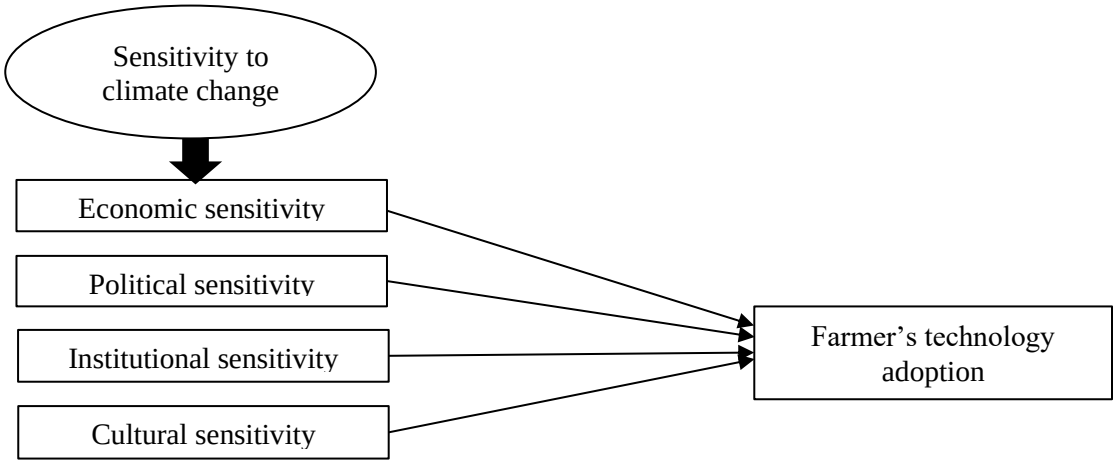

Figure 5. Dimensions of climate sensitivity influencing farmers' adaptive capacity

The framework identifies climate change sensitivity as the overarching driver that activates responses in each domain. Environmental variability, such as droughts, floods, and shifting rainfall patterns, interact with farmers' economic resources, political environments, institutional support systems, and cultural norms to create complex technological adoption pathways. These pathways are rarely linear and frequently depend on farmers' perceptions of risk, trust in governance systems, and resource availability (Gemenne et al., 2014). For example, if institutional capacity is weak, financial incentives may be rendered ineffective, whereas strong cultural values may either encourage or hinder the adoption of innovative practices, depending on alignment with local knowledge and traditions (Crate & Nuttall, 2016).

By combining these sensitivities into a single framework, the study emphasises the importance of viewing adaptation as a multidimensional, context-dependent process. This conceptualisation allows us to identify critical leverage points where interventions can have the greatest impact. Policies that strengthen institutional mechanisms, increase trust in governance, and align with cultural practices, for example, can help to reduce barriers to technology adoption while improving resilience outcomes (Adade Williams et al., 2020). At the same time, the framework emphasises the importance of developing adaptation strategies that are flexible and responsive to the diversity of farmer experiences, rather than relying on uniform, top-down solutions.

Furthermore, the framework advances theoretical and practical knowledge by providing an integrative perspective that links social, environmental, and institutional processes. For researchers, it serves as a foundation for conducting empirical studies to test these interconnections. For policymakers, it emphasises the importance of cross-sectoral interventions that align technical innovation with local realities. It provides practitioners with insights into designing context-sensitive programs that strengthen adaptive capacity at the community level. In this way, the framework contributes to a comprehensive understanding of how sensitivities interact to shape technological choices and adaptive strategies in the face of climate change (Ostrom, 2010; Rizzo et al., 2024).

Discussion

This study demonstrates how economic, political, cultural, and institutional sensitivities influence farmers' decisions to implement climate-change mitigation technologies. Together, these findings reinforce the paper’s central objective of framing technology adoption as a multidimensional process shaped by interlinked sensitivities. These sensitivities influence not only how farmers perceive climate risks, but also how they evaluate technological options and make decisions based on their financial resources, social contexts, and institutional environments. Recognising these interconnected dynamics is critical for creating adaptive strategies, supportive policies, and institutional frameworks that respond to local needs and realities.

Farmers' ability and willingness to adopt new technologies is often determined by their economic sensitivity to climate change. When declining yields, extended droughts, or unexpected floods put additional strain on farm income, farmers are compelled to consider technologies that reduce risks and stabilise productivity. However, when this sensitivity manifests itself in the form of high initial costs, limited credit access, or uncertainty about long-term returns, adoption rates fall, particularly among resource-limited households. Addressing this issue will necessitate targeted subsidies, low-interest loans, and insurance programs that reduce financial vulnerability. Strengthening these support mechanisms ensures that the benefits of innovation are distributed more equitably and that resilience is increased across a range of farming contexts.

Political sensitivity shapes trust in governance and policy framework stability, creating an environment conducive to technological adoption. Farmers are more likely to adopt new technologies when governments show clear commitments to climate adaptation through consistent policies, transparent incentives, and ongoing investment in agricultural innovation. Political sensitivity, on the other hand, becomes a barrier when policies are inconsistent or the government is slow to respond, resulting in uncertainty and diminished trust. Strengthening participatory governance, involving farming communities in decision-making, and improving communication channels can all have a positive impact on this sensitivity, creating a sense of inclusion and security that encourages innovation.

Cultural sensitivity, which shapes farmers' perceptions of technological change, is another social factor that influences adoption decisions. Technologies that complement existing cultural norms are more readily accepted, whereas those perceived as disruptive or incompatible face opposition. Cultural sensitivity is enhanced by engaging community leaders, incorporating indigenous knowledge into program design, and promoting participatory implementation methods. These approaches not only increase technology acceptance, but also foster social cohesion and a shared sense of ownership over adaptive solutions, both of which are critical for long-term behavioural change.

Farmers' access to innovations is also influenced by institutional sensitivity, which measures how credible, competent, and supportive agricultural institutions are perceived to be. Research organisations, extension services, cooperatives, and financial institutions all play an important role in establishing trust and providing resources for adoption. When institutional sensitivity is high, farmers have greater confidence in the information and assistance provided, making them more likely to adopt new technologies. Improving institutional performance through better training, increased outreach, and stronger collaboration among local, regional, and national actors can help to reduce service fragmentation and ensure that farmers receive consistent, context-specific assistance.

To effectively integrate these sensitivities, inclusive, cross-sectoral approaches must be used that recognise the diversity of farmers' experiences and resource capacities. By addressing their interdependence, policymakers and practitioners can create more context-specific, equitable, and sustainable adaptation strategies. Aligning technological innovation with social realities, cultural values, and institutional structures ensures that adaptation strategies are not only technically sound, but also practical, participatory, and responsive to the changing challenges confronting farming communities. By synthesizing across the four domains, the discussion confirms the need for an integrated conceptual framework, moving beyond single-factor explanations to align with the objectives of this study

Conclusion

Finally, the adoption of climate adaptation technologies by farmers is influenced by a complex interplay of economic, political, cultural, and institutional factors. These dimensions do not act in isolation, but rather as interconnected forces that influence how farmers perceive risks, assess opportunities, and make decisions in the face of climate uncertainty. Understanding these interdependences is critical for developing strategies that improve both agricultural resilience and productivity.

To achieve meaningful and widespread adoption of climate-smart technologies, responses must go beyond addressing isolated barriers and instead take a comprehensive approach that takes into account the larger social and environmental context in which farmers operate. This process relies heavily on providing appropriate economic incentives, maintaining policy stability, and encouraging cultural acceptance. Equally important is increasing institutional support through accessible extension services, responsive governance, and dependable financing mechanisms that promote technology adoption and long-term adaptation.

Improving policymaking is critical to achieving these outcomes. Policies that are context-sensitive, evidence-based, and consider local priorities can help to bridge the gap between technological advancements and the realities of farming communities. This necessitates engaging farmers as active participants rather than passive recipients, and ensuring that adaptation strategies are tailored to their specific needs, capacities, and knowledge systems. Such approaches not only increase adoption rates, but they also foster trust and ownership, both of which are necessary for long-term behavioural change.

Future research should focus on more nuanced, context-specific solutions that address the diversity of sensitivities found in various agricultural settings. Comparative studies looking at variations in adoption patterns across regions and farming systems could help identify the most effective pathways under various climatic and socioeconomic conditions. Furthermore, cross-disciplinary collaborations among governments, researchers, private sector actors, and local communities are critical for speeding up the integration of technological innovation with practical, locally grounded adaptation plans.

Recognising the interconnected nature of these sensitivities and strengthening cooperation among multiple stakeholders can help agricultural systems navigate the challenges of climate change while also

allowing farmers to adopt technologies that improve resilience and long-term productivity. Future adaptation policies should therefore be co-designed with farmers, institutions, and governments, ensuring that economic, political, cultural, and institutional sensitivities are addressed in unison through collaborative, context-specific strategies.

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