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Enhancing Sustainability in Apple Farming in Jammu and Kashmir: An Analysis of Agricultural Innovation Adoption.

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Abstract

The thesis investigates the factors influencing the adoption of agricultural innovations in apple farming in Jammu and Kashmir from the perspectives of technological, organisational, and environmental dimensions. Using the Agricultural Systems of Innovation (ASI) Theory, Technology-Organisation-Environment (TOE) framework, and Institutional Theory, the study examines barriers like high costs, technical complexity, absence of infrastructure, and sociocultural resistance In terms of adoption, qualitative data were collected through 10 newly conducted semi-structured interviews (5 farmers and 5 agricultural officers). These interviews replaced a previous set of 15, following changes in the theoretical framework and interview design. where farmers are good at adopting, they have access to credit, training, and to a policy that is efficient enough to sustain and maintain agriculture. The paper contributes to theory by merging several frameworks to better explain the adoption of innovation and offers practical advice to policymakers, which includes subsidising entrepreneurship, infrastructure development, and gender inclusive extension services. Beyond analysis, this study innovates by proposing context-specific, technology-enabled interventions, such as an efficient system for improving agricultural processes and gender-responsive training models, to systemically enhance sustainability and competitiveness. In future research, context-specific interventions could help to improve sustainability in apple farming in the region. Thus, the results call for stakeholder collaborations to create an enabling environment for the adoption of innovation.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Apple production is a crucial economic and a source of livelihood to the people of Jammu and Kashmir, as it is the mainstay of its horticultural exports (Sheikh and Baba, 2023). Nevertheless, the industry is encountering mounting obstacles caused by climatic variations, market volatility, and traditional farming methods (Aerni et al., 2015; Shah et al., 2022). These issues jeopardize the productivity and sustainable performance of the industry in the long-run.

Modern farming advances such as high-density planting, drip irrigation, and varieties resistant to climate have the potential to improve the yield and quality, but their use in the area is low (Bhat et al., 2022). The causes of this reluctance can be explained by the high costs, the lack of proper infrastructure, and sociocultural resistance (Dessart et al., 2019). Despite the studies on the adoption of apples in other regions of India where apples grow, little research has been conducted in Jammu and Kashmir (Alaie, 2020).

This research seeks to address that gap by analyzing the impact of technological, organizational and environmental forces on the use of technological innovations in apple farming in Jammu and Kashmir. It aims to provide context-based recommendations that can assist policymakers and practitioners to achieve sustainable agricultural development in the region by relying on the Agricultural Systems of Innovation (ASI) Theory, the Technology-Organization-Environment (TOE) framework, and the Institutional Theory.

1.2 Research Problem and Justification

While agricultural innovations can significantly increase productivity and sustainability in Jammu and Kashmir's apple farming sector, adoption rates are still low. Such barriers include inadequate infrastructure and farmers' lack of awareness of sustainable practices. In this context, sustainable practices refer to methods that promote long-term environmental and economic viability, such as integrated pest management (IPM), organic farming, precision irrigation, climate-resilient crop varieties, and post-harvest techniques that reduce spoilage and enhance efficiency (Sapbamrer & Thammachai, 2021; Bhat et al., 2022). Other than that,

fluctuating market demands and sudden demand variability, combined with weak policy support, continue to obstruct advancements. Such a gap in adoption negates the sector's overall long-term viability.

Policymakers, agricultural extension services, as well as farmers need to understand the factors affecting innovation adoption. They also need evidence-based insights to develop tailored interventions. Without systemic analysis, solutions would end up siloed in — for example, subsidising technologies without considering infrastructural lag or cultural resistance (Juárez-Luis et al, 2018). For example, intervention designs inspired by ASI in Himachal Pradesh's apple sector (for ex., farmer-researcher cooperatives for adoption of cold storage) succeeded in realising associations across technological, organisational and policy dimensions (Shah et al., 2022).

Three Theoretical frameworks are employed in this study to analyse the complex adoption of innovation barriers systematically: Agricultural Systems of Innovation(ASI) Theory, Technology-Organisation-Environment(TOE) framework, and Institutional Theory. This case is complex due to the interplay of multiple, overlapping challenges—including fragmented extension services, climate volatility, entrenched sociocultural norms, weak market linkages, and policy implementation gaps—which together influence adoption outcomes in non-linear and context-specific ways.

The analysis of these frameworks shows that technological access, the organisational capacities of the farming operation affected adoption, and the institutional environment also affect adoption. The thesis identifies the key constraints along these dimensions, from low technical knowledge to lack of policy support. The findings are informed as strategies towards innovation uptake aim to boost the sector's environmental sustainability for policymakers and agricultural stakeholders. Since this is an all-encompassing approach, this provides useful data not just about Jammu and Kashmir's apple industry but also other agricultural systems similar to this trying to adopt innovation.

1.3 Research Aim and Objectives

Research Aim:

This study aims to improve understanding of the key factors limiting innovation adoption in apple farming in Jammu and Kashmir, to strengthen the region's agricultural system and its long-term sustainability. Theoretically, the thesis contributes by integrating the Agricultural

Systems of Innovation (ASI) Theory, the Technology-Organisation-Environment (TOE) framework, and Institutional Theory into a unified model. This multi-theory approach advances current understanding by bridging gaps between system-level interactions and context-specific barriers in innovation adoption

To direct this goal, the study adopts a systemic perspective that focuses on the broader dynamics influencing innovation adoption in Jammu and Kashmir's apple farming. While single-factor explanations fall short in capturing the interlinked barriers, this research draws on the strengths of three complementary frameworks. The ASI perspective provides a systems-level view of stakeholder interactions and institutional coordination. Insights from the TOE framework help structure the analysis of technological feasibility, organisational capacity, and environmental context. Institutional Theory adds depth by examining how formal policies and informal cultural norms shape adoption behaviour. This integrated approach allows for a more nuanced understanding of the multi-layered constraints affecting innovation uptake.

Research Objectives:

1. To examine how technological attributes influence the adoption of specific agricultural innovations in apple farming in Jammu and Kashmir.
2. To analyse the impact of organisational characteristics of farmers/farms on the innovation adoption process.
3. To evaluate the role of the broader environmental context (market, policy, infrastructure) in shaping innovation outcomes.
4. To investigate how government policies, market demands, and local norms and values influence the adoption of sustainable practices.

1.4 Research Question

What are the key factors influencing the adoption of agricultural innovations in apple farming in Jammu and Kashmir?

1.5 Innovative Scope of This Study

This study uses a new integrative approach that integrates three separate theoretical frameworks, Agricultural Systems of Innovation Theory, the Technology-Organisation-

Environment framework, and Institutional Theory, to comprehensively study the adoption of innovation in apple farming, given its distinctive socio-political and agro-ecological surroundings in Jammu and Kashmir. While previous research tends to consider single factors in isolation, this research attempts to examine the interplay of technological, organisational, and institutional factors while integrating cultural resistance. This intersectional and system-level lens provides greater context-specific insights and allows for a strategic pathway to innovation uptake for marginalised agricultural communities in volatile areas.

1.6 Significance of the Study

The results of the study will be useful for various stakeholders of the apple farming sector of Jammu and Kashmir. It helps identify the key technological, organisational, and environmental factors influencing the adoption of innovation for farmers and guides them in making better decisions in terms of increasing productivity and sustainability. Evidence-based insights will inform policymakers and agricultural extension agencies what targeted interventions, like improved training programs, infrastructure development, and policy reform, are needed to overcome the adoption barriers.

By synthesizing ASI, TOE, and Institutional Theory, this work adds to academic discussions by delivering an integrated, situational understanding of the adoption of innovation from the perspective of addressing these factors in a holistic manner, rather than in isolation and neglecting the uniqueness of Jammu and Kashmir which has been the case with previous research.

In addition, global agricultural priorities are aligned with the focus on sustainability, setting the scene for other parts of the world facing equivalent difficulties. Therefore, it can help in enhancing innovation adoption, increasing farmers' livelihoods, and promoting environmental resilience. This study has a lot of meaning for the apple farming industry in Jammu and Kashmir, so that it could have a long-term and sustainable future.

1.7 Outline of Methodology

This research examines context-specific concerns such as farmers' attitudes, institutional barriers, and socio-cultural dynamics within Jammu and Kashmir's apple economy. It is unique in combining ASI, TOE, and Institutional Theory to examine systemic interactions alongside examining less-researched dimensions like intergenerational knowledge and policy-practice gaps through a qualitative, experience-based methodological framework.

Data was gathered from 10 respondents in the form of semi-structured interviews, in which 5 apple farmers and 5 agricultural officers were interviewed. This approach was flexible to explore emerging themes while ensuring consistency in vital questions. Technological, organisational, and environmental aspects of innovation adoption factors, such as policy impacts and social norms, were the issues that fell under the interviews' scope.

Thematic analysis was conducted to retrieve the recurring patterns and code them according to the ASI, TOE, and Institutional Theory frameworks. Triangulation with secondary sources made the study more robust. Although small in sample size, it allowed fine, nuanced analysis, appropriate to the exploratory nature of the research.

1.8 Scope and Limitations

The study analyses driving factors towards innovation adoption in apple farming in Jammu and Kashmir based on the ASI Theory, TOE framework, and Institutional Theory. The technology, organisation, and environmental attributes are included in the scope, technological attributes (e.g., advanced farming techniques), organisation characteristics (e.g., farm size, farmer knowledge) and environmental factors (e.g., policies, market demands). The source of the research is interviews with officials and apple farmers.

The benefit of the qualitative approach is that it offers detailed information, but the use of such a small sample set makes generalisation to other populations or agricultural sectors difficult. Furthermore, unpredictable external shocks like extreme weather events are not taken into consideration in the study. Despite these constraints, the research identifies key drivers and barriers and offers actionable recommendations for stakeholders, highlighting the need for further large-scale studies to validate and expand upon these findings.

1.9 Thesis Structure

This thesis is structured into 6 chapters to systematically address the research objectives:

Chapter 1: Introduction

This chapter provides the background, research problem, aims, objectives, significance, scope, limitations, and methodology. Establishes the foundation for the study.

Chapter 2: Literature Review

Critically examines existing theories (ASI, TOE, Institutional Theory) and empirical studies on agricultural innovation adoption, and sustainability, identifying gaps this research addresses.

Chapter 3: Theoretical framework

Develops and presents the integrated theoretical framework combining ASI, TOE, and Institutional Theory to analyse innovation adoption in apple farming.

Chapter 4: Research Methodology

Details the research methodology, data sources, thematic analysis techniques, and validation methods.

Chapter 5: Findings and Discussion

Presents and interprets results on technological, organisational, and environmental factors influencing innovation adoption, linking findings to theoretical frameworks.

Chapter 6: Conclusion and Recommendations

Summarises key insights, proposes actionable recommendations for stakeholders, and suggests future research directions to enhance innovation adoption in apple farming

CHAPTER 2 LITERATURE REVIEW

The chapter is the review of the major academic and empirical literature on the issue of agricultural innovation adoption, specifically, sustainability in apple farming in Jammu and Kashmir. It initially describes the key theoretical bases of this research Agricultural Systems of Innovation (ASI) Theory, Technology-Organisation-Environment (TOE) Framework, and Institutional Theory that give the conceptual filters through which technological, organisational and environmental issues affect the adoption of innovation. According to the ASI Theory (Aerni et al., 2015), farmers, researchers, policymakers, and markets will collaborate to innovate agriculture as a system-wide process.

Adoption according to the TOE Framework (Baker, 2011) is influenced by three interconnected dimensions which include the technology itself, organisational capacity of the adopter and the environment around it. Institutional Theory (Juárez-Luis et al., 2018) is concerned with the way in which the rules of the government, market mechanisms, and social norms either facilitate or restrict innovation. A combination of these theories assists the study of the influence of the apple industry in Jammu and Kashmir by various layers of technological, organisational, and policy issues.

The chapter then examines the literature on agricultural innovation adoption in the world and India before going ahead to discuss in detail the technological, organisational, environmental and institutional factors that affect the uptake of innovation. Lastly, it determines the research gaps and how this study can help fill in new information by applying ASI Theory within the context of the apple farming in the region of Jammu and Kashmir - a method that has never been used before.

2.1 Introduction to Agricultural Innovation Adoption

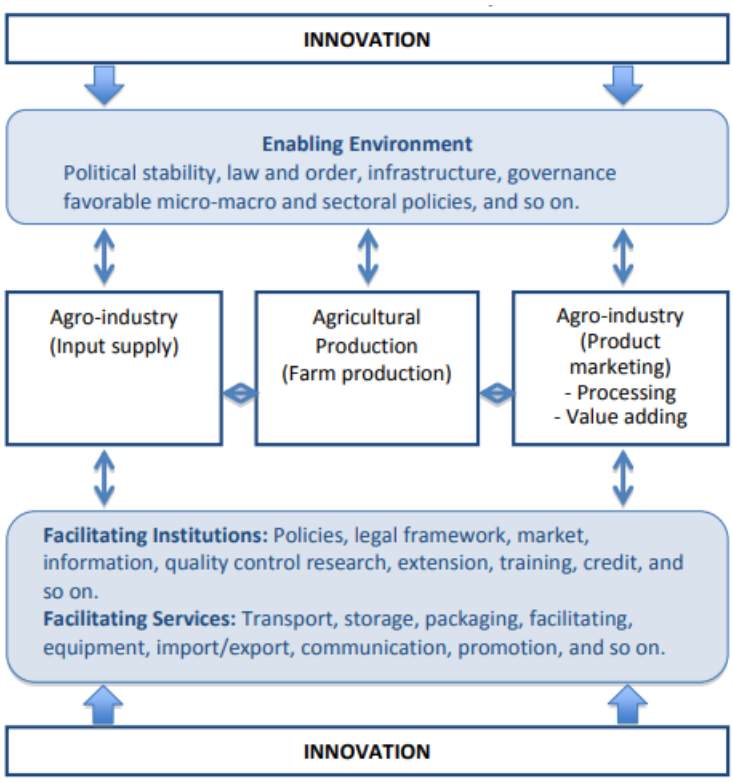

Figure 1: Agricultural innovation system

Source: (Ponniah Anandajayasekeram, 2011)

The concept of innovation adoption in agriculture describes the process of accepting and putting new technologies, ideas or practices into practice with the aim of making agricultural processes more productive and sustainable (Rogers, 2003; Aerni et al., 2015). In the agricultural context the process has a series of stages of awareness, interest, trial and implementation which are affected by the farm level, institutional or environmental circumstances. The Indian and other developing world studies have demonstrated that farm efficiency and resilience have improved as a result of adoption of agricultural innovations like drip irrigation, high-yield crop varieties and integrated pest management (Montes de Oca

Munguia et al., 2021; Dessart et al., 2019; Shah et al., 2022). Nevertheless, challenges like increased input costs, poor extension services, and poor technical expertise are still significant (Bhat et al., 2022; Wani et al., 2019).

In Kenya, Brazil, and Thailand, adoption studies across the world provide insights on effective diffusion of innovation that relies on effective institutional support and linkages between farmers and researchers (Sapbamrer and Thammachai, 2021; Jucca-Luis et al., 2018). In Himachal Pradesh and Maharashtra in India, it was found in the work that the adoption of sustainable practices such as precision agriculture and organic farming is enhanced by training and access to credit (Shah et al., 2022; Pereira et al., 2023). Nevertheless, the state of Jammu and Kashmir has not yet reached the desired level of the apple industry development due to the underdeveloped infrastructure, the inability to reach the entire market, and the lack of a supportive policy (Rashid et al., 2020, Sheikh and Baba, 2023).

Figure 2: Determining factors in innovation adoption

Source: Alexandre Rodrigues Silva et al., (2023)

This study applies the ASI, TOE, and Institutional frameworks together to gain an insight into these obstacles in a systems context, which previous studies on Indian horticulture have failed to do. The originality is to apply ASI Theory that has seldom been used in analysing the apple industry in Jammu and Kashmir on how weak institutional linkages and the policy gaps contribute towards the impossibility of sustainable innovation. Through a blend of these theories, this study is expected to be able to provide a comprehensive and context-based comprehension of innovation adoption to sustainable apple farming in the area.

2.2 Technological Factors Influencing Innovation Adoption

Technological factors serve a decisive role in deciding innovation adoption. Farmers' willingness to adopt new technologies is determined by key attributes that differentiate them from each other (compatibility), the degree of their complexity (complexity), and relative advantage. Rogers' Diffusion of Innovations Theory suggests that those technologies are more likely to be adopted (Montes de Oca Munguia et al., 2021) if they are compatible, easy to use (low complexity) and present clear advantages to existing farming methods (relative advantage). For instance, high-density apple planting systems have been slow to diffuse in Jammu and Kashmir, where they exhibit long-term yield advantages, because of their perceived complexity, as well as their implementation costs (Bhat et al., 2022).

According to the ASI Theory, when connections between researchers, extension services and farmers are poor, important information may not get to farmers (Singh and Mishra, 2024). Moreover, the technological element of the TOE Framework shows that when innovations like drip irrigation do fit local farmer needs, they may not be successful because the environment and organisation are not suited to their use (Pereira et al., 2023).

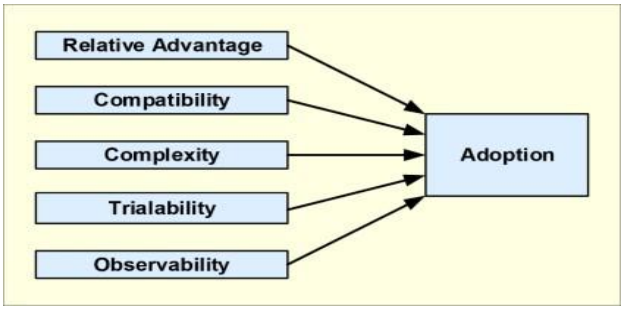

Figure 3: Diffusion of Innovation Theory

Source: (Al Hadwer et al., 2021)

Case studies demonstrate the value of utilising technological interventions in apple farming when adapted to local circumstances. For example, the use of precision agriculture tools such as soil moisture sensors and drip irrigation in Kashmir's apple orchard improved water use efficiency (Shah et al., 2022). These tools are considered innovations in this context because they represent a significant shift from traditional irrigation practices, offering improved precision, resource efficiency, and yield outcomes, and have only recently been introduced to the region. These technologies succeed (Shang et al., 2021) when supported by ease of use, technical assistance, and farmers' ability to access training and interpret the data they generate.

However, although the spoilage rates have been reduced by postharvest technologies like controlled atmosphere storage, adoption has not been effective because of high infrastructure costs and lack of local expertise (Hassan et al., 2021).

Additionally, the market-driven technologies, such as weather-based insurance schemes, have also been found to be effective in climate risk mitigation for apple farmers. Such innovations are more likely to be adopted by farmers because studies suggest that they could feel economic benefits (Sharma et al., 2024). However, the implementation (Wani et al, 2019) is opposed by the absence of consistent policy support and fragmented extension services.

Overall, the potential improvements in technological innovations have great potential to improve apple farm efficiency and sustainability, but to the extent of the costs, complexity and compatibility barriers. And policymakers have to bridge this gap through farmer education, subsidised access and sanctioned demonstrations at a local level.

2.3 Organisational Factors Affecting Innovation Adoption

Organisational factors explain the adoption of innovations in general. Key determinants to farmers' capacity to adopt new technologies and practices include farm size, farmer education and resource availability (Rizzo et al., 2023). Giant farms have access to financial and logistical resources to spend on different kinds of innovations for agriculture, whereas small farms have the capital and labour (Roussy et al., 2017). In the case of an apple grower, for example, in Jammu and Kashmir, high upfront costs on high-density planting systems, plus no facility for credit (Bhat et al., 2022).

Farmer education is the last critical factor as it helps in the understanding and use of new technologies. Such a sustainable approach to farming is adopted by farmers with more education in integrated pest management or precision irrigation (Dessart et al., 2019).

Institutional Theory describes why gender roles in Kashmir can lead to women being excluded from training opportunities, while ASI Theory highlights the importance of having all stakeholders involved to address such gaps (Berthod, 2018; van Rooyen et al., 2017). Also, literacy rates are wide apart in Kashmir, and many farmers do not follow modern techniques and which verifies as evidence of a lack of adoption of modern techniques (Sheikh & Baba, 2023).

Also, the resource availability, number of extensions and technical support availability determine the extent how much innovation would be taken up. In this regard, farmers with links to agricultural advisors or cooperatives are more likely to engage to experiment with newmethods (Rizzo et al. 2023). In areas where the extension services are undeveloped, the farmers in the area tend to be risk-averse in adopting new practices as they are afraid of risks (Wani et al, 2019).

The farmer's decision-making process is also subject to risk perception. According to Dissanayake et al. (2022), many farmers prefer to be stable in the long term and avoid any kind of innovation because it is uncertain. For example, the adoption of climate-resilient apple varieties is what has been proven to work for Kashmiri farmers, but they don't adopt them because they are afraid of yield variability (Rashid et al., 2020). That notwithstanding, Sharma et al. (2024) state that these concerns can be overcome with the use of tailored incentives, like subsidies and a guaranteed buyback scheme.

Organisational factors, however, have the potential to both enable and constrain the adoption of innovation in apple farming, as there are both variations in and at different levels of organisational factors. There are indeed challenges that need to be dealt with through targeted policies to raise the level of farmer education, getting more access to resources, and promoting risk management strategies that would help restructure the agricultural sector to be more adaptive.

2.4 Environmental Context and Innovation Outcomes

In agricultural innovation adoption, environmental factors such as market conditions, infrastructure, and climate variability often determine the success or failure of new practices (Sharma et al., 2024; Aerni et al., 2015). According to the TOE Framework, market turbulence and climate factors create uncertainty in adoption, while Institutional Theory makes clear that government delays with subsidies (such as payments) add to these problems (Malik et al., 2021).

In the case of Jammu and Kashmir's apple farming sector, these factors play a similarly crucial role, with market volatility and infrastructure drawbacks posing major bottlenecks to adoption outcomes. The market volatility, characterised by the unpredictability of price movements, changes in consumer demand patterns, leads the farmers not to invest in new technologies (Naqash & Wani, 2018). For example, Arab farmers prioritise short-term survival through reduced prices for apples due to oversupply or a ban on exports over their long-term innovations, such as high-yield varieties or post-harvest technologies (Hassan et al., 2021). Farmers, too, are prone to exploitation by middlemen because of this risk aversion in the growing market volatile and with no stable market linkage or price support mechanism (Shah et al. 2022).

The adoption further suffers due to the infrastructure limitations of the region. Rashid et al. (2020) mention that Jammu and Kashmir's rugged terrain and its underdeveloped transportation networks result in an inefficient movement of produce that leads to an increased post-harvest loss. However, the scarcity of cold storage facilities poses a particular problem as up to 30 to 40 % of the apples are lost to spoilage (Hassan et al., 2021). This prevents farmers from storing their produce to take advantage of off-season price spikes, thereby reducing the economic incentive to adopt productivity-enhancing innovations such as high-density planting, controlled atmosphere (CA) storage, and improved packaging systems (Md Ozair Arshad et al., 2022). Furthermore, the erratic electricity supply negatively affects irrigation systems and cold chain operations, thus, the feasibility of precision agriculture technologies (Bhat et al., 2022).

Climate variability makes it more complex. With warmer winters and erratic snowfall lashing the region, apple growing cycles have been drastically altered and farmers are forced to rethink their practices, says Rashid et al. (2020). Climate resilient inventions like drip irrigation and varieties resistant to frost could virtually mitigate these risks, but their adoption is minimal due to high costs and lack of adequate extension support (Wani et al., 2019).

Integral solutions are needed to address these environmental barriers. Adoption risks could be lowered through policy interventions, specifically stabilisation funds to the market, infrastructure development and climate adaptation subsidies (Sharma et al., 2024). Case studies from Himachal Pradesh show how government-backed cold storage chains and farmer cooperatives have facilitated innovation uptake (Shah et al, 2022) in replicable models for Jammu and Kashmir.

2.5Policy, Market, and Sociocultural Influences on Sustainable Practices

This section reviews how guidelines, competition among companies, and social and cultural settings affect the use of sustainable tactics in apple farming. In this framework, the main focus is on how government policies, links with the market, and social standards influence the way multiple farms and organisations adopt innovations. Policy has to be considered because farmers and extension staff are influenced by the rules and investments provided by the public sector. Understanding the policies is necessary to explain why some changes in agriculture occur, because in this region, the government often provides major resources for agricultural progress.

The literature on sustainable agricultural innovation points out that government policy, market dynamics and sociocultural norms are critical factors influencing adoption decisions across the heterogeneous farming systems (Juárez-Luis et al., 2018; Sapbamrer & Thammachai, 2021). These 3-d drivers –policy, market and culture interact positively to support or negatively resist transitions to sustainable practices. In the case of apple farming in Jammu and Kashmir, this triad critically influences the adoption of innovation, while regional dynamics also tend to confuse sustainability endeavours.

Government policies are instrumental in forming the enabler space of innovation. Results show that subsidies for organic inputs, tax incentives for sustainable technologies and robust extension services are powerful (Sapbamrer & Thammachai, 2021). In the negative direction, inconsistent policy implementation and bureaucratic delays tend to stifle progress. For example, the uptake of integrated pest management (IPM) techniques in Kashmir has been limited by delays in disbursing horticulture subsidies and inadequate use of training programs (Bhat et al., 2022). Moreover, such policies that do not cater to smallholder farmers' needs—

little or no return on their viable initiatives with sustainable technologies; only advanced forms are facilitated by credit schemes—only aggravate the inequities in access to the sustainable technologies (Wani et al., 2019).

More and more, sustainable farming practices are being driven by market demands as consumers the world over become more and more interested in ethically produced and environmentally friendly food. Certifications as organic and fair trade have benefited markets to supply organic and fair, sustainably grown apples, encouraging farmers to adopt eco-friendly methods (Shah et al., 2022). Nevertheless, in the case of small-scale farmers in Kashmir, such standards are hardly met, as such costs are high and market linkages are either missing or weak (Naqash & Wani, 2018). On the one hand, volatile export markets and price fluctuations can discourage long-term investments into sustainability (Hassan et al., 2021).

Traditional practices also hold great influence, and local norms play their role as well. Some Kashmiri communities resist change because deeply rooted agricultural traditions militate against innovation when culture and generational knowledge are at odds (Sheikh & Baba, 2023). For instance, some farmers view chemical-free farming as an embrace of organic practices, whereas some consider new technologies as a disruption of their means of living (Juárez-Luis et al., 2018). Participatory approaches that bridge the gap between indigenous knowledge and modern science in such a way that the innovations are culturally congruent are how this needs to be achieved.

In conclusion, the policies should be in line, the market should be responsive, and the intervention should be culture-sensitive. Therefore, policymakers must bring on board inclusive support mechanisms, and market actors need to create mechanisms through which smallholders can benefit from a sustainability premium. At the same time, extension programs should be engaging local leaders toward building trust and showing that new practices are compatible with the values of the local people.

2.6Research Problem and Justification

The existing literature on the apple farming links with the agricultural innovation adoption shows that some things match. As highlighted by studies (Montes de Oca Munguia et al., 2021; Roussy et al., 2017), technological (e.g. complexity, cost) as well as environmental (e.g. market volatility, infrastructure), and organisational characteristics (e.g. farm size, farmer education) combine to affect adoption decisions. Theory, based on ASI, TOE and Institutional Theory, empirically illuminates the relationship between these dimensions because the things highlighted are, firstly, policy gaps, limited technical support and second, sociocultural resistance (Aerni et al., 2015; Baker, 2011). Jammu & Kashmir case studies specifically highlight postharvest losses, climate vulnerability and poor market linkages as key constraints (Hassan et al., 2021; Rashid et al., 2020).

Nevertheless, relevant research gaps exist in the literature on the adoption of innovation in apple farming, specifically in Jammu and Kashmir. Although there are several previous studies discussing the individual factors which affect adoption, i.e., technological attributes or policy support (e.g., Montes de Oca Munguia et al., 2021; (Shah et al., 2022), the majority tend to examine these factors in isolation rather than the complex ways by which they work together. Some selected exceptions, including the work by Wani et al. (2019) and Bhat et al. (2022), offer some integrative insights, yet do not advance the idea of regional specificities in depth and scope.

And, furthermore, sociocultural dimensions, i.e. farmer behaviour, gender dynamics and intergenerational knowledge transfer, are still under-researched (Dessart et al., 2019). The above sections of this study attest to the significance of these social factors in determining adoption decisions; however, extant literature does not pay sufficient attention to these. The filling of these gaps is important to shaping an understanding of how the organisational and cultural contexts are paramount in determining innovation uptake.

Thirdly, most of the studies are based on cross-sectional data, and this makes it difficult to understand how adoption patterns change over time, even under concerns of climatic or market shocks. Longitudinal and dynamic analysis are scant but must be done to capture time in the adoption process of innovation with altered environmental and economic conditions.

Lastly, even though some studies have recommended context-specific policy frameworks that are appropriate to Jammu and Kashmir's unique agroecological and socioeconomic realities

(Bhat et al., 2022), these are preliminary. There is a need to conduct more specific and dynamic policy research that concurs with the complications that the region's apple farming sector experiences.

This thesis has tried to address these gaps through:

- Integrating multiple theoretical lenses (ASI, TOE, Institutional Theory) to analyse interactions between technological, organisational, and environmental factors.
- Investigating sociocultural dimensions (e.g., gender, tradition) as moderators of adoption.

By bridging these gaps, the study aims to provide a holistic, actionable roadmap for innovation adoption in similar agricultural systems.

2.7Chapter Summary

This chapter reviews the theoretical and empirical insights about the adoption of agricultural innovation in apple farming in the Jammu and Kashmir region. Using the Agricultural Systems of Innovation (ASI) Theory, Technology Organisation Environment (TOE) framework, as well as Institutional Theory, these barriers were analysed in the context of technological, organisational and environmental aspects. Challenges identified in the empirical studies included the high costs, lack of technical support, market volatility, and sociocultural resistance to sustainable practices made the readiness to use them hard. Case studies from the region showed the influence of climate vulnerability, infrastructure weaknesses and inconsistent policy. But many of the reasons underlying these factors' interactions with both sociocultural dynamics and long-term adoption trends are not yet understood. The gaps must be addressed by developing context-specific strategies. The next chapter will outline the theoretical framework.

CHAPTER 3 THEORETICAL FRAMEWORK

Building on the literature review presented in Chapter 2, this chapter develops and integrates the theoretical frameworks that underpin this study. It presents a detailed discussion of the Agricultural Systems of Innovation (ASI) Theory, the Technology-Organisation-Environment (TOE) Framework, and Institutional Theory, and explains their combined application to the context of apple farming in Jammu and Kashmir. It documents these theories as a set of theories that can be added as an analytical lens for understanding the characteristics of Technological, Organisational and Environmental factors that affect innovation adoption. In synthesising these perspectives, the framework seeks to fill the gaps noted in the literature research, and to provide a structured way of approaching the barriers and enablers of innovation in the apple farming sector in the region.

3.1 Agricultural Systems of Innovation (ASI) Theory

According to the Agricultural Systems of Innovation (ASI) Theory, farmers, researchers, policymakers, as well as markets, have an interconnected role in driving technological change (Aerni et al., 2015). The theory assumes that innovation adoption is a systemic process where different stakeholders and institutions' interactions are necessary. The ASI Theory is useful in explaining how knowledge diffusion, institutional support and collaboration between stakeholders can support or block the adoption of sustainable practices relevant to apple farming in Jammu and Kashmir (Kamara, Lalani and Dorward, 2023).

Key components of the ASI Theory relevant to this study include:

- **Knowledge Diffusion**: Extension services, farmer networks, and training programs spread information about innovations. Extension services were limited in Jammu and Kashmir, and certainly weak linkages between stakeholders have impeded the adoption of modern farming processes (Wani et al., 2019).
- **Institutional Support**: The impact of government policies, subsidies, and research institutions on promoting innovations. Another example is that the implementation of policy is not consistent or there are delays in subsidy disbursement, which impede the uptake of integrated pest management (IPM) techniques (Bhat et al., 2022).
- **Collaboration**: Partnership among the farmers, cooperatives, and the private sector actors in the process of innovation. For example, cold storage technologies have been adopted by farmer cooperatives in Himachal Pradesh (Shah et al., 2022).

ASI is more systemic than individual-oriented models such as Rogers' Diffusion of Innovations, which include social, institutional, and organisational aspects in recognising structural barriers. ASI shows how gaps in policies, sociocultural resistance, and broken systems prevent innovation in the apple farming industry in Jammu and Kashmir. This framework emphasizes the need for integrated efforts among the stakeholders in order to enhance sustainability through elimination of complexities which are not paid attention by conventional theories.

3.2 Technology-Organisation-Environment (TOE) Framework

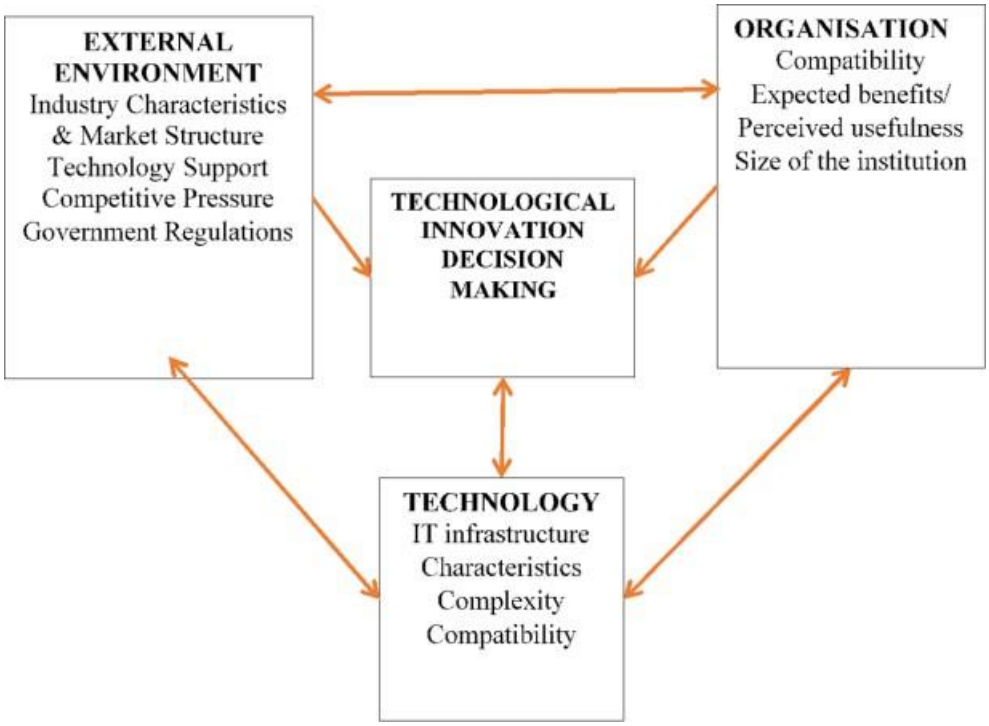

Figure 4: TOE Framework

Source: (Ansong and Boateng, 2023)

Baker (2011) developed the framework of TOE to structure the analysis of the innovation adopted with three dimensions of technological, organisational and environmental. This is especially helpful for the analysis of multiple barriers to apple farm innovation.

Technological Factors

Compatible, complex, and relative advantage are the main attributes of technology in the line of adoption decision (Rogers' Diffusion of Innovations Theory). However, in the state of

Jammu and Kashmir, long-term yield advantages of high-density apple planting systems are masked by low adoption as they are perceived to be complicated and expensive to implement (Bhat et al., 2022). Similarly successful in precision agriculture tools such as soil moisture sensors have been successful when they are user-friendly and trained on the technical side (Shang et al., 2021).

Organisational Factors

Influential characteristics of the organisation include farm size, the level of education of their farmer(s) and the availability of resources. In other words, farms that have more capital resources can invest in innovations more so than smaller smallholders, who are constrained by capital (Roussy et al., 2017). The adoption of the latest modern techniques is also dependent on farmer education, as higher levels of literacy are correlated with better farmers' comprehension and utilisation of such techniques (Dessart et al., 2019). In Kashmir, education disparities and lack of access to extension services have been responsible for the low adoption rate (Sheikh & Baba 2023).

Environmental Factors

Adequate solutions to promote adoption outcomes are also shaped by environmental contexts that include market volatility, infrastructure constraints, and climate variability. Pricing of apples is highly unpredictable and has been accompanied by an underdeveloped cold storage infrastructure that discourages long-term investments in post-harvest technologies (Hassan et al., 2021). Adoption is further complicated since climate change disturbs the traditional farming cycles due to erratic snowfall and warmer winters (Rashid et al., 2020).

By disentangling the interplay of various factors that shape innovation adoption, the TOE framework offers a keen sensitivity for identifying measures of interventions.

3.3 Institutional Theory

According to Juárez-Luis et al (2018) Institutional Theory focuses on how formal and informal institutions (such as the government policies, market structures), and sociocultural norms influence agricultural practices. The institutional factors in Jammu and Kashmir have both facilitated and restricted the adoption of sustainable innovation.

Formal Institutions Encouraging or discouraging innovation requires government policies, subsidies and a regulatory framework. Likewise, for example, organic input subsidies and tax incentives for sustainable technologies have been effective in other regions (Sapbamrer &

Thammachai,2021). Despite that, in Kashmir, measures such as have suffered from bureaucratic delays and inconsistent policy enforcement (Bhat et al., 2022).

Informal Institutions

Other important roles are the sociocultural norms and traditional practices. Since the 1980s, agricultural traditions that run throughout Kashmir have resisted some new technologies, particularly any new technology viewed as disruptive to cultural practice (Sheikh & Baba, 2023). To overcome this resistance, there needs to be participatory approaches to align innovations with local values (Juárez-Luis et al., 2018).

The factor of Institutional Theory is the policies must not only be economically right but also cultured right to accept innovation, rather than resistant.

3.4 Integration of Theoretical Frameworks

This paper combines three theoretical approaches; Agricultural Systems of Innovation (ASI) Theory, Technology-Organisation-Environment (TOE) Framework and Institutional Theory in order to gain a comprehensive insight into the use of agricultural innovations by apple farmers in Jammu and Kashmir. The different theories represent different levels of analysis: the system, the farm or organisational level and the institutional environment. Terracotta banding together provides an all-inclusive framework that links technological, organisational, and policy-related factors influencing adoption.

1. **Theory of ASI System-Level Perspective.** The ASI Theory is a system-wide perspective regarding the interactions among several actors (farmers, extension services, markets and policymakers) as part of the innovation ecosystem (Aerni et al., 2015; Kamara, Lalani and Dorward, 2023). It describes how the flow of knowledge, coordination, and the institutional linkages can contribute to the production and propagation of an innovation. With Jammu and Kashmir, ASI lens point to poor linkages among stakeholders and disjointed networks of extensions that curtail the adoption of innovations (Wani et al., 2019).

2. **Organisational/Farm-Level View- TOE Framework.** The TOE Framework (Baker, 2011) is concerned with the internal and the contextual factors that predetermine adoption decisions at the farm or organisational level. It establishes three dimensions which include the technological preparedness, organisational preparedness and environmental pressure that when

combined make the difference whether an innovation is adopted or not. TOE assists in evaluating the interaction between the aspects of farm size, education, and access to resources and the technological factors, including cost, complexity, and compatibility in this study (Roussy et al., 2017; Bhat et al., 2022).

3. **Institutional- Level Perspective- Institutional Theory.** The third theory (Institutional Theory) supports the other two theories by investigating the influence of formal institutions (policies, subsidies, regulations) and informal institutions (norms, traditions, and gender roles) on the adoption behaviour of the farmers (Juárez-Luis et al., 2018). In Jammu and Kashmir, such discrepancies in policies, bureaucracy, and cultural opposition provide the environment in which even technically effective innovations do not penetrate fast (Sheikh and Baba, 2023; Sapbamrer and Thammachai, 2021).

4. **Connecting the Frameworks**

These three models are inseparable and complementary: ASI gives the systemic dynamism of interactions and coordination. TOE examines farm-level determinants of decision making. In the Institutional Theory, the rules and norms governing system and organisational behaviours are captured.

Collectively they offer a multi-level structure of analysis. ASI places the emphasis of innovation into a bigger framework, TOE divides organisational and technological processes into the bigger system, and Institutional Theory puts both of them into the context of the broader policy and culture. This integration permits an analysis of innovation adoption in a holistic manner, that is, interrelated technology, organisation, and institution as a chain of continuum, but not as distinct factors.

Framework	Key Focus	Relevance to Study	Example from Jammu & Kashmir
Agricultural Systems of Innovation (ASI) Theory	Systemic interactions among stakeholders (farmers, researchers, policymakers).	Explains knowledge diffusion, institutional support, and collaboration barriers.	Limited extension services and weak farmer-researcher linkages hinder innovation adoption.
Technology-Organisation-Environment (TOE) Framework	Technological, organisational, and environmental factors influencing adoption.	Analyses cost, complexity, farm size, and market volatility.	High-density planting adoption is low due to high costs and perceived complexity.
Technology-Organisation-Environment (TOE) Framework	Technological, organisational, and environmental factors influencing adoption.	Analyses cost, complexity, farm size, and market volatility.	High-density planting adoption is low due to high costs and perceived complexity.
Institutional Theory	Formal policies and informal norms shaping practices.	Highlights policy gaps and cultural resistance.	Subsidy delays and gender norms limit women's access to innovations.

Table 1 Summary of Theoretical Frameworks:

5. Conceptual Summary (Visual Integration)

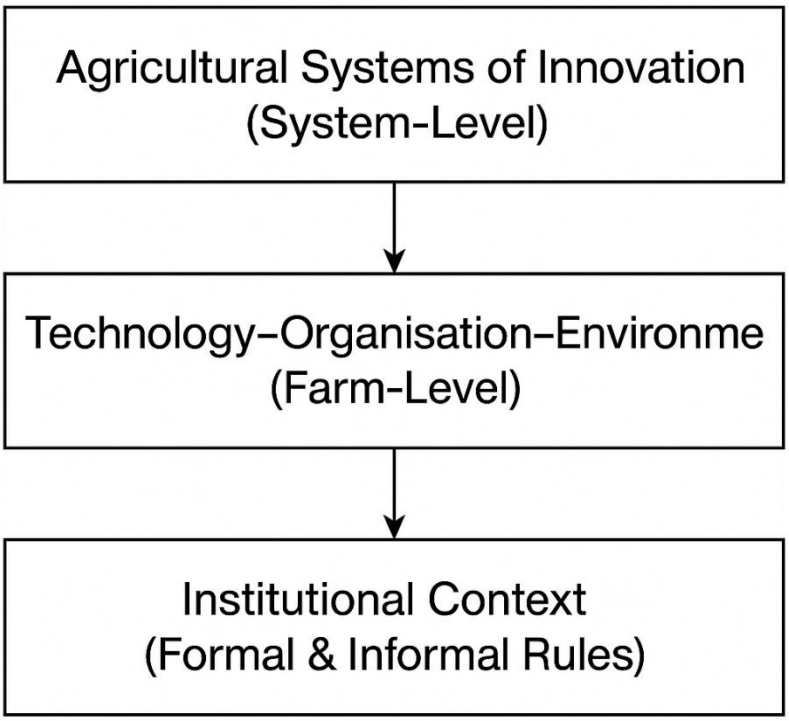

Figure 5: Multi-level framework for understanding innovation in agricultural systems.

This model makes sure that interventions are not considered separately, such as technological subsidies (TOE) are examined in relation to the institutional policies (Institutional Theory) and systemic coordination mechanisms (ASI). The integrated model helps to offer a solid basis in the analysis of the adoption of sustainable agricultural innovations in the apple farming in Jammu and Kashmir.

3.5 Chapter Summary

This chapter, therefore, presents a mix of theoretical frameworks which take ASI Theory, TOE framework and Institutional Theory to make a robust grounding for the innovation adoption with the concept of apple farming in Jammu and Kashmir. This framework addresses the interplay of technological, organisational, environmental factors, as well as institutional and cultural influences, in a holistic manner to understand and remove the adoption barriers. The next chapter will then apply this framework to empirical evidence to further elaborate on the innovation adoption dynamics in the region.

CHAPTER 4 RESEARCH METHODS

4.1 Research Methodology

This paper is dedicated to the example of apple farming in Jammu and Kashmir since the industry is economically important, climate sensitive, and reliant on government subsidies (Bhat et al., 2022). The apples are the main trade in the horticultural economy of the area and there are thousands of farm households whose survival is directly depended on the sustainability of the apples. The adoption of innovation has however been low because of some of the challenges like climate change, market uncertainties and absence of policies. The experiences and choice of farmers and policy actors should thus be comprehended in a depth, contextual manner.

Qualitative research design was developed to reflect the lived experiences, motivation and constraint factors that affect innovation adoption. It was believed that this method is appropriate since the research questions aim to comprehend how and why technological, organisational, and environmental influences determine adoption behaviour, not to measure them (Aspers and Corte, 2019). The semi-structured interviews were also flexible to give the respondents the opportunity to talk about the issues in their own terms, as well as giving the researcher the opportunity to dig deeper into other issues like the effectiveness of the policies, cultural resistance and gender disparities. The design conforms to the problem orientation of the study because innovation adoption in apple farming is a social, institutional and behavioural issue, which is most desired to be investigated qualitatively (Lim, 2024).

4.1.1 Qualitative Approach

The process of adopting agricultural innovation in the apple farming industry in Jammu and Kashmir entails a set of intricate, interconnected factors—technological, organisational, and environmental—mutually interacting dynamically. Whereas some farms have adopted some of the innovations like drip irrigation, high-density planting, and organic pest management, adoption is inconsistent and incomplete, thus necessitating a probe into both success stories and enduring obstacles. Jammu and Kashmir's apple sector is a particularly salient case in point for this research because of its economic significance, exposure to climate change, dispersed farm structures, and dependence on state subsidy—factors that simultaneously make innovation necessary and difficult. To grasp farmers' and stakeholders' lived experiences,

motivations, and systemic limitations in their entirety, this research takes a qualitative perspective. This approach allows for the gathering of rich contextual understanding that cannot be produced through quantitative questionnaires and is consistent with the study questions and the study's systemic, social, and institutional theoretical bases (Aspers & Corte, 2019).

A particular advantage of this research is the qualitative paradigm. First, it offers depth of understanding in terms of understanding participants' views in their own words to reveal the true reasons behind their choice of adoption of innovation. Second, flexibility is introduced in the process of data collection as interviews adapt to lines of inquiry that emerge, not anticipated in the study design phase. Third, qualitative data collection techniques are used to reveal the intricacies specific to Jammu and Kashmir's apple farming sector and ensure that the findings are relevant to local stakeholders (Lim, 2024).

4.1.2 Primary Data Collection

Semi-structured interviews were the primary method of data collection employed in the study. Interviews were selected because they improve respondent as opposed to interviewer control by allowing the study to make specific and detailed requests of respondents in a way that is tailored to those objectives. The use of a semi-structured interview format allowed for consistent core questions with enough flexibility to explore emergent but meaningful themes as they evolved in conversation (Monday, 2020).

All the interviews were held remotely with Zoom video conferencing, since it was difficult to have interviews in person with a long distance involved. This way, people in Jammu and Kashmir could join the sessions when they were able to and both sides could quickly establish a rapport. Audio recording of the sessions was allowed by the participants for the process of accurate transcription.

The selection of interviews as the major means of data collection was favoured by several considerations. Because of the direct interaction between researcher and participant, questions and probing to get more detailed responses could happen immediately, allowing for immediate clarification of questions and for probing where deeper responses ensued in understanding complex adoption barriers (Monday, 2020). This method produced rich, qualitative data appropriate for thematic analysis as it fits with the aim of the study of an exploratory nature. In addition, by bringing both farmers and agricultural officers into interviews, this method

provided a more complete picture of the innovation adoption process than would have been possible otherwise.

4.2 Data Sources

4.2.1 Participants

The sample used in the study consisted of 10 informants chosen on a purposive basis; the sample was representative because it covered the major participants of the innovation adoption process. These included 5 apple growers, 3 agricultural extension officers and 2 policy officers who were directly engaged in the development of horticulture in Jammu and Kashmir. The interviews took between 30 and 45 minutes and were held in the selected apple-growing areas like Shopian, Pulwama, and Sopore which are the primary apple-giving areas of the region (Rashid et al., 2020).

The participants were selected based on the fact that they have a first-hand experience in applying or supporting innovative agricultural practices and are the necessary linkages among policy, technology, and practice that were emphasized in the Agricultural Systems of Innovation (ASI) Theory (Aerni et al., 2015). Farmers were used to give their views regarding the limitations and opportunities at the field level, and officers added their views regarding the institutional and policy frameworks. Such a mix of informants made the difference of having a comprehensive picture of the way innovation decisions are made throughout the system.

4.2.2 Sampling Strategy

The purposive sampling method was thus suitable to make sure the sampled participants were informed and experienced in matters relating to innovation adoption. They were not selected based on the need to represent a population but rather because they would provide the rich and context-based information regarding the interaction between the technological and organisational factors and policy and environment (Nyimbili & Nyimbili, 2024).

4.2.3 Interview Design

The theoretical frameworks—Agricultural Systems of Innovation (ASI) Theory, the Technology-Organisation-Environment (TOE) framework, and Institutional Theory—were deliberately embedded in the interview design. Questions were crafted to examine three key dimensions of innovation adoption: technological aspects (e.g., complexity, ease of use), organisational features (e.g., resources, leadership), and environmental settings (e.g., infrastructure, market access, policy). These frameworks facilitated exhaustive coverage of both structural and behavioural drivers of adoption decisions across the regional farming system.

For this, the interview guid consisted of questions seeking to identify barriers to adoption, for example, whether or not they had adopted or rejected agricultural innovations and reasons for this. Next, other questions tried to learn exactly what type of support was needed to run new technologies. Other questions assessed the impacts of the policy through questions about the impacts of climate risk and market volatility on one's willingness to try innovations. To maintain a structured format for consistency, open-ended questions were used in the interviews so that participants could expand on their experiences and views at their will.

4.3 Thematic Analysis Techniques

4.3.1 Data Analysis Process

To analyse the interview data, the study employed thematic analysis as a method for identifying, analysing, and reporting patterns in qualitative datasets. Drawing from the flexibility and appropriateness of thematic analysis for exploratory research aimed at understanding abstract and complex social phenomena, thematic analysis is offered to be the most appropriate procedure for thematic work. The analytical process followed a path similar to that of qualitative research.

Through a thorough familiarisation phase of repeated close readings, analysis began with transcription of in-depth interviews, then verbatim transcription of focus group interviews. The amount of data 'imprisoned' the researchers to prepare them for the subsequent phases of coding. It was first coded that the data contained discrete elements to identify discrete concepts and ideas, ultimately creating labels for concepts and ideas. Then, these codes were grouped into broader themes according to the study's theoretical frameworks. The last part involved

checking and adjusting themes to match the dataset, overcoming any discrepancies through repeated examination.

4.3.2 Coding and Categorisation

The coding and categorisation of interview responses were systematic and followed the theory within the study. The coding for technological factors used terms like 'access to technology', 'perceived complexity' and 'relative advantage', which refer to agricultural technology experiences of the participants. Possible themes for categories under organisational factors were 'farm size', 'farmer education' and 'resource availability' that could have influenced the adopters' decisions. Labels such as 'market volatility', 'infrastructure limitations ', and 'climate variability' were used to code environmental factors which influence the decisions to adopt innovation.

Keeping strong ties to the theoretical underpinnings of the study, this structured coding approach was both responsive to the richness and complexity of the qualitative data. It enabled a patterned as well as an emergent set of themes to be captured and analysed (based on the narratives given by the participants) (Linneberg and Korsgaard, 2019).

4.4 Validation Methods

To guarantee that the thesis was valid, research strategies, based on both methodology and theory, were used. The research team chose semi-structured interviews to talk to farmers and agricultural officers so they could learn valuable and detailed facts about the topic. The validity of the research improved by choosing people through purposive sampling so that knowledgeable key stakeholders were involved. Also, since the study creatively used ASI, TOE, and Institutional Theory, it was possible to code and interpret the results following proven frameworks. Even though triangulation was noted, the authors focused most on keeping

the same interview approach, being reflexive, and ensuring the coding and theme process were open and transparent. All of this contributed to making the results credible and relevant for the study, even though the sample was not very large and not very broad.

4.5 Limitations

Several limitations should be considered when interpreting the findings of the study. This precluded generalizability of results to broader populations, but afforded depth of analysis by utilising a small participant sample. However, findings have limited applicability to other agricultural contexts without further research because of the regional focus on Jammu and

Kashmir. The study also did not consider anything that was unforeseeable, including extreme weather events that could influence the types of innovation adoption patterns.

The study mitigates these limitations with context-specific recommendations and recommends further study. This explicit acknowledgement of limitations presumably allows other researchers to know the study's boundaries, and it highlights directions for future research beyond these findings.

4.6 Chapter summary

In this chapter, the methodological framework used in the study of the adoption of agricultural innovation in the apple farming sector of Jammu and Kashmir has been presented. The study employed a qualitative research design, primarily using semi-structured interviews and thematic analysis. Importantly, the data collection and analysis were grounded in an integrated theoretical framework comprising the Agricultural Systems of Innovation (ASI) Theory, the Technology-Organisation-Environment (TOE) framework, and Institutional Theory. These frameworks informed the design of interview questions and guided the coding process by categorising findings into technological, organisational, and environmental dimensions, while also accounting for systemic interactions and sociocultural influences. This theoretical alignment ensured that the analysis not only captured surface-level themes but also interpreted them through robust, theory-driven lenses. Together, this approach allowed for a comprehensive and context-sensitive exploration of innovation adoption barriers and enablers in the region.

CHAPTER 5: DATA ANALYSIS

In this chapter, the qualitative data collected through semi-structured interviews are analysed to identify the factors that determine the adoption of agricultural innovations in apple farming in Jammu and Kashmir. 10 apple farmers and agricultural officers were interviewed to gather data on what they had experienced and what they think. The ASI Theory, TOE framework and Institutional Theory were used as the basis for the identification of patterns and themes in the technological, organisational and environmental factors, through Thematic Analysis.

5.1 Data Preparation and Coding Process

The interview data were transcribed verbatim and anonymised using participant codes such as F1 for Farmer 1 and O1 for Official 1, to ensure confidentiality. It followed a systematic coding of the data to pinpoint, categorise, and make inferences from the key patterns it found. First, initial open coding of the transcripts consisted of a line-by-line analysis of them that resulted in granular codes like cost barriers, there are training needs, there are policy gaps, and gender disparity. This study documented these preliminary codes in a structured code book, which was to be used as a reference to ensure consistency in our analysis.

After that, axial coding was carried out to bring together similar codes into main themes. Essentially, “cost barriers” and “subsidy delays” were put under “Financial Constraints” as part of the Environmental dimension and Institutional Theory’s policy insights, as they both represent external institutional and market challenges. Also, “lack of technical support” and “language barriers” were grouped into “Access to Knowledge” in the TOE framework, since this is related to Technological Factors in the ASI Theory and underlines the need for good communication and extension between stakeholders. Besides using evidence from the data, the three-way organisation of the factors with the help of the three underlying theories improved the groupings. With this approach, I made sure my coding consistently followed the study’s theory, and every theme captured the main points in the research as well as the important elements of ASI, TOE, and Institutional Theory.

The coding process presented challenges relating to reconciling contradictions, for example, dissimilar representations of a policy's effectiveness as understood by the farmers and officers over the one they held for implementation hurdles. Reflexivity was maintained to ensure rigour by constantly documenting my own biases and going back to the data to check that the emergence of themes was not contingent on assumptions I had previously held. Trustworthiness of the analysis was further enhanced by peer debriefing and by iterative

reviews of the codebook. The process of this meticulous procedure made certain that the conclusions were properly based on the participants' lived experiences and yet remained theoretically coherent.

5.2 Presentation of Themes

This chapter displays the findings of the research which were central to the qualitative interviews based on the apple farmers and the agricultural officers in Jammu and Kashmir. This structure of the results answers the research question on the main technological, organisational and environmental factors likely to affect the adoption of agricultural innovations with the three main themes. Every theme represents the

Category	Barriers	Participant Quotes	Theoretical Link
Technological	High costs, technical complexity, and lack of local adaptations.	F1: "The sapling and drip system cost was too high for me to expand."	TOE Framework (Technological Factors)
Organisational	Small farm size, gender disparities, low farmer education.	F4: "Extension workers don't take women farmers seriously."	ASI Theory (Stakeholder Exclusion)
Environmen al	F2: "Unpredictable prices make me hesitant to invest in new technologies."	Institutional Theory (Market and Policy Failures)	F2: "Unpredictable prices make me hesitant to invest in new technologies."

Table 2: Barriers to Innovation Adoption

experience of the farmers and officers of practice barriers, which are supported by the opinions of the participants and explained through the ASI Theory, TOE Framework, and the Institutional Theory.

5.2.1 Theme 1: Technological Barriers to Adoption

One of the most decisive factors in the adoption of innovation was created by technological barriers. The issue of farmers struggling with learning to purchase, learn, and use new technologies was repeatedly adopted. Such problems included costs, technicality, and absence of local adaptation and training services.

High cost and affordability constraints.

Cost is the most common reason given by most farmers as something that prevented them use of new technologies like drip irrigation, high-density planting system and precision tools. F1 observed that the sapling and drip system were too expensive that I could not afford to grow, which is an example of the high initial investment cost that leaves out smallholders. In the same manner F5 indicated that to install drip irrigation in our area would require a lot of money besides training people and we lack trained personnel. Such results have been in line with those of Bhat et al. (2022), who discovered that high-cost technology and small subsidies discourage the adoption by small farmers in Kashmir. The TOE Framework identifies cost and perceived economic feasibility as the key technological variables influencing the decisions to adopt.

Technical complexity and poor localisation.

Other than cost, there was perceived complexity of technologies, which contributed to hesitation. F3 reasoned his choice not to use laser levelling since it could not be applied in hilly regions: “It does not fit our land”. This implies that despite the availability of technology, when it does not work well with the local conditions, it cannot be useful. Another reason cited by farmers was that the technical manuals and apps used to be in foreign languages and unless there was localised instructions, they could not use them without doubts. Such barriers indicate the principles of complexity and compatibility of Diffusion of Innovation in the works of Rogers (Montes de Oca Munguia et al., 2021).

Lack of technical support and training.

A number of respondents mentioned that suppliers or even the government agencies would do little follow up after the new equipment was bought. O2 acknowledged that there was a training and awareness gap even in areas where subsidy programmes were in place. This proves weak connections between the producers of knowledge and the end-users, according to ASI Theory (Wani et al., 2019). Farmers did not have a chance to undergo practical demonstrations or refresher trainings, this reduced their ability to sustain innovations.

Perceived benefit and risk.

Farmers doubted the possibility of innovations being worth the risk, even in situations when they perceived some benefits. F3 was willing to pay the price of bio-fertilisers since he regarded them as costly but sustainable whereas others did not see the payback. Adoption is affected by perceived benefit in the sense that it should be greater than uncertainty which is in line with the model proposed by Rogers. There is also poor feedback mechanisms observed by officers whereby learning is not possible before adopters. O4 replied, there is no proper system to reintroduce farmers experience into policy or design.

All in all, the technological barriers are comprised of three inter-related dimensions, namely, cost, complexity, and capability gaps. The farmers who were well-endowed financially or technically (including F3) embraced more innovations compared to the farmers who lacked these advantages. TOE Framework describes this by the technological readiness dimension and ASI Theory indicates the lack of interaction between stakeholders that otherwise would foster the adaptation that is user-friendly. The facts indicate that technological acceptance cannot be just a question of availability; the technology should be affordable and appropriate to the geography and language, and technical support should be stable. These problems need to be solved by specifically designed subsidy plans, translated manuals, and learning initiatives based on demonstrations.

5.2.2 Theme 2: Organisational Barriers to Adoption

Structural and social aspects in the farming community form the organisational barriers that affect the decision-making and ability to embrace innovations. These have to do with the small-size farms, lack of education, gender inequality, and poor collaboration systems.

Farm size and resource constraints.

Divided land ownership and small plots of land were cited severally as a significant setback. O1 replied, “Largely interventions in Kashmir are hard because of broken land-holding patterns. Small farms find it difficult to cover the cost of technology and are not able to enjoy economies of scale. Farmers like F1 and F2 reported that they were not in a position to obtain credit and take the risk of experimenting with costly inputs as compared to large commercial growers. This corresponds to the organisational aspect of the TOE Framework, which bridges the availability of resources and scale and the ability to innovate (Roussy et al., 2017).

Gender disparities and social exclusion.

There is a high influence of gender inequality on innovation adoption. F4 told me, — extension workers do not consider women farmers. She explained that the role played by women in apple farming was never considered and they were hardly provided with training opportunities. O1 affirmed, women are not usually encouraged to follow training. This lockout restricts half of the agricultural population to access to information or inputs. Both the institutional and ASI theories focus on the inclusive stakeholder engagement; therefore, gendered exclusion is indicative of institutional weakness in the system, as opposed to personal constraint (Berthod, 2018).

Education and information access.

Farmers did not have high levels of education so it was hard to decipher technical instructions or handle computer programs. O4 added the cultural inertia to the older farmers who depend on the inherited procedures. He explained that farmers are already familiar with how to do things the old-fashioned way and are not ready to take the chance of losing a hard-earned meager income on the new gimmickry. To experimentation, younger farmers were more receptive. There was many peer learning effects: F1 high density planting was adopted after witnessing a neighbour to be successful. The result is consistent with Dessart et al. (2019) who identify social learning and networks as critical to agricultural innovation diffusion.

Weak collective learning and coordination.

Officers noted that there was underdevelopment in the area of farmer-to-farmer learning and organised cooperatives. As O5 remarked, it would bring about isolation on many progressive farmers, which, if peer-to-peer models were encouraged formally, would be decreased. This implies that collective problem-solving and dissemination of good practices may be better supported by institutions that have been structured to operate in a manner of cooperation.

The organisational hindrances in Jammu and Kashmir are multi-layered. The small size of farms and lack of financial access inhibit the ability of farmers to invest as well as the social factors like gender discrimination and poor literacy limits the beneficiaries of innovations. The TOE Framework presents such problems as organisational readiness issues, and ASI Theory perceives them as stakeholder inclusion failures. The evidence indicates that the lack of systemic actions to create inclusive training, empower cooperatives, and acknowledge women farmers will keep the adoption at a low level.

5.2.3 Theme 3: Environmental and Institutional Barriers

The external environment is made up of environmental and institutional factors that influence innovation decisions. Climate change, market volatility and inefficiencies in policies were noted by farmers and officers as long-running discouraging factors.

Climate variability and production risk.

Unpredictability of weather was cited as the reason why most farmers adopted lowly. F1 has cited the change in the snowfall pattern which brought impact on flowering and F2 reported of frost in unexpected months. This uncertainty adds more risk aversion and discourages long-term investment. Equivalent results by Rashid et al. (2020) reveal that shifting climatic patterns disrupt conventional patterns of apple production. The weakening of the formal support systems (insurance, extension) through the help of the Institutional Theory explains that farmers have to manage these risks on their own and, therefore, do not innovate.

Market instability and poor price control.

Market volatility was another notable disincentive raised by farmers. F2 replied, and stated that fluctuating prices deter me when investing in new technologies. The farmers are not able to make investments with the assurance because of the unpredictable prices of apples, and because they rely on the few middlemen. According to Bhat et al. (2022), smallholders are affected by price falls more than others, which is also an indicator of market failures. The project is not certain about the perceived payoff of innovation without stable returns.

Policy implementation and bureaucratic hurdles.

Farmers and officers both cited issues with the government schemes. O3 referred to substantial duration and gradual provision of funds, which is bureaucratic unproductiveness. O4 criticised poor feedback mechanisms that do not bring in the experience of farmers when they are designing programmes. These stories indicate a disconnect between the policy and practice, a similar outcome of the research by Bhat et al. (2022) on policy-implementation failures in the horticultural industry in Kashmir. The Institutional Theory describes these barriers as being caused by inflexible administrative structures and a lack of involvement of the farmers in policy making.

Infrastructure limitations.

Other gaps in infrastructure that were noted by officers and farmers included poor cold-storage, electricity, and transport connections. Such weaknesses augment post-harvest losses and minimize incentives in adoption of yield-enhancing technologies. According to Hassan et al. (2021), they estimated that 30-40 per cent of the apples will end up being wasted as they will be spoiled because they are not stored appropriately. In the absence of a credible infrastructure, the innovation environment will not be favorable.

There are environmental and institutional constraints that result in the climate of uncertainty where farmers are willing to survive rather than experiment. Uncontrollable weather, fluctuating markets, and bureaucracies come together to lessen the trust in implementing innovations. The Institutional Theory assists in understanding how these external forces interplay with the local practices in order to perpetuate risk-averse behaviour. Redesign of the policy should aim at streamlining access to subsidies, timely payment of subsidies, and engage farmers in the policy review processes.

5.2.4 Interconnections between Barriers

The trio of barriers namely, technological, organisational and environmental interrelate and tend to support each other. As an illustration, smallholders (organisational) are most vulnerable to high technology costs (technological) which also impacts them the most in a fluctuating market (environmental). Gender inequalities also cross all the categories and limit access of women to technology, organisational membership and representation in policy-making.

The threat posed by the environment increases technological and organisational factors. The increase in climatic risks leads to farmers being more cautious, and it also decreases the adoption of expensive or complicated innovations. Correspondingly, weak institutions do not offer compensatory policies in terms of insurance or a price guarantee hence sustaining a loop

of indecision and reliance. This interdependence in the system is emphasised by ASI Theory, where innovation cannot advance unless the improvement of technological, organisational, and institutional connections.

Therefore, the implementation of agricultural innovation in Jammu and Kashmir are to be considered as a networked problem and not a technical or social problem. Policies or subsidies focusing on one of the barriers and not the other are bound to produce little. A systematic mechanism helping to connect efficient institutions, organisational capacity and affordable technology is the key to sustainable change.

5.3 Negative or Deviant Cases

There were a number of outstanding situations contradicting the overall tendencies. F3, is an orchardist company that is more financially secure and implemented several technologies successfully, such as high-density planting and bio-fertilisers. The combination of three facilitating conditions such as financial access, technical training, and risk tolerance made him successful. He said, it is not cheap but sustainable, which exemplifies pragmatism in making decisions, which most policy models lack.

On the same note, the young farmers were more accepting of experimentation particularly when they were getting technical help. This is opposed to the assumption of the officers that all farmers are conservative. These deviant examples demonstrate that the structural barriers have no absolute value; given favorable conditions: possibility to access credit, peer networks, and training, farmers can reduce them. These examples show that there are areas of focused intervention where enabling environments might be mimicked and larger-scale adoption facilitated.

5.4 Discussion of Key Findings

The study question that informed this research was the following: *"What are the key factors influencing the adoption of agricultural innovations in apple farming in Jammu and Kashmir?"* According to the results of the interviews, the processes of innovation adoption can be determined by the interplay of such factors as technological, organisational, and environmental factors which may be interpreted with the help of the combination of the ASI Theory, TOE framework, and Institutional Theory.

Technological Dimension – TOE Framework and ASI Theory

According to the data, one of the technological barriers is high costs, absence of technical support, and low local adaptation (F1, F5). TOE framework indicates that these are drawbacks in the technologies readiness aspect (Baker, 2011). The attitude towards innovation as being expensive or complicated makes it less compatible and compared advantageous, which speaks to the principles of Diffusion of Innovation proposed by Rogers (Montes de Oca Munguia et al., 2021). The ASI Theory also explicates why the flow of knowledge that is needed to pass on to foster innovation is weakened by the lack of linkages between farmers, researchers, and extension services (Wani et al., 2019). This lays emphasis on the systemic gap between the research outputs and the needs of farmers in the region.

Organisational Dimension – TOE and ASI Integration

Adoption is heavily dependent on the organisational factors, which include access to finance, education, gender inclusion and the size of the farm. Smallholders are short of resources and are prone to risk aversion, whereas women farmers tend to be left out in training (F4; O1). The results align with the organisational aspect of TOE, the internal ability of which determines the adoption of innovation (Roussy et al., 2017; Dessart et al., 2019). This is supported by the ASI view, which demonstrates how structural inequalities decrease the stakeholder participation and cooperation (Aerni et al., 2015). More specifically, the lack of women restricts the potential of innovation at the system level, and this aligns with the focus of the Institutional Theory on informal norms and gender-based restrictions (Sheikh and Baba, 2023).

Environmental and Institutional Dimension – Institutional Theory and TOE

Innovation adoption is also limited by environmental uncertainty brought about by market volatility and climatic risks (F2; O3). The results can be attributed to the environmental context of the TOE framework, in which volatile markets and poor infrastructure reduce the incentive to invest on a long-term basis (Hassan et al., 2021). The barriers are contributed to by institutional Theory which shows how bureaucratic delays, sporadic subsidies, and insufficient involvement of farmers in policy-making (Bhat et al., 2022). Lack of a weak coordination between the formal institutions and the grassroots actors results in disjointed and inefficient support structures (Juárez-Luis et al., 2018).

Integration Across Frameworks

The three frameworks together will give a holistic picture of innovation adoption in apple farming. ASI is used to describe the collaboration at the system level to produce effective diffusion, TOE to describe the impact of technological and organisational preparedness to drive

or restrain adoption, and Institutional Theory to describe how policies and norms influence the behaviour of adoption. Their integration demonstrates that innovation success is based on parallel advances in these interlocked layers as opposed to the isolated interventions.

Policy Implications and Recommendations

Targeting of policy support should thus be on both the systemic and local restraints. The information flow and trust can be enhanced by strengthening the connection between farmers and researchers and extension services (ASI). Equity in access can be promoted by simplifying the process of subsidy and credit (particularly to smallholders and women) (Institutional Theory). Lastly, there should be development of technology that is cheap, simple-to-use, and situational-based solutions with training and care (TOE). A sustainable, innovation-driven apple industry in Jammu and Kashmir will require coordinated effort of institutions, markets, and communities.

5.5Comparative Reflections

Looking at Himachal Pradesh, another major apple-growing region in India, shows that the two places are very different when it comes to choosing new technologies. Although northern regions struggle with weather and land problems, Himachal Pradesh has managed to perform better in implementing innovations like planting many crops together and using cold storage (Devi, 2020). The main reason is better infrastructure, stronger groups of farmers and responsive government help from agricultural experts (Shah et al., 2022). Meanwhile, participants in Jammu and Kashmir pointed out that because of complicated government procedures, they hardly had access to training and using technologies was challenging due to the region's hilly topography. In addition, getting access to services for women was more unequal in Jammu and Kashmir. Such variations make it clear that efficient institutions, participation in policy approaches and broad-based training are crucial for successful adoption. It suggests that understanding local conditions is vital and reveals that models proven in Himachal could support the apple industry in Jammu and Kashmir.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Summary of Key Findings

This research used the Agricultural System of Innovation (ASI) Theory, the Technology-Organisation-Environment (TOE) framework, and Institutional Theory to explore the variables that affect the adoption of agricultural innovations in apple cultivation in Jammu and Kashmir. The qualitative analysis of interviews with farmers and agricultural officers revealed several critical insights:

- **Technological Barriers**: The high costs, technical complexity, and lack of localised adaptations acted as a serious deterrent in the adoption of innovation. They deemed high density planting systems and precision agriculture tools as expensive and unlikely to fit in local conditions. To further exacerbate these challenges, there was limited access to technical support and training.
- **Organisational Challenges**: The adoption decisions were greatly influenced by factors such as farm size, farmer education, and the gender disparities. Financial and logistic constraints faced by the smallholders, while women farmers were excluded from extension services. Enablers such as social networks and peer demonstrations unfolded as the enablers bringing in the importance of community-based learning.
- **Environmental and Institutional Constraints**: Perceived risks were on the climate variability, market volatility, and inadequate infrastructure (e.g., cold storage). Institutional support was also hampered by policy gaps, bureaucratic inefficiencies, and weak feedback mechanisms.

The findings agree with the theoretical frameworks and specify how the technological, organisational, and environmental factors interact and affect the adoption decision. Exceptions mentioned in the study included commercial orchardists and the younger farmers who did adopt innovations because they had financial stability, were technically supported, or had an openness to change.

6.2 Contributions to Theory and Practice

Theoretical Contributions

To have a holistic approach in understanding the adoption of innovation in agriculture was the integration of ASI Theory, the TOE framework, and Institutional theory. Through this tripartite

approach, this research has sought to fill gaps in the literature by examining these technological, organisational, and environmental interaction points, rather than treating these

independently. The research incorporated sociocultural dynamics, such as gender roles and traditional practices that moderate adoption decisions. Further, the study provided context-specific insights related to the agroecological and socioeconomic settings of Jammu and Kashmir, thus filling the gap between theoretical frameworks and agricultural problems faced in reality.

Practical Contributions

The implications of the findings are important to stakeholders in the apple farming industry. The study highlighted the need for affordable, simple technologies and peer demonstrations to lower perceived risk and to encourage adoption for farmers. The evidence-informed recommendations can be used by policymakers to make policy inclusive, make infrastructure better, as well as improve subsidy disbursement so that only those who need the benefits get them. The actionable insights also extended to agricultural extension services, for instance, the need for gender sensitive training programmes, stronger farmer-researcher linkages to enhance an innovative ecosystem through collaboration and efforts. The goal of these practical contributions is to contribute to increasing the sustainability of diploid apple farming in Jammu and Kashmir.

6.3 Recommendations

For Policymakers

1. **Enhance Financial Support**: Introduce targeted subsidies and low-interest credit schemes to reduce the financial burden of adopting innovations like high-density planting and drip irrigation.
2. **Improve Infrastructure**: Invest in cold storage facilities, transportation networks, and reliable electricity to mitigate post-harvest losses and support precision agriculture.
3. **Strengthen Policy Implementation**: Address bureaucratic delays and ensure timely disbursement of subsidies. Involve farmers in policy design to align programs with local needs.
4. **Promote Climate-Resilient Practices**: Develop and disseminate technologies tailored to climate variability, such as frost-resistant apple varieties and efficient water management systems.

For Agricultural Extension Services

1. **Expand Training Programs**: Offer hands-on training and demonstrations to farmers, with materials available in local languages to overcome literacy barriers.
2. **Foster Gender Inclusivity**: Design extension services that actively engage women farmers, ensuring they have equal access to resources and decision-making opportunities.
3. **Leverage Peer Networks**: Utilise successful adopters as ambassadors to promote innovations through community-based learning.

For Farmers

1. **Collaborate and Share Knowledge**: Participate in farmer cooperatives or groups to pool resources, share experiences, and reduce individual risks.
2. **Adopt Incremental Changes**: Start with low-cost, low-risk innovations (e.g., bio-fertilisers) before scaling up to more complex technologies.
3. **Engage with Policymakers**: Advocate for their needs by providing feedback on policy effectiveness and suggesting improvements.

6.4 Innovative Interventions

To address the systemic challenges uncovered in this study, the following innovative interventions are proposed:

- **An efficient system** to reduce bureaucratic delays, ensure transparency, and improve timely access to financial support for smallholder and women farmers.
- **Gender-inclusive digital extension hubs** using multilingual voice-enabled apps and peer-led learning models to deliver customised training, encourage community participation, and bridge rural literacy gaps.

6.5 Limitations and Future Research

This study has certain limitations. The small sample size of ten interviewees does not yield generalizability of findings, but an in-depth qualitative insight was possible due to the small sample size. Regional orientation to Jammu and Kashmir also limits the use of conclusions to other agricultural settings, for which environmental or policy conditions are different. Also, forces outside the organisation, such as extreme weather events/economic shocks, were not discussed, although they can have a significant effect on innovation adoption.

In the future, then, larger or longitudinal studies should be used to validate these findings among other diverse farming communities. Other regions or crop-based comparative analyses might help to discover applicable insights. As well, investigation of the role of women in innovation adoption is also important, since gender-specific dynamics remain underexplored. Finally, given the rising threat of climate variability, studies on the ways such alteration impacts long-term adoption patterns and resilience strategies would add to knowledge and lead to improved agricultural innovation interventions.

6.6 Final Thoughts

A variety of issues pose problems for adopting agricultural innovation in Jammu and Kashmir's apple farming sector, requiring the support of concerted efforts by the farmers, policymakers, and the extension service. To unlock the potential for the sector to be competitive, there is also the potential for the sector to be sustainable; technological barriers, organisational inequities and environmental constraints must be addressed. This study is crucial to show the significance of systemic context-specific intervention and sets forth the path for further research to be built on the findings of this research study. In the end, we will need to create an environment of innovation and collaboration to ensure that apple farming remains resilient and fruitful for the future.

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Appendix 1: Interview Questions

For Farmers:

1. Which agricultural innovations (e.g., high-density planting, cold storage) have you adopted or rejected? What drove your decision? *(Technological adoption barriers)*
2. What support (training, subsidies, infrastructure) do you need most to adopt new technologies? *(Organisational/Policy gaps)*
3. How do climate risks (erratic snowfall, warmer winters) and market volatility impact your willingness to try innovations? *(Environmental challenges)*

For Officials (Policy/Extension):

4. What policies or programs exist to promote innovation adoption in apple farming? How effective are they? *(Institutional support)*
5. What are the biggest systemic barriers (e.g., infrastructure, farmer awareness) hindering innovation uptake? *(TOE framework analysis)*
6. How do you collaborate with researchers/farmers to design locally viable solutions? *(ASI: Stakeholder linkages)*

For Both Groups:

7. How do sociocultural norms (e.g., traditional practices) accelerate or resist change? *(Institutional Theory)*
8. What role can cooperatives or farmer groups play in scaling innovations? *(Organisational enablers)*
9. What quick wins (e.g., low-cost tech, policy tweaks) could boost adoption in the next 2–3 years? *(Actionable solutions)*
10. If you could prioritise one intervention to transform J&K's apple sector, what would it be? *(Strategic vision)*

Appendix 2: Interview transcript table

Title: *Technological Adoption and Innovation in Apple Farming in Jammu & Kashmir*

Participants:

- **Farmer 1 (F1)**- Smallholder apple grower in Baramulla.
- **Farmer 2 (F2) -** Mid-scale farmer in Sopore.
- **Farmer 3 (F3)** - Commercial orchardist in Shopian.
- **Farmer 4 (F4)** - Woman farmer from Anantnag.
- **Farmer 5 (F5)**- Apple grower from Tangmarg
- **Official 1 (O1)** - Agricultural Extension Officer, North Kashmir.
- **Official 2 (O2)** - District Horticulture Officer, Pulwama.
- **Official 3 (O3)** - Scheme Implementation Officer, Department of Horticulture.
- **Official 4 (O4)** - Agricultural Scientist.
- **Official 5 (O5)** - Assistant Horticulture Officer

Question	Farmer 1 (F1)	Farmer 2 (F2)	Farmer 3 (F3)	Farmer 4 (F4)	Farmer 5(F5)	Official 1 (O1)	Official 2 (O2)	Official 3 (O3)	Official 4 (O4)	Official 5 (O5)
1. Which agricultural innovations have you adopted or rejected? What drove your decision?	Adopted HDP on a small scale due to neighbour's success; high costs and lack of cold storage hindered expansion.	Not specified in transcript.	Adopted anti-hail nets, mulching, low-chill varieties, mobile spray unit, and bio-fertilizers. Avoided laser levelling due to terrain incompatibility.	Rejected major innovations due to a lack of training and gender exclusion. Tried weather apps but faced language/connectivity issues. Avoid imported varieties due to climate unpredictability.	Adopted high-density planting (HDP) on a small plot after observing success in a nearby orchard. Yields were promising, but high costs for saplings and drip irrigation hindered expansion. Cold storage remains a challenge, forcing immediate sales at lower prices.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.
2. What support do you	Upfront financial assistance and hands-	Reliable access to subsidi	Better infrastructure (roads, water,	Gender-sensitive outreach, cooperat	Upfront financial assistance is critical, as subsidie	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.

need most to adopt new technologies?	on training in local dialects.	es/credit, helpdesk for advice.	electricity) and soft loans for modernisation.	ive models for women to pool resources.	s are often delayed or inaccessible. Requests training sessions in local languages, especially for maintaining equipment like drip systems.					
3. How do climate risks and market volatility impact your willingness to try innovations?	Erratic snowfall and bloom timing make him reluctant to invest in new saplings/irrigation methods.	Unpredictable prices (e.g., bumper crop in Himachal) reduce investment willingness. Suggests price guarantees/in	Adopts climate-resilient innovations (drought-tolerant rootstock, solar pumps) due to irregular rainfall and pests.	Lost crops to frost; unwilling to risk further without safety nets (disaster relief, gradual tech support).	Erratic snowfall and unpredictable blooming seasons create hesitation to invest in new saplings or irrigation methods. A sudden frost last year ruined part of the crop, increasing risk aversion. Would	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.

		surance.			be more open to experimenting with insurance or price guarantees.					
4. What policies/programs exist to promote innovation adoption? How effective are they?	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	MIDH, RKVY grants, KVK awareness programs. Reach is uneven; remote areas lack access.	50% subsidy on HDP (UT govt), PMKSY irrigation support. Gaps in training, awareness, and post-harvest logistics.	CA store/polyhouse programs exclude smallholders due to documentation/co-funding requirements.	SKUAST disseminates innovations, but feedback mechanisms are weak. Suggests two-way farmer-researcher communication.	Schemes like CA storage and polyhouse subsidies exist but are often inaccessible to smallholders due to complex paperwork and co-funding requirements.
5. What are the bigges	Not specified in	Not specified in	Not specified in	Not specified in	Not specified in transcript.	Lack of awareness, poor infrastru	Low farmer confidence	Bureaucracy (delayed	Cultural inertia (resist	Delays in fund disbursement and rigid

t systemic barriers hindering innovation uptake?	transcript.	transcript.	transcript.	transcript.		cture (e.g., road access).	(failed experiments discourage others), fragmented landholdings.	funds, complex paper work, strict eligibility).	ance to change), generational divides (youth are more open).	eligibility criteria are major barriers.
6. How do you collaborate with researchers/farmers to design locally viable solutions?	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Occasional field demos with SKUAST; unstructured liaison.	Relies on innovative farmers for informal feedback; lacks formal data collection.	Partners with NGOS/cooperatives for co-designed solutions (e.g., irrigation). Suggest scaling this model.	Engages farmers in varietal trials; limited by staffing/transport.	Partners with NGOs and cooperatives to co-design solutions (e.g., tailored irrigation systems). These collaborations are effective as they address actual farmer needs.
7. How do	Traditional methods	Community percep	Not specified in	Not specified in	Older farmers in the village adhere	Older farmers resist	Not specified in	Not specified in	Literacy gaps and	Not specified in

socioc ultural norms influen ce innova tion adopti on?	are deeply rooted; failure with new techniqu es discoura ges others.	tion matter s (elders ' adopti on inspire s trust).	transcrip t.	transcrip t.	to tradition al methods and discoura ge change.	change; women are exclude d from training.	transcrip t.	transcr ipt.	male migrat ion strengt hen resista nce. Youth involv ement increas es openn ess.	transcr ipt.
8. What role can cooper atives/ farmer groups play in scaling innova tions?	Not specifie d in transcrip t.	Group adopti on (e.g., HDP) inspire s others; cost-sharin g and peer learnin g occur.	Coopera tives reduce costs (bulk purchas es, shared storage), empowe r bargaini ng with traders.	Not specifie d in transcrip t.	Not specifie d in transcrip t.	Not specifie d in transcrip t.	FPOS need capacity building (govern ance, finance, markets) to function effective ly.	Succes sful cooper atives require leaders hip, transp arency , digital tools, and policy suppor t.	Not specifi ed in transcr ipt.	Succes sful cooper atives require strong leaders hip and transp arency . Examp le: One group pooled resour ces for shared cold storag e, reduci ng losses.
9. What quick	Subsidie s for pruning	Not specifi ed in	Not specifie d in	Multilin gual voice-	Mobile extensio n vans with	Streamli ne Direct	Not specifie d in	Not specifi ed in	Train rural youth	Not specifi ed in

wins could boost adoption in the next 2–3 years?	tools/sprayers, mobile extension vans for on-site advice.	transcript.	transcript.	based apps for weather/ market info, inclusive of illiterate farmers.	experts visiting villages regularly would help. Subsidies for small tools (e.g., pruning equipment, soil test kits) would make a significant difference for smallholders.	Benefit Transfers; showcase local success stories.	transcript.	transcript.	as "innovation champions" for knowledge transfer.	transcript.
10. If you could prioritise one intervention to transform J&K's apple sector, what would it be?	Not specified in transcript.	Build Controlled Atmosphere (CA) storage units per block to stabilise prices.	Modernise orchards with climate-resilient rootstock; 5-year support packages (tech, inputs, insurance).	Gender-specific interventions (training, credit, representation in cooperatives).	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Not specified in transcript.	Establish an "Apple Innovation Hub" to connect stakeholders (farmers, researchers, govt).	Streamlining subsidy delivery through a single-window system would have immediate impact. Farmers waste time navigating multiple

										depart ments.

Appendix 3: Interview Transcript

Question 1: Which agricultural innovations have you adopted or rejected? What drove your decision?

F1: Seeing the neighbour's orchard was something that had me give HDP a go on a small scale. Growth rate was good, but the sapling and drip system cost was high. I had no funds to expand. They also don't have cold storage nearby, so I still depend on local traders.

F4: In addition to HDP, I have started a little cold storage with a local farmer-producer group. I also fertilise, which saves time. I've tried weather monitoring apps, but often they are in English, and with no network, they don't help. I also stayed away from imported plant varieties as our climate was unpredictable.

F3: Ranging from using anti-hail nets, reflecting mulching, to low chill varieties in my 20 kanal orchard. I've also brought a mobile spray unit and covered bio-fertiliser. It's expensive but sustainable. It didn't suit our hilly terrain, so I avoided laser levelling.

F4: I have not adopted any important innovations. So, I'm still using the traditional planting method. I want to learn, but the trainings are not done in our village. But I am also excluded as a woman; extension workers do not visit often, do not take it seriously when they do visit, and do not pay much attention to my queries.

F5: I tried high-density planting (HDP) on a small plot after seeing its success in a nearby orchard. The yields were promising, but the costs for saplings and drip irrigation were too high for me to expand further. Cold storage is another challenge—without it, I'm forced to sell my produce immediately at lower prices.

Question 2: What support do you need most to adopt new technologies?

F1: I need upfront financial assistance. Right now, we get paid later by the current system, but we can't afford the initial investment. I think that hands-on training in local dialects would help a lot.

F2: They also need reliable access to subsidies and credit. We fill out forms, the payments come later. Secondly, we'd recommend a helpdesk or local extension kiosk to which we could get regular advice and scheme updates.

F3: It would help to have better infrastructure — roads, water pipelines, and electricity. Soft loans for orchard modernisation would also encourage more people to innovate.

F4: I need gender-sensitive outreach. It's just designed to support male participation. I'd also like to find cooperative models of women working together to pool resources for equipment or storage.

F5: Financial help upfront is critical. Subsidies often come too late or are hard to access. I'd also benefit from training sessions in our local language, especially on how to maintain new equipment like drip systems.

Question 3: How do climate risks and market volatility impact your willingness to try innovations?

F1: We used to get our snowfall in December. The bloom timing is off, and when I need it or at all, it's not there. These shifts make me reluctant to plant new saplings or attempt new irrigation methods for fear that one bad season will ruin everything.

F2: The market is unpredictable. Prices had fallen last year after a bumper crop in Himachal. It modifies how much I am ready to invest in innovation. I'd appreciate some assurances, in the form of price guarantees or insurance support.

F3: Climate change is real. Rainfall becomes irregular and chilling hours drop, while pests rise. That's why I'm adopting innovations drought drought-tolerant rootstock and solar-powered pumps. There is no room to stand still.

F4: Last year, I lost half my crop from early flowering and unexpected frost. Except I won't risk putting in any more until there's a safety net. Disaster relief should be included in government schemes, and there should be a push to adopt the technology gradually with support.

F5: Erratic snowfall and unpredictable blooming seasons make me hesitant to invest in new saplings or irrigation methods. Last year, a sudden frost ruined part of my crop, so I'm wary of risks. If there were insurance or price guarantees, I'd be more open to experimenting.

Question 4: What policies or programs exist to promote innovation adoption in apple farming? How effective are they?

O1: We have several schemes under the MIDH and provide grants in infrastructure and for planting material under the Rashtriya Krishi Vikas Yojana (RKVY). Apart from that, we also promote awareness through Krishi Vigyan Kendras (KVKs). However, reach varies; some remote areas remain unattainable.

O2: There is a 50% subsidy on HDP offered by the UT government and schemes in support of irrigation like PMKSY. However, the training, awareness and postharvest logistics still have gaps. 'You don't know where to apply, whom to contact,' say farmers.

O3: We have programs for CA stores, poly houses, or processing units. But, it only takes in medium or large farmers. Documentation and co-funding requirements are too much for smallholders.

O4: Innovations are disseminated by SKUAST in collaboration with the Department of Horticulture. The feedback mechanism, however, is a weak one. There must be a two-way system that enables farmers to report what works and doesn't.

O5: We have schemes like CA storage and polyhouse subsidies, but they're often out of reach for smallholders due to complex paperwork and co-funding requirements. Many farmers give up mid-process because the bureaucracy is overwhelming.

Question 5: What are the biggest systemic barriers hindering innovation uptake?

O1: The first is a lack of awareness. Many farmers are not tech savvy or informed about how technologies function or should be serviced. Second comes infrastructure — even ferrying saplings to far-off villages is a challenge in areas that have poor access to the roads.

O2: Farmer confidence is low. A few attempted experiments failed, some in the face of inclement weather, others as a result of mismanagement. That discourages others. And, the broken landholding pattern in Kashmir makes large interventions difficult.

O3: Bureaucracy is a problem. The requirement to wait to receive funds, complex paperwork and strict eligibility rules are barriers to participation. We need to make these functions simpler.

O4: Cultural inertia is strong. Farmers know how to do things in the old way and are unwilling to risk a scarce income on new-fangled gimmickry. Generational differences also play out in adoption — younger farmers are more experimental, while elders are more resistant to change.

O5: Delays in fund disbursement and rigid eligibility criteria are major hurdles. For example, a farmer might qualify for a subsidy but lose the planting season waiting for approval. Simplifying these processes is urgent.

Question 6: How do you collaborate with researchers/farmers to design locally viable solutions?

O1: Once in a while we hold joint field demonstrations with the SKUAST scientists. This is key to ensuring the transfer of research into practice. More detailed An alternative is to establish just-in-time or time-bound liaisons, but the trend (undeniably) continues toward less frequent and less structured involvement.

O2: We depend on innovative farmers to test technologies and provide us with the feedback. There isn't really a feedback loop, at least not in any formal sense, it's mostly informal communication, and that means the data collection and learning is incomplete.

O3: NGOs and cooperatives often fill the void. In some areas, we have co-designed the irrigation design or storage units with farmer groups. That model should be expanded.

O4: We engage farmers in participatory varietal trials to ensure any new cultivars developed will thrive within the unpredictable climate and have market viability. However, outreach remains a challenge due to staffing and transportation restrictions.

O5: We partner with NGOs and cooperatives to co-design solutions, like tailored irrigation systems. These collaborations work well because they're grounded in farmers' actual needs. Scaling this model would require more institutional support.

Question 7: How do sociocultural norms influence innovation adoption?

F1: My father and grandfather used traditional methods, and many in my village say "why fix what's not broken?" However, that attitude is holding us back. And if a person fails with a new technique, then everyone immediately stops using it.

F2: Community perception matters. If an elder or respected farmer adopts something, you will copy them. However, if young farmers do it first, people hesitate. There's a trust hierarchy.

F5: Many older farmers in my village stick to traditional methods and discourage change. When someone tries something new and fails, it reinforces their skepticism. But younger farmers like me are more willing to take risks if we see proof of success.

O1: It's a comfort and a barrier. Older farmers fear failure, and many will not change. In addition, women are often not encouraged to attend training or have orchards in many areas, closing down half of our potential.

O4: Where literacy is low, and men are often absent in migration, cultural resistance is strongest. Openness increases where youth are more involved. It is time for tradition and innovation to bind together.

Question 8: What role can cooperatives or farmer groups play in scaling innovations?

F3: Reduction of costs and opening the market to commodities/services for the actors remains the transformative role of Cooperatives. For our case forming a cooperative enabled us to buy fertilisers and saplings in bulk. We pooled resources together in order to access cold storage. It helped us cut our transport expenses and empowered us with bargaining power, in terms of middlemen and traders.

F2: Faster community acceptance occurs when the group adopts innovation. It took five of us to adopt High Density Plantation (HDP) all together, and we made a visible and successful model that other people were inspired with. Beyond that, cost sharing through group adoption occurs, allowing tools and equipment to be split amongst all the members; and then peer learning, where troubleshooting and improving the use of the chosen tool, or service, is solved through collective experience and support.

O2: Agricultural innovation could be transformed by the potential of Farmer Producer Organizations (FPOs). Although, many FPOs do not exist on the ground due to lack of training. These groups cannot scale innovations sustainably nor function effectively without capacity building in governance, financial management, and the market. They are only realisable by proper training.

O3: Cooperatives that manage their operations well can help support innovation, by helping process, brand and assisting with direct sales to consumers. It reduces the farmer's dependency on the middlemen and helps to increase the farmer's income. However, having a truly successful consumer generation market based on four core pillars: capable leadership, transparency and access to digital tools, is what makes the difference. Without these, cooperatives can stagnate. Policy support should be digitised, and leadership training should also be a part of it.

O5: Successful cooperatives need strong leadership and transparency. For example, one group pooled resources to buy shared cold storage, which cut their losses. But without training in governance and finance, many groups struggle to sustain such efforts.

Question 9: What quick wins could boost adoption in the next 2–3 years?

F1: Subsidising pruning tools, sprayers, and soil testing kits would vastly help small farmers take up new practices. Mobile extension vans with agricultural experts could also be sent out to visit villages regularly to give on-the-spot advice, demonstration, and motivation for the adoption of modern techniques that are suitable for the local conditions and challenges.

F4: Having a mobile app on weather conditions, market prices, and upcoming training sessions in Kashmiri or Urdu can be critical. Also, the app should include a voice based interface to ensure easy access even by illiterate farmers so as to be inclusive with other different levels of literacy in the community.

F5: Mobile extension vans with experts visiting villages regularly would help. Also, subsidies for small tools like pruning equipment or soil test kits could make a big difference for farmers like me.

O1: Better execution of Direct Benefit Transfers is required. Delays or discrepancies erode the confidence of the farmer in government support. But simplifying and streamlining the process will restore trust. They also highlight success stories locally through media or field visits, to inspire others and accelerate the adoption of proven innovations and practices.

O4: Training could turn rural youth into 'innovation champions'. These young people serve as local ambassadors, supporting their families and spreading the word. They are perfect agents for knowledg e transfer and leadership development in the agriculture space due to their energy, tech savviness, and desire for engaging with the community.

O5: Introducing terrain-specific subsidies, expanding local training centres, and simplifying loan procedures could provide immediate impact and build confidence among farmers to try innovative techniques.

Question 10: If you could prioritise one intervention to transform J&K's apple sector, what would it be?

F2: The most impactful intervention would be to build more Controlled Atmosphere (CA) storage units in each block. That would help to stabilize apple prices by minimizing post-harvest losses and consequently assist farmers to hold on to produce until times market prices improve, rather than sold at distress prices as harvest time.

F3: Top priority should be given to modernising orchards with climate resilient, high yielding rootstock. This has to go beyond one time subsidies. Farmers would be able to invest in weather related risk management and long term improvements if they were supported and confident that a guaranteed support package of at least five years (technical guidance, quality inputs, insurance, education, etc.) was coming down the road.

F4: Women are integral to apple farming but are largely invisible in decision-making and support systems. Gender specific interventions (gender specific training, easy access to credit, women's representation in the cooperatives) will be prioritised for women, through which women will be empowered to be more productive, which will lead to a more equitable development in the apple sector.

O4: A transformation of the sector can be spurred through the establishment of an 'Apple Innovation Hub' to connect farmers, researchers, start-ups and government departments on a single platform. It would be a hub for sharing knowledge, trialling new technologies and coordinating policy. Innovation thrives when there is ongoing institutional support and an ecosystem is in place.

O5: Streamlining subsidy delivery through a single-window system would have an immediate impact. Farmers waste too much time navigating multiple departments. A centralised, transparent process would boost trust and participation.