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Review

Water Scarcity Impacts on Rain Fed Agriculture in Pakistan: Challenges and Adaptive Strategies

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Abstract | With a focus on the semi-arid regions of Attock, Rawalpindi, and Chakwal, this study investigates the growing effects of water scarcity on rain-fed (barani) agriculture in Pakistan. It examines how climate hazards, such as protracted dry spells, unpredictable rainfall, rising temperatures, and soil degradation, compromise natural, human, financial, social, and physical capital, making smallholder farmers more vulnerable, using the Sustainable Livelihoods Framework (SLF). The study takes a qualitative approach, combining data from a systematic review of the literature (2014–2025) with primary data gathered using Participatory Rural Appraisal (PRA) techniques, such as focus groups (FGDs) with community members and key informant interviews (KIIs) with local experts in water management and agriculture. Water-related pressures have been more severe over the past ten years, according to findings from FGDs and KIIs. This has led to lower agricultural yields, a higher chance of crop failure, decreased animal output, and greater household food insecurity. Community-adopted adaptive techniques, such as growing drought-tolerant crops, modifying sowing dates, conserving soil and water, putting small-scale rainwater collection into practice, and diversifying livelihoods, are highlighted in both literature and field data. However, due to a lack of institutional backing, insufficient technical expertise, and limited financial resources, adoption is still uneven. The study comes to the conclusion that integrated multi-capital interventions, bolstered by policies, improved extension services, community-based water governance, and investments in climate-smart agricultural infrastructure, are necessary to increase resilience in Pakistan's rain-fed systems. Policymakers, researchers, and development professionals seeking to guarantee sustainable agricultural and livelihood security in water-stressed areas can benefit from these ideas.

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Introduction

Pakistan's agricultural sector is severely and urgently threatened by water scarcity, particularly in rain-fed (locally referred to as barani) regions where farming relies more on rainfall than irrigated water supplies (Rahman *et al*., 2024; Ashraf, 2016). Rain-fed agriculture is still essential for maintaining rural livelihoods, supplying fodder and staple crops, and supporting livestock rearing in semi-arid and arid regions like the Pothwar plateau, portions of Punjab, Sindh, Balochistan, and other marginal drylands, even though irrigated agriculture, supported by extensive canal systems drawing from rivers, has historically dominated national crop production (Baocheng *et al*., 2024; Durrani, 2020).

However, Pakistan's rain-fed agriculture has always been vulnerable to structural issues, such as irregular and inconsistent rainfall, poor soil fertility, soil erosion, a lack of institutional support, and the historical disregard for water harvesting infrastructure (Fahad and Wang, 2020). Climate stress has increased these vulnerabilities in recent decades. The predictability necessary for crop planning in rain-fed areas has been undermined by Pakistan's increasing monsoon and winter rainfall patterns, which include prolonged dry spells, decreasing total precipitation, and changing seasonality (Syed *et al*., 2022).

Current statistics demonstrate how serious the problem is. National studies state that rainfall reductions of up to 70% have occurred during some winter seasons, creating severe water shortages and endangering the planting or growth of important crops (Khetran and Salik, 2024). These deficiencies immediately result in lower yields and a higher chance of crop failure in Punjab's and other provinces' rain-fed zones. Reduced agricultural productivity, less animal feed, smallholder farmers' income loss, increased debt, and increasing food insecurity are the effects that ripple through rural economies (Nadeem *et al*., 2024).

Furthermore, climate change increases the frequency of extreme weather events, such as torrential downpours following protracted dry spells, unplanned floods or waterlogging, and increased soil erosion, in addition to decreasing the availability of water. Because rain-fed farming systems lack strong infrastructure to withstand such extremes, they become even more unstable (Arnell, 1999; Beran *et al*., 2016). The growing water scarcity issue requires immediate action given the significance of rain-fed agriculture for food security, livelihoods, and the socioeconomic fabric of rural Pakistan. A thorough evaluation of the effects of water scarcity on rain-fed agriculture is urgently needed, as is the identification of both conventional and contemporary adaptation methods that can increase resilience. In order to protect livelihoods and advance sustainable agriculture in rain-fed regions, this paper will: (1) examine the type and extent of water scarcity impacts on rain-fed agriculture in Pakistan; and (2) investigate a range of adaptive strategies, from crop and climate smart agriculture to water harvesting and soil conservation (Qureshi, 2005; Mukheibir, 2010; Beran *et al*., 2016).

By providing information pertinent to national water resource management, rural development planning, and climate adaption methods in arid and semi-arid agro-ecosystems, the study advances both academic knowledge and policy debate.

Scope of the research

In order to improve resilience and sustainability, this analysis looks at how water scarcity affects rain-fed (barani) agriculture in the semi-arid regions of Attock, Jhelum, and Rawalpindi. Due to their reliance on rainfall for crop production, these Pothwar Plateau regions are extremely susceptible to climate fluctuations and water scarcity. In addition to addressing issues like rising drought frequency, unpredictable rainfall, soil degradation, and inadequate water management infrastructure, the study examines how water scarcity impacts crop yields, livestock productivity, rural livelihoods, food security, and environmental sustainability (Rashid *et al*., 2004; Konapala *et al*., 2020).

Objective of the study

This project aims to determine and assess local adaptive solutions for improving resilience and sustainability, as well as to examine the effects of water shortage on rain-fed agriculture and rural lives in semi-arid Pakistan.

Theoretical background

One of the most important environmental issues influencing agricultural productivity globally is water scarcity, especially in semi-arid and dry regions (Aziz and Tariq, 2018). Millions of rural livelihoods in Pakistan are supported by rain-fed (barani) agriculture, which makes up a sizable section of the country's agricultural landscape (Shemer *et al*., 2023). These systems are intrinsically susceptible to water shortages and climate variability because they rely so strongly on the timing, amount, and distribution of rainfall.

Concept of water scarcity

The imbalance between water availability and demand, which is made worse by things like population expansion, ineffective water management, and climate change, is known as water shortage. It can be divided into two categories: economic scarcity, which occurs when infrastructure or management constraints prohibit appropriate water usage, and physical scarcity, which occurs when water supplies are insufficient to fulfil demand (Pereira *et al*., 2009; Lautze and Hanjra, 2014).

Impact on rain fed agriculture

Pakistan's rain-fed farming systems, which lack access to major irrigation infrastructure, mainly rely on rainfall for crop development. Rainfall variability, prolonged dry spells, and frequent droughts lower soil moisture, restrict crop growth, and eventually lower yields (Kuzucu *et al*., 2016). Even small changes in water availability can have a disproportionate impact on rain-fed yields, particularly for staple crops like wheat, maize, and pulses, according to theoretical models of crop water connections like the Soil Water Atmosphere Plant (SWAP) model (Kuzucu *et al*., 2016).

Livelihood vulnerability and socio economic implications

The Sustainable Livelihoods Framework (SLF) offers a helpful perspective for comprehending how rural populations are impacted by water constraint. It highlights how human, natural, financial, social, and physical capital are all linked to agricultural productivity. Water scarcity reduces crop yields, which lowers income, restricts food security, and makes people more susceptible to poverty (Osman-Elasha *et al*., 2009; Natarajan *et al*., 2022). This produces a feedback loop in which farmers with limited resources encounter difficulties implementing adaptable tactics or cutting-edge water-saving devices.

Theoretical background: Sustainable livelihoods framework (SLF)

DFID's sustainable livelihoods framework (SLF) offers a comprehensive method for comprehending how people earn a living and address environmental and socioeconomic issues. In Pakistan, where livelihoods are extremely vulnerable to water scarcity, it is particularly pertinent to rain-fed agriculture (Mensah, 2011; Natarajan *et al*., 2022). The framework highlights that five essential categories of assets, or capitals, are necessary for the sustainability of livelihoods:

Natural capital: Land, water, soil fertility, and other environmental resources fall under this category (Ruijs *et al*., 2019). Rainfall and soil moisture are the most important natural resources in rain-fed agriculture. These resources are directly diminished by water scarcity, which results in poor crop growth and decreased agricultural productivity.

Human capital: The farming community's labour, expertise, health, and skills. Reduced water availability can have an impact on health and food security, which in turn reduces labour productivity and farmers' capacity to implement creative farming techniques (Tamura, 2002).

Financial capital: Availability of credit, loans, savings, and income. Farmers' ability to invest in seeds, fertilisers, irrigation systems, or other adaptive measures is limited when crops fail owing to water constraint.

Social capital: Social support networks, cooperative organisations, and community networks. During droughts, communities with high social capital can pool labour, water resources, and expertise to lessen the effects of water scarcity (Baker and Hopkin, 1969). Farmers are more susceptible when social networks are weak.

Physical capital: Storage systems, irrigation facilities, equipment, tools, and infrastructure. Rain-fed farmers are more vulnerable to water stress when they lack access to irrigation infrastructure or contemporary water-saving technologies (Kataria *et al*., 2012).

Application of SLF to rain fed agriculture

All five of Pakistan's capitals are impacted by water scarcity in rain-fed regions, which creates a vicious circle of vulnerability. Lower income (financial capital), impaired health and labour capacity (human capital), restricted community support (social capital), and poor access to resources and technologies (physical capital) are all consequences of reduced agricultural yields (natural capital).

Adaptive strategies based on SLF

The SLF emphasizes that initiatives across several capitals are necessary to strengthen livelihoods. Examples consist of:

- Using drought-tolerant crops and conserving water to safeguard natural capital.
- Educating farmers on contemporary agronomic techniques to improve human capital.
- Offering crop insurance or microloans to enhance financial capital.
- Creating cooperative irrigation organizations to

improve social capital.

- Building irrigation infrastructure, tiny dams, and wells to bolster physical capital.

By using the SLF, researchers and policymakers can comprehend how water scarcity undermines farming communities' total livelihood resilience in addition to lowering agricultural output. In Pakistan's water-stressed areas, this integrated viewpoint aids in the development of focused adaptive measures to maintain rain-fed agriculture.

Materials and Methods

Conceptual framework

Early studies viewed vulnerability mainly as a biophysical outcome of natural hazards, a perspective dominant in both climate research and social sciences until the 1980s (Adger, 1999). A shift later recognized that hazard impacts vary across communities due to differences in social structures, economic conditions, and resource access (Wisner, 2003; Krieg and Faber, 2004). In Pakistan's rain-fed agriculture, vulnerability to water scarcity results from both climatic factors such as irregular rainfall and drought and socio-economic factors including land ownership, farming practices, income, and access to adaptive resources, leading to uneven impacts on productivity and food security (Gerlitz *et al*., 2014; Bakhsh and Kamran, 2019). This study follows Campbell's (2017) systematic review principles to ensure transparency and reproducibility.

Literature search and screening

Following Campbell's (2017) guidelines, a systematic search was conducted across ABI/INFORM Collection, Web of Science, and Science Direct. Keywords related to water scarcity, climate change, rain-fed agriculture, and livelihoods were used, generating 1,350 studies. After removing irrelevant papers and duplicates, 139 studies remained. Full-text screening resulted in 51 articles that met the criteria of focusing on water scarcity, climate-smart agriculture, and rain-fed farming in developing countries. The selection process followed PRISMA standards.

Data extraction and appraisal

Data was extracted on publication details, objectives, study areas, methods, and target populations. Priority was given to studies examining water scarcity impacts on crop yields, livestock productivity, livelihoods, and food security in Attock, Jhelum, and Rawalpindi. Adaptive strategies including rainwater harvesting, soil and water conservation, climate-smart agriculture, and livelihood diversification were assessed to understand their effectiveness in semi-arid rain-fed systems.

Flow diagram of included studies

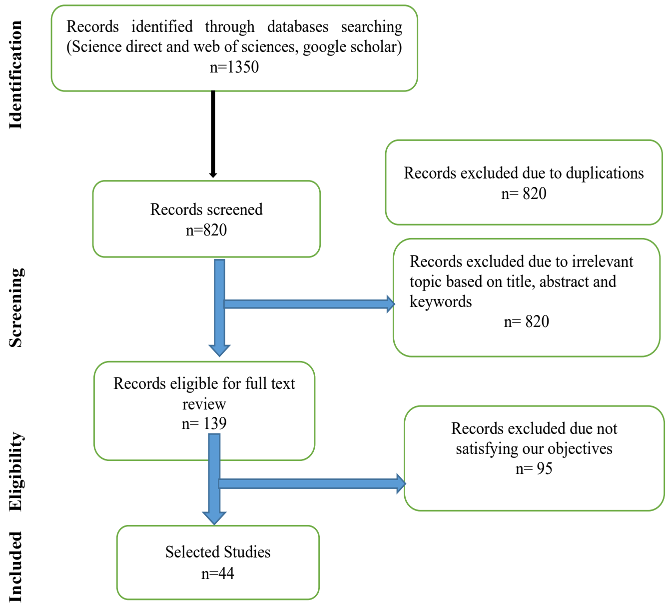

Figure 1: *Flow diagram of included studies following PRISMA framework.*

Synthesis

In order to evaluate how water scarcity impacts rain-fed agriculture and smallholder livelihoods in Attock, Jhelum, and Rawalpindi, this review synthesized data. Crop yields, animal productivity, food security, income, and associated social and environmental circumstances are highlighted. Additionally, the analysis demonstrates how livelihood capitals natural, human, social, financial, and physical influence farmers' capacity to implement climate-smart practices, rainfall harvesting, soil and water conservation, and livelihood diversification. All things considered, the synthesis offers a clear knowledge of the vulnerabilities brought on by water scarcity and the adaptation strategies employed by farming communities (Figure 1).

Data extraction and critical appraisal

To systematically address the research issues, data from the chosen studies was retrieved. Authorship, publication year and location, study aims, country focus, research methodology, study type, and target population were among the characteristics that were extracted. Information relating to agricultural methods, livelihood diversification, and water scarcity received particular attention. A summary of the extracted data is presented in Table 1.

Table 1: *Detail of collected data sites.*

District	FGDs (No. of sessions)	KIIs (No. of sessions)	Field observations	Focus areas
Attock	2	8	✓	Activity profiles, division of labor, socio demographics, household assets, climatic hazards, adaptive capacities, water scarcity impacts
Rawalpindi	2	8	✓	Activity profiles, division of labor, socio demographics, household assets, climatic hazards, adaptive capacities, water scarcity impacts
Chakwal	2	8	✓	Activity profiles, division of labor, socio demographics, household assets, climatic hazards, adaptive capacities, water scarcity impacts

Source: *Survey, 2025.*

Data synthesis

In order to comprehend the effects of climate change and water shortage on agriculture in rain-fed countries, especially in Pakistan, the review's primary objective was to synthesize the gathered data. The results were arranged to emphasize methods for enhancing livelihoods, lowering poverty, and guaranteeing food security and nutrition in communities under water stress.

Data collection

In the rain-fed areas of Attock, Rawalpindi, and Chakwal, a Participatory Rural Appraisal (PRA) method was employed. Key informant interviews (KIIs), focus group discussions (FGDs), and field observations were used to gather data. Eight KIIs and two FGDs were carried out. Social demographics, household assets, climate hazards, gendered labor division, vulnerabilities, and capacities were the main topics of information. The synthesis of qualitative data was done using a semi-structured method.

Results and Discussion

Research findings

The most important issue affecting rain-fed agricultural systems, according to the study communities in Attock, Rawalpindi, and Chakwal, is water scarcity. Over the past ten years, local farming cycles have been more interrupted by rainfall unpredictability, extended dry spells, delayed monsoon commencement, rising temperatures, and sporadic severe downpours, according to the PRA data. Farmers have often stated that scant and erratic rainfall has decreased soil moisture, hindered crop germination, and decreased the yield of important rain-fed crops like sorghum, wheat, millet, and groundnuts. Climate patterns have clearly changed, according to local impressions acquired through KIIs and FGDs.

Communities observed

Communities in Attock, Rawalpindi, and Chakwal observed a marked rise in climate-related water stressors that negatively impact rain-fed agriculture. Prolonged dry spells are becoming more common, especially during sensitive crop growth stages, which results in poor germination and lower yields, according to farmers. With unexpected, intense downpours that frequently harm standing crops and disrupt soil structure, rainfall has grown more variable and unpredictable. At the same time, crop water stress is getting worse and soil moisture loss is quickening due to quickly rising summer temperatures. Existing wells and conventional dug water sources are now unreliable due to the decreased groundwater recharge caused by these climate changes (Qureshi and Ashraf, 2019; Hafeez *et al*., 2024).

Additionally, the rain-fed zone's overall livelihood vulnerability has been exacerbated by the deterioration of natural resources, particularly rangelands and grazing areas, which has decreased the availability of fodder and put extra strain on households who depend on cattle. These risks have a negative impact on agricultural livelihoods, especially for smallholders who depend only on rainfall (Qaisrani *et al*., 2018; Zeng *et al*., 2021; Shah *et al*., 2021). Even though they are rare, bouts of heavy rains frequently fall around harvest times, causing crop lodging and quality degradation. In a similar vein, crops are more susceptible to pests and illnesses when temperatures rise during the flowering and fruit-setting periods.

Households that relied on livestock also reported decreased milk production, decreasing feed availability, and increased animal health issues related to heat stress and inadequate water supply. Land-poor households, families headed by women, and those reliant on a single source of income are the most susceptible populations (de Haan, 2016; Hashmi *et al*., 2021).

Community perceived impacts

Crop failure risk has significantly increased in the rain-fed areas of Attock, Rawalpindi, and Chakwal due to water constraint, especially during critical growing seasons when rainfall is either insufficient or delayed. Household food security is drastically decreased as agricultural productivity drops, making families more dependent on purchased food. Financial strain is increased by this increasing reliance, particularly for low-income farming households already dealing with erratic yields. Women, who have historically been in charge of gathering water for their homes and cattle, are now forced to travel greater distances in search of dependable water sources, which exacerbates these constraints. This exacerbates already-existing disparities in rural communities by increasing their physical strain and reducing their time for employment or educational pursuits. While poorer households frequently have unstable livelihoods, wealthier households with a variety of income sources are better equipped to withstand losses.

Adaptive strategies reported

As water scarcity worsens, communities in the rain-fed areas of Attock, Rawalpindi, and Chakwal are using a variety of coping mechanisms (Khan *et al.*, 2024). Farmers are switching to short-duration and drought-tolerant crops, changing the dates of sowing, and employing methods like mulching to conserve soil moisture. The use of small-scale water harvesting techniques, such as runoff collection, farm bunds, and village ponds, is growing. Diversification of livelihoods into small companies, poultry, and wage labour lessens reliance on climate-sensitive agricultural (Fahad and Wang, 2018). Plans for collective water sharing can aid in the equitable distribution of limited water. However, institutional, technical, and economical limitations prevent widespread implementation. It is advised to expand community-based water harvesting, strengthen extension services, and support climate-smart agriculture (Amir *et al.*, 2020; Elahi *et al.*, 2022).

Research findings

The study area's major climatic shocks, gender perceptions of climate change, gender perceptions of livelihood capital vulnerabilities, and gender perceptions and adaptation strategies are all covered in detail below.

Key trends of climate hazards

The Pothwar region's climate, especially in Attock, Jhelum, and Rawalpindi, is highly variable in terms of temperature and rainfall, which puts a lot of strain on rain-fed agriculture. "The rains no longer come when we need them for sowing or harvesting" was a common observation made by communities describing irregular and untimely rainfall. As one farmer put it, "When the temperature suddenly rises during flowering, our wheat don't develop properly." This unpredictability is exacerbated by rising temperatures during critical crop stages, constituting the issue of heat stress on crops. Respondents emphasized that "a single heavy downpour can wash away an entire field in minutes," citing flash floods caused by intense, brief rainfall events as a key concern. Gullies and soil erosion, which are prevalent in the Pothwar environment, also surfaced as a significant subject; participants observed that "every year the water cuts deeper into our land, reducing the area we can cultivate."

Additionally, livestock keepers in all three regions reported an increase in animal health issues brought on by the heat. "Our animals get sick quickly in the heat, and milk production drops sharply," said one reply. Low-income households who rely only on agriculture and animals are disproportionately affected by these combined risks because they lack the means to deal with frequent losses. "Poor families like ours struggle the most because we have no backup income when crops fail," said an Attock farmer. As participants summed up, "People with other earnings recover quickly, but farmers depending only on rain fed fields suffer for months." In contrast, wealthier households with multiple sources of income such as small businesses, government jobs, or remittances show greater resilience.

Concerns about growing long-term climate threats, such as frequent droughts and strong storms, were also expressed by communities. "Every year the weather becomes more extreme, and we fear the next season will be worse than the last" was a typical sentiment. When taken as a whole, these themes show how climate risks in the Pothwar region have turned into long-term stressors that are gradually eroding livelihood security, animal health, and agricultural output in Attock, Jhelum, and Rawalpindi.

Local respondents who had direct knowledge of the changing climate over the past ten years were

Table 2: *Trends in climate related hazards in Attock, Rawalpindi, and Chakwal (2014–2024).*

Hazard category	Indicators	Attock (2014 → 2024)	Rawalpindi (2014 → 2024)	Chakwal (2014 → 2024)
Rainfall changes	Decline in seasonal rainfall	Moderate → High	Moderate → Very High	High → Very High
	Erratic/ unpredictable rainfall	Moderate → High	High → Very High	High → Very High
Dryness and drought	Dry spell frequency	High → Very High	High → Very High	High → Very High
	Flash drought events	Low → Moderate	Moderate → High	Moderate → Very High
Temperature stress	Rise in summer temperatures	Moderate → High	Moderate → High	High → Very High
	Soil moisture loss	Moderate → High	High → Very High	High → Very High
Water availability	Groundwater table decline	Moderate → High	Moderate → Very High	High → Very High
	Reduced recharge from rainfall	Moderate → High	High → Very High	High → Very High
Land and ecosystem stress	Land / soil degradation	Moderate → High	Moderate → High	High → Very High
	Rangeland degradation	Moderate → High	Low → Moderate	High → Very High
	Crop water stress	High → Very High	High → Very High	High → Very High

Source: *Survey, 2025.*

Table 3: *Assessment of climate adaptation measures across districts (2014–2024).*

Adaptation category	Specific strategy	Attock (2014 → 2024)	Rawalpindi (2014 → 2024)	Chakwal (2014 → 2024)	Effectiveness / notes
Crop management	Drought tolerant / short duration crops	Moderate → High	Moderate → High	Moderate → High	Reduced crop failure risk
	Adjusting sowing dates	Low → Moderate	Low → Moderate	Low → Moderate	Aligns crops with rainfall patterns
Soil and water conservation	Mulching, contour farming	Moderate → High	Moderate → High	Moderate → High	Improves soil moisture retention
	Small scale water harvesting (ponds, bunds)	Low → High	Low → High	Low → High	Provides supplementary water during dry spells
Livelihood diversification	Wage labor, poultry, small businesses	Moderate → High	Moderate → High	Moderate → High	Reduces dependency on rain fed crops
Community measures	Collective water sharing arrangements	Low → Moderate	Low → Moderate	Low → Moderate	Ensures equitable water distribution
Technological support	Use of irrigation tools / rain gauges	Low → Moderate	Low → Moderate	Low → Moderate	Improves water use efficiency

Source: *Survey, 2025.*

Table 4: *Key findings, implications, and recommendations on water scarcity and climate hazards (Survey, 2025).*

Category	Key findings	Implications / Recommendations
Water scarcity and climate hazards	Increased dry spells, erratic rainfall, rising temperatures, groundwater depletion, soil and rangeland degradation	Threatens crop yields, livestock health, and household food security; urgent water management needed
Agricultural impacts	Reduced crop productivity (wheat, maize, pulses), increased pest and disease risks	Promote drought tolerant crops, adjust sowing dates, and implement soil water conservation measures
Livelihood vulnerabilities	Greater reliance on purchased food, income loss, gendered burdens	Support livelihood diversification and provide targeted assistance to vulnerable households
Community adaptation	Small scale water harvesting, collective water sharing, crop diversification, soil conservation	Scale up community based adaptation, strengthen local institutions, and enhance knowledge dissemination
Policy implications	Uneven adoption of adaptation strategies, limited technical support	Encourage climate smart agriculture policies, extension services, and investment in water infrastructure

Source: *Survey, 2025.*

consulted in order to establish the trends of water scarcity and climate-related risks in the rain-fed districts of Attock, Rawalpindi, and Chakwal. These patterns were confirmed by historical occurrences and local expertise. Each hazard's effects were evaluated on three levels: livestock, agricultural, and population. There have been reports of growing dry periods, decreasing rainfall, rising temperatures, and groundwater depletion in Attock. While Chakwal had increasing rainfall unpredictability, water shortages, temperature increases, and agricultural water stress, Rawalpindi saw unpredictable rainfall, extended dry spells, flash droughts, and soil moisture loss (Table 2).

According to the overall evaluation, between 2014 and 2024, soil degradation, high temperatures, and water scarcity all increased, resulting in serious socioeconomic and livelihood vulnerabilities. Over the past four to five years, there has been a noticeable increase in the severity of these risks, which primarily affect low-income and smallholder households. Crop and fruit harvests have been adversely affected by decreased soil moisture due to reduced rainfall and extended dry spells, while livestock health has been impacted by heat and water stress. Table 3 provides an overview of these changing risks and their effects throughout the study districts.

Between 2014 and 2024, communities in the rain-fed districts of Attock, Rawalpindi, and Chakwal developed a number of methods to deal with growing water scarcity and climate-related pressures. These tactics include using soil and water conservation methods including mulching, contour farming, and small-scale water collecting through ponds and farm bunds; switching to drought-tolerant and short-duration crop types; and modifying sowing dates to coincide with rainfall patterns. In order to lessen their reliance on rain-fed crops, households have also diversified their sources of income through small businesses, poultry, and wage labor. While some farmers have adopted simple irrigation equipment and rain gauges to increase water usage efficiency, collective water sharing agreements have been put in place at the community level to guarantee equitable access to limited water resources. Popularity of these strategies varies by district; crop management and water conservation have moderate to high uptake, while community measures and technological support have emerging popularity. Although there are still gaps, especially for smallholder and disadvantaged households, these tactics have improved resilience, decreased the probability of crop failure, and lessened some of the socioeconomic effects of water scarcity.

Conclusions

The evaluation of climate-related risks in Attock, Rawalpindi, and Chakwal from 2014 to 2024 shows that water scarcity, unpredictable rainfall, rising temperatures, soil degradation, and frequent drought occurrences have significantly increased. Agricultural production has been directly influenced by these environmental pressures, which have increased animal vulnerability, decreased crop yields, and increased pest and disease incidence. Income loss and a greater reliance on purchased food are two of the increasing livelihood issues faced by households that rely on rain-fed agriculture. Although adaptation strategies including drought-tolerant crops, water and soil conservation, and small-scale water collection have demonstrated some efficacy, their uptake is still unequal and insufficient to completely lessen the negative consequences of climate stress (Table 4).

Promoting climate-smart agricultural practices, such as using drought-tolerant and short-duration crops, modifying sowing dates to coincide with shifting rainfall patterns, and integrating pest and disease control, is crucial to increasing resilience. In order to preserve soil moisture and lessen degradation, rangelands should be protected and restored in addition to expanding soil and water conservation techniques including contour farming, mulching, and small-scale water harvesting. Diversification of livelihoods is essential, with assistance for alternative sources of income such poultry, small enterprises, and wage labour, with a focus on women and disadvantaged populations. To guarantee fair resource allocation and knowledge sharing, community-based adaptation techniques, such as collective water sharing agreements and capacity building programs, should be reinforced. Lastly, in order to develop long-term resilience against climate risks, strong institutional and policy support is needed, including investments in water infrastructure, increased extension services, and the adoption of climate wise agriculture policies.

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Novelty Statement

This study combines literature review and field data to assess water scarcity impacts on rain-fed agriculture using the Sustainable Livelihoods Framework. It evaluates adaptive strategies and highlights gaps in support, providing insights to enhance resilience in semi-arid regions.

Authors' Contribution

Asim Zubair: Conceptualization, literature review, data collection, analysis, and manuscript drafting.
Lingling Zhang: Supervision, methodology guidance, critical review, and manuscript editing.

Generative AI and AI-assisted technology statement
The authors declare that no Generative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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