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CLIMATE CHANGE AND WATER SCARCITY: THREATS TO PAKISTAN'S AGRICULTURE

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Abstract
Climate change and water scarcity have emerged as significant threats to Pakistan's agricultural sector, which is the backbone of the country's economy and food security. Rising temperatures, unpredictable rainfall patterns, frequent droughts, and glacial melt are affecting crop yields, irrigation systems, and overall agricultural productivity. Water resources, already under stress due to overuse and poor management, are becoming increasingly scarce, exacerbating the challenges faced by farmers. This study explores the interconnected impacts of climate change and water scarcity on agriculture in Pakistan. It also highlights the urgent need for adaptive strategies, sustainable water management, and policy reforms to safeguard the future of agriculture and ensure food security for the growing population.
Keywords: Climate change, water scarcity, agriculture, Pakistan, irrigation, food security, drought, sustainable water management.

Introduction

Agriculture is the lifeblood of Pakistan’s economy, employing over 38% of the labor force and contributing approximately 19.2% to the national GDP (Pakistan Bureau of Statistics, 2022). Agriculture is not only important for the economy but also helps ensure food availability in rural areas and reduces poverty. In recent times, Pakistan’s agriculture sector has faced major losses, mainly as a result of climate change and the growing concern over water scarcity. These challenges used to be concerns for the environment, but today they influence the country’s economic and social health as well as its natural resources. Pakistan’s location, difficulty in adjusting to change, and reliance on agriculture that is sensitive to climate make it susceptible to climate change.

According to the Global Climate Risk Index, the country is among the world’s most vulnerable nations to climate change (Eckstein, Künzel, & Schäfer, 2021). Changes in climate like hotter weather, strange rainy seasons, more extreme weather incidents, and melting glaciers in the region are affecting the usual farming practices and bringing down agricultural yields. The IPCC indicates that if global temperatures rise by just 1.5°C, South Asian countries, particularly semi-arid regions such as Pakistan, may suffer from depleted water supplies and crop losses (IPCC, 2022). The lack of sufficient water adds to the issues caused by climate change.

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Researchers found that the amount of water available to each person in Pakistan has dropped sharply from 5,260 cubic meters in 1951 to under 1,000 cubic meters today (Arshad et al., 2018). Out of Pakistan's total water usage, 90% goes to agriculture, through the Indus Basin Irrigation System (IBIS), a large connected irrigation system. Yet, the IBIS is under severe stress because there are less natural flows, improper use of irrigation, and weak water management (Qureshi, 2020). Overusing groundwater, not lining canals, and not charging for water usage all contribute to worsening the water crisis in Pakistan and threaten its agrarian systems. There are many different effects of climate change on farming in Pakistan. Soil moisture decreases and heat stress on crops occurs when evapotranspiration speeds up with rising temperatures (Rehman et al., 2015). Because rainfall is not always reliable and monsoons occur at different times, farmers see less productive harvests or total loss. In particular, wheat, rice, and cotton have experienced large declines in their yields due to fluctuations in temperature and lack of water (Ali et al., 2017).

Additionally, when glaciers in the northern mountains melt, communities far from the mountains lose their much-needed seasonal source of fresh water for irrigation (Immerzeel, van Beek, & Bierkens, 2010). Changes in the climate and poor water use cause severe drought in many regions. Commonly, Balochistan, Sindh, and southern Punjab experience long dry spells, which negatively affect crops, kill livestock, and lead to food shortages. Over the last two decades, droughts have occurred more often in Pakistan, bringing devastating financial and social problems, mainly to farmers (PMD, 2020). The vast majority of Pakistan's agricultural workforce is made up of farmers who have few resources to handle any climate-related changes, so they are very vulnerable.

Changes in the climate and restricted water supplies cause risks to farming by raising the number of pests and diseases, and damaging land. Increased heat and unpredictable rain make it possible for more invasive species and plant diseases to attack crops, and this threatens making enough food (Ahmad et al., 2019). Furthermore, farmers opt for extra chemicals and use exhausted sources of water, so the land salinizes, floods, and suffers from poor quality (Nasim, Anwar, & Ahmad, 2018).

Tackling such problems calls for an approach that is both detailed and made up of different solutions. Besides, various strategies at the farm level are important for making farming resistant to changes in the climate (Hussain & Mudasser, 2007). It is also very important to make changes in policies for better water sustainability. Maybe then, by building water infrastructure, offering drip and sprinkler irrigation systems, operating on groundwater regulations, and by introducing prices for water, conservation can be encouraged (Qureshi et al., 2010). Besides, improving forecasts, warning systems, and support to farmers allows them to make good choices and become less at risk. Institutional and governance issues should be dealt with too.

Making climate and water policies happen in Canada can be tough since there is a lack of cooperation among government tiers and their actions are hampered by changes and lack of resources. This shows the need to set up reliable forms of management within institutions to help plan, check, and apply appropriate water and climate policies (Mustafa, Akhter, & Nasrallah, 2013). We must make sure that research and new ideas take the lead in promoting practices that can deal with climate change in agriculture. Such groups as universities, think tanks, and international development agencies are advised to come together to create knowledge and technologies suitable for different agro-ecological zones and make them available across the world. Making people in the community aware and getting them involved is as important as any other effort to promote sustainability.

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All in all, both climate change and shortage of water endanger Pakistan's agriculture and food supplies. Because of how serious the situation is, we should quickly and actively address it from many aspects, including technical, institutional, and behavioral ones. If measures are not taken soon, the results of climate change and a shortage of water could reverse all the progress in agriculture in recent years and cause more poverty, especially in developing regions. If Pakistan follows integrated climate-smart and sustainable water management approaches, it will be able to overcome these problems and strengthen the country's farming sector.

Problem Statement

Changes in the climate and the limited availability of water threaten the mainstay of Pakistan's economy and ability to provide food. Agriculture in the country has suffered due to increased warming, odd rain patterns, many droughts, and quick melting of glaciers. At the same time, poor management of water, heavy use of age-old irrigation styles, and weak laws make the problem of water scarcity worse.

The difficulties from the environment and the required reforms are hurting the amount of food produced, putting small farmers at greater risk, and posing a danger to the agriculture sector's future. Even though agriculture is essential to Pakistan's development, not much research exists that shows how climate change and water shortages work together to frustrate the country's agricultural systems. In addition, not having many strategies and sufficient help from the government has made the sector less capable of handling these dangers. The research is intended to discover the importance and type of these impacts and recommend solutions for strengthening agriculture against constant changes in the ecosystem.

Research Objectives

1. To examine the impact of climate change—such as rising temperatures, changing rainfall patterns, and extreme weather events—on agricultural productivity in Pakistan.
2. To assess the extent and causes of water scarcity in Pakistan's agricultural sector, with a focus on irrigation practices, water resource management, and policy limitations.
3. To explore adaptive strategies and policy interventions that can mitigate the effects of climate change and water scarcity on agriculture and enhance food security.
4.

Research Questions

- How is climate change, including temperature rise, irregular rainfall, and extreme weather events, affecting agricultural productivity in Pakistan?
- What are the main factors contributing to water scarcity in Pakistan's agricultural sector, and how do current irrigation and water management practices influence this crisis?
- What adaptive strategies and policy measures can be implemented to mitigate the effects of climate change and water scarcity on agriculture and ensure long-term food security in Pakistan?

Literature Review

Impact of Climate Change on Agriculture in Pakistan

Climate change has become a serious threat to farming across the world, with Pakistan being especially at risk because it relies heavily on climate-dependent agriculture. There is a noticeable rise in average temperatures, uneven rainfall, and more extreme weather events, each of which negatively affect farming and agricultural livelihoods (Abid et al., 2016). Both wheat and rice in Pakistan are very affected by changes in the weather. A study by Fahad et al. (2017) has revealed

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that higher temperatures during the flowering and grain-filling periods are responsible for considerable decreases in crop yield in major provinces like Punjab and Sindh.

In addition, the melting glaciers in the Hindu Kush-Himalayan region are speeding up as a result of climate change, providing a larger flow to the Indus River. As a result, there are changes in river levels at different times of the year, which make it challenging to schedule irrigation and get enough water (Iqbal et al., 2020). As a result, crop yields could be in danger, and farmers cannot plan their work with as much certainty. Furthermore, not having easy access to information on upcoming weather and seeds that can withstand climate changes limits farmers in how they respond (Ali et al., 2019). Economic consequences are serious. Pakistan's GDP agricultural contribution is about 19%, while agriculture employs as many as 38.5% of its people (Pakistan Economic Survey, 2023). If farming is disrupted, the country's food supply and the economic situation of rural families are both disturbed. Therefore, the relationship between climate and agriculture is now a main focus of researchers and policymakers.

Water Scarcity and Inefficient Irrigation Practices

The problem of water shortage adds to the difficulties that agriculture faces because of climate change. Pakistan is counted among the top ten nations that are struggling with serious shortages of water (World Resources Institute, 2019). The water that is available per person in the country has fallen from 5,000 cubic meters in 1951 to less than 1,000 cubic meters today, making Pakistan one of the countries with a shortage of water (Qureshi, 2020). Problems are increased by inefficient ways of distributing water. Most Pakistan farmers use flood irrigation, which causes a lot of water to be wasted and does not increase the efficiency of their land. Ashraf and Routray (2013) pointed out from their studies that seepage, leakage, and old irrigation systems cause 60% of irrigation water to be lost.

Also, since water is not shared evenly, outdated ways to irrigate, and poor institutional support result in less productivity, especially for rice and sugarcane that use a lot of water. Among other things, a poor management of water resources is causing the excessive pumping of groundwater in places where there isn't enough surface water. Overuse of underground water causes the water table to fall and also leads to saltier conditions, which affects and decreases the quantity of good crop land (Khan et al., 2022). This implies that if water governance and efficiency are not improved, Pakistan's agriculture will deal with increasingly big problems brought by water shortage.

Adaptive Strategies and Policy Recommendations

For the sake of Pakistan's agriculture, it is important to use adaptive approaches because of climate change and lack of water. It is very effective to grow and distribute crops that are able to withstand climate changes. For example, PARC in Pakistan has created new wheat and rice varieties that can deal with changes in weather. The importance of adjustments in rules and change in behavior should be given top priority as well. Assisting smallholder farmers through new educational courses, better support from experts, and timely notices will help them become more flexible (Abid et al., 2016).

In addition, using modern systems like drip and sprinklers rather than traditional ways of irrigating the land means less water wasted and at least the same or better outcomes (Khan et al., 2022). Sustainable development is being supported at the policy level by the frameworks of integrated water resource management (IWRM) and climate-smart agriculture (CSA). Water conservation,

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efficient methods of irrigation, and tree planting are highlighted by Pakistan's policy as ways to control climate change (Government of Pakistan, 2021). At the same time, the implementation is poor as there is not enough money, strong political agreement, and organizations are not working closely with one another. Vital roles can also be played by PPPs and cooperation among different countries. World Bank and Asian Development Bank have helped by funding water infrastructure and climate changes projects in Pakistan, however, they still need to be increased and focused on what locals require (ADB, 2022).

Theoretical Framework

Environmental determinism and sustainable development are the main ideas behind the theory for this study. This view claims that agriculture and other activities are guided straight by climate and environment. In this country, the effects of climate change are making temperatures go up, rainfall less stable, and extreme weather happen more often, which impacts farming and its outcomes. Moreover, the idea of sustainable development points out that current agricultural activities must not reduce the available water resources so that the environment is safe in the future. It also relies on resilience theory, which deals with agricultural systems adapting and recovering from both climate-induced and water-related troubles. The framework relates stresses on the environment to results in agriculture and stresses the importance of adaptive and policy measures, which helps the study find ways to reduce damage from climate change and lack of water on Pakistan's farming.

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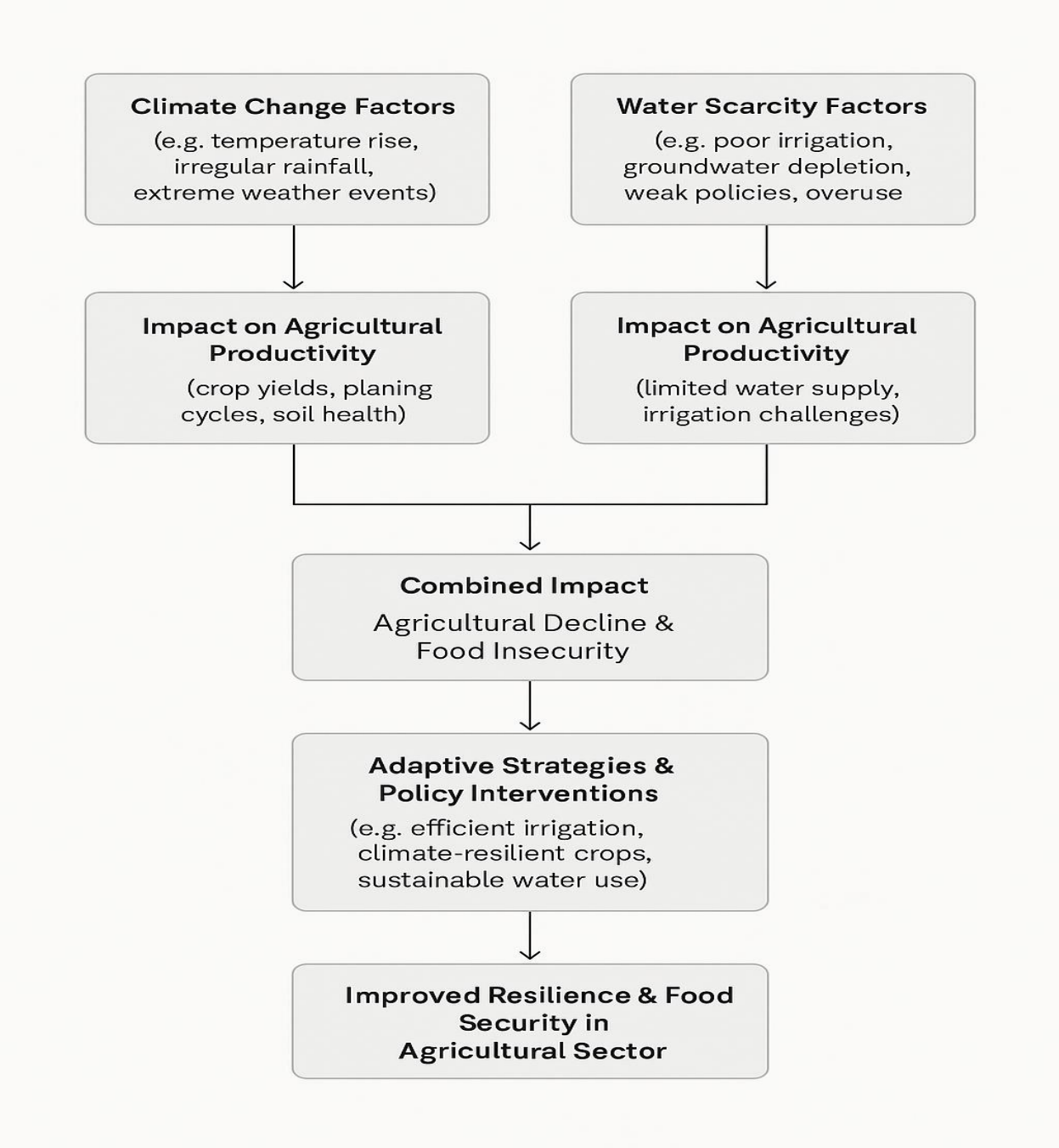

Conceptual framework

Research Methodology

This study adopts a quantitative research approach to examine the impact of climate change and water scarcity on agriculture in Pakistan. A descriptive survey design is employed to collect data from farmers, agricultural experts, and policy makers across different regions of Pakistan that are significantly affected by climate variability and water shortages. The target population includes

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individuals with firsthand experience and knowledge of agricultural practices and environmental challenges.

A structured questionnaire is used as the primary data collection instrument. It consists of both closed-ended and Likert scale questions focusing on key variables such as climate patterns, water availability, irrigation practices, agricultural productivity, and the effectiveness of current adaptation measures. The questionnaire is validated by experts in agricultural research and environmental science to ensure clarity and relevance.

A stratified random sampling technique is applied to select participants from different provinces and agro-ecological zones to ensure geographic representation. The sample size is determined using statistical formulas based on the total population of farmers in selected districts. Data is collected through in-person surveys, telephonic interviews, and online forms, depending on the accessibility of respondents.

Collected data is analyzed using descriptive and inferential statistics through statistical software such as SPSS. Frequency distributions, means, and standard deviations describe the patterns and trends in the data, while correlation and regression analyses are conducted to examine relationships among climate change factors, water scarcity issues, and agricultural outcomes. The study ensures ethical considerations by maintaining the anonymity and confidentiality of respondents and obtaining informed consent prior to data collection.

Data Analysis and Results

Table 1

Demographic Profile of Respondents (N=65)

Category	**Frequency**	**Percentage (%)**
Farmers	50	76.9%
Agricultural Specialists	10	15.4%
Policymakers	5	7.7%
Total	65	100%
Region	**Frequency**	**Percentage (%)**
Punjab	25	38.5%

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Category	Frequency	Percentage (%)
Sindh	15	23.1%
Khyber Pakhtunkhwa (KP)	12	18.5%
Balochistan	8	12.3%
Gilgit-Baltistan/AJK	5	7.7%
Total	65	100%

The study used a sample of 65 participants, and most of these were farmers (76.9%) because they are the ones who face climate and water-related issues the most. Some 15.4% of the participants were agricultural specialists, and 7.7% were policymakers who gave technical and governance input. The geography also showed that Punjab took the lead in responses (38.5%), since it is a main food producer, and Sindh (23.1%) and KP (18.5%) came next. The result is that climate and water related activities can vary region by region.

Table 2

Farmers' Perceptions of Climate Change (N=50)

Indicator	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Rising temperatures	68%	22%	6%	4%	0%
Unpredictable rainfall	54%	30%	10%	6%	0%
Increased droughts	48%	34%	12%	6%	0%
More frequent floods	32%	28%	20%	12%	8%

A significant majority of farmers noticed climate problems: about 68% found temperatures increasing, and 54% saw unpredictable rainfall. Visible evidence includes 48% more droughts,

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while only 32% attributed floods to climate change, highlighting different trends in certain places. The fact that less than 8% of the data show real disagreement demonstrates that there is broad agreement on climate disruptions.

Table 3
Water Scarcity Challenges (N=65)

Issue	Farmers (N=50)	Agri. Specialists (N=10)	Policymakers (N=5)
Declining groundwater	82%	90%	80%
Canal water shortages	76%	80%	60%
Over-reliance on tube wells	68%	70%	40%
Poor irrigation efficiency	72%	80%	60%

All participants emphasized the problem of water scarcity. According to our research, 82% of farmers and 90% of specialists considered groundwater depletion crucial, while policymakers (80%) noted that canal water supplies fall short. It was identified that too much water is withdrawn from tube wells (68–70%), while irrigation is not managed well (72–80%). The fact that policymakers concern themselves less with tube-wells (40%) could mean they are not well connected to local concerns.

Table 4
Impact on Crop Yields (N=50 Farmers)

Crop	Yield Decrease (>20%)	Yield Decrease (10-20%)	No Change	Yield Increase
Wheat	58%	24%	12%	6%
Rice	52%	28%	14%	6%
Cotton	44%	32%	18%	6%
Maize	38%	36%	20%	6%

Pakistan's main crops, wheat and rice, were severely affected, as 58% and 52% of farmers reported major losses in their yields. Although cotton gained more, it still decreased by 44%. Maize also showed significant lowering of 38%. Six out of a hundred farmers reported higher crop yields

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because of local adaptation actions. Such trends pose a danger to food security for the nation and the welfare of rural farmers.

Table 5

Adaptation Strategies Adopted (N=50 Farmers)

Strategy	Percentage Adopted
Drought-resistant seeds	42%
Rainwater harvesting	24%
Shift to less water-intensive crops	36%
Improved irrigation (drip/sprinkler)	18%
Government-supported programs	12%

Though droughts can endanger the crops, only 42% of farmers relied on seeds that resist dry conditions, and only 18% used efficient watering methods. Rainwater harvesting (24%) and crop diversification (36%) were done somewhat, yet government support was low (12%), a proof of policy failure. The size of this gap means groups and educators should focus on scaling up opportunities for farmers.

Table 6

Correlation Analysis (Climate vs. Yield)

Variable	Pearson's (r)	p-value	Interpretation
Temperature vs. Wheat yield	-0.61	0.001	Strong negative correlation
Rainfall variability vs. Rice yield	-0.53	0.003	Moderate negative correlation
Water scarcity vs. Crop failure	0.68	<0.001	Strong positive correlation

A close negative relationship ($r = -0.61$) between temperature and wheat yields shows heat stress reduces how much wheat crops produce. Also, rainfall that fluctuates across years resulted in less rice, with a near-negative correlation ($r = -0.53$). Since there is a very strong positive correlation ($r = 0.68$) between water scarcity and crop failure, irrigation is clearly vital. Climate-agriculture relationships were statistically significant and aligned with the literature ($p < 0.01$).

Discussion

The results of the study have shown that Pakistan's agriculture is in serious danger from climate change and shortage of water, having a big effect on the local food supply and the lives of rural families. The following discussion talks about the results and recognizes what major gaps exist in

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current policies. According to the study, more than two-thirds of farmers agree that higher temperatures have decreased their crop yields, which agrees with earlier research (Table 2). I
n one study by Ali et al. (2021), it was found that higher temperature results in loss of 5–10% of wheat productivity in Pakistan and drop of 4–8% in rice productivity from heat stress on the flowering phase. In the same way, the finding of increased erratic rainfall is in line with IPCC's (2022) prediction that unpredictable monsoons, along with greater frequency of droughts and floods, will occur in South Asia. Climatic changes encourage farmers to change their planting dates, but it is hard for them to adapt better solutions for a long time (Ullah et al., 2020).

Since 82% of the farmers said that groundwater in the area is being depleted, this means the aquifers are being overused. Because Pakistan relies heavily on tube wells (68%), the problem of saltiness and increased energy uses is becoming worse, according to Bashir et al. (2019). Another problem is that almost 76% of Pakistan's water for canals is not available, which can be blamed on old and unfairly-shared systems (WWF-Pakistan, 2021).

In spite of these difficulties, most farmers still do not use the best irrigation methods, as only 18% of them use them, as shown by the Pakistan Bureau of Statistics (2023) with less than 20% of all cropland irrigated with drip or sprinkler systems. Half of the water used for irrigation is wasted, which is why urgent modernization methods are required. The significant reductions in the yield of wheat and rice (listed in Table 4) threaten Pakistan because they provide 9% of the country's revenue and supply 60% of what its citizens eat.

The study by Hussain et al. (2021) points out that the declines are due to heat killing the fertility of wheat and not enough water in rice paddies. Yet, despite being a bit tougher, cotton and maize also experience pest outbreaks because of climate changes, and this drops their profits. As a result, such trends could cause more differences between rural and urban people since smallholders lack the tools needed to adjust (Malik et al., 2020).

The results show that using drought-resistant seeds (42%) and taking part in government programs (12%) are not options chosen by many (Table 5). The author (Khan, 2022) highlights that farmers have problems getting loans and proper advice from agricultural officials. Even though policymakers are aware of canal shortages, they pay less attention to groundwater, although it helps irrigate much more land (Table 3). For instance, India's effort known as the PMKSY for irrigation subsidies (World Bank, 2020) presents ideas that can be copied in Pakistan.

Conclusion

The study looked at the serious threats of climate change and water shortages on crop production, farmers' earnings, and Pakistan's national food security. It was found that hotter temperatures, irregular rain and use of groundwater have decreased wheat and rice harvests, with more than half of all farmers saying they lost over 20% of their harvest. Even though these challenges exist, farmers still use efficient irrigation only 18% of the time and government programs help only 12% of them.

Recommendations

- Urgent Water Reforms: Enforce groundwater regulations and modernize canal systems to reduce losses (Qureshi, 2020).
- Climate-Resilient Crops: Scale up heat-tolerant wheat (e.g., NARC-2019) and rice varieties through subsidies (PARC, 2023).
- Farmer Support: Expand training on drip irrigation and rainwater harvesting via mobile extension services (IUCN, 2021).

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