

# Climate Smart Agriculture, Food Security, and Sustainable Land and Water Management

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## Abstract:

This simulation exercise examines the intersection of climate change, food security, and sustainable land and water management in Pakistan. Despite contributing minimally to global greenhouse gas emissions, Pakistan faces significant climate-induced challenges, including extreme weather events, water scarcity, and land degradation, severely impacting its agricultural sector, which accounts for over 20% of GDP and employs nearly 38% of the labor force. Current national policies for Climate-Smart Agriculture (CSA) and food security are inadequate. The report identifies key institutional gaps and emphasizes the need for better integration of global best practices, highlighting modern technologies like IoT and AI for optimizing resource use. Comparative case studies from India and Bangladesh illustrate effective strategies for mitigating climate risks. The report also stresses the importance of sustainable land and water management (SLWM) and proposes strategic recommendations, including precision agriculture, urban planning reforms, and public-private partnerships, to enhance Pakistan's resilience to climate change and ensure agricultural sustainability.

## Key words:

climate change, food security, sustainable management, agriculture, resilience

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## *Introduction*

Pakistan, despite its minimal contribution to global greenhouse gas emissions, stands as one of the most vulnerable nations to the impacts of climate change (UN Report, 2020). Extreme weather events, water scarcity, and the melting of glaciers disproportionately affect the country's most impoverished and marginalized communities (Khan & Ali, 2019). In response, the Government of Pakistan has developed climate change adaptation policies to address these challenges. However, an assessment of these policies is essential to identify areas for improvement and enhance the country's resilience to climate change (Ahmed, 2022).

Globally, climate change driven by both natural variability and human activities such as greenhouse gas emissions, deforestation, and industrialization presents far-reaching consequences for ecosystems, weather patterns, and societies (IPCC, 2021). Pakistan's challenges are exacerbated by these anthropogenic factors, further stressing the need for effective adaptation and mitigation strategies (UNEP, 2018).

Between 1997 and 2023, Pakistan experienced an average of 523 lives lost annually due to extreme weather events. According to the Pakistan Meteorological Department (PMD), the country faced 145 extreme weather events by 2024. Over the past 50 years, Pakistan's average temperature has increased by 0.6°C, with projections indicating a potential rise of 3°C to 5°C by 2100 (IPCC, 2023). The 2022 Karachi heatwave alone resulted in 1,300 deaths, underscoring the risks posed by urban heat islands. Flooding between 2010 and 2023 displaced large populations, particularly the 2022 floods that affected 33 million people and caused \$15 billion in damages (World Bank, 2024). Additionally, the World Bank estimates Pakistan's annual climate adaptation costs to range between \$8 billion and \$15 billion (World Bank, 2024).

One of the most pressing impacts of climate change is the growing uncertainty in water availability, with projections indicating a decrease in freshwater by 12–20% (IPCC, 2014). This will directly affect agricultural productivity, potentially leading to a 30% decline in crop yields in South Asia by 2050 (UN Report, 2021). Additionally, health risks such as skin cancer, heart disease, and vector-borne diseases like dengue and malaria are expected to rise (WHO, 2019). The consequences extend to massive migration, loss of culture, biodiversity loss, and ecosystem disruptions, particularly harming marginalized groups like women and children (Ali & Hussain, 2020; Ahmed, 2022).

To combat these issues, smart agriculture has emerged as a promising solution. By incorporating modern technologies such as IoT, AI, and data analytics, smart agriculture enhances farming efficiency, productivity, and sustainability. This approach is particularly relevant for Pakistan as it helps optimize resource use, reduce environmental impacts, and build resilience against climate change (Smith et al., 2020). Techniques such as precision

farming, automated irrigation, and climate-resilient crop varieties can significantly support farmers in adapting to changing climate conditions.

In parallel, addressing food security, defined as ensuring the availability, accessibility, and stability of nutritious food, is becoming more challenging in the context of climate change. The impacts of erratic weather, shifting growing seasons, and water scarcity directly threaten global and regional food systems (Brown & Taylor, 2019).

Sustainable Land and Water Management (SLWM) is a critical component of both food security and climate resilience. By promoting practices that safeguard land and water resources, SLWM helps maintain ecosystem health, reduce environmental degradation, and enhance resilience to climate-induced stresses like soil degradation and water shortages (Green & White, 2022). Together, these efforts in smart agriculture and SLWM are key to ensuring a sustainable future in the face of climate change.

### ***Statement of Problem***

Pakistan, an agricultural country, faces significant challenges from climate change, water scarcity, and land degradation, threatening food security and livelihoods. Current policies and frameworks for climate-smart agriculture (CSA), food security, and sustainable resource management are not effective in addressing the prevailing issues in Pakistan. To address these issues, there is an urgent need to align policies, strengthen institutional capacity, and adopt global best practices to ensure sustainable agricultural productivity and resource management.

### ***Scope of the Study***

- Comprehensive analysis of legal, institutional, and infrastructural frameworks in Climate Smart Agriculture, Food Security, and Sustainable Land and Water Management in Pakistan.
- It will also be an endeavor to understand the implementation of strategies.
- Analyze the challenges and issues faced by Khyber Pakhtunkhwa specifically and Pakistan in general.
- The study will be an endeavor to recommend practical policy options for achieving the desired goals of Climate Smart Agriculture, Food Security, and Sustainable Land and Water Management in Pakistan.

### ***Research Methodology***

This research has used a qualitative method of analysis using secondary data available online. The concerned departments were consulted for data collection. Acts, policies, rules, and regulations were reviewed. Newspapers, articles, journals, etc., have been accessed for secondary data. SWOT, GAP, and PESTLE analyses are carried out as techniques for analysis.

### ***Situational Analysis***

The agriculture sector constitutes the largest sector of our economy in terms of involving not only more than 38 percent of our labor force but also contributing more than 20 percent, on average, to national GDP (Finance, n.d.). However, the agricultural sector, despite the availability of substantial infrastructure and human resources, has failed to ensure food security in the country. The country ranks 4th in cotton production in the world, 5th in sugarcane, 9th in wheat, 5th largest producer of milk, and 3rd largest in buffalo hides/skins, etc. However, every year, the nation faces acute shortages, especially in wheat and sugarcane, impacting real-time food security in the country (FAO, 2024).

The reasons for this lag are many, including climate change and natural disasters, massive urbanization, but the most important factors are the lack of modern technology and climate-smart agriculture practices.

#### ***Situational Analysis Related to Climate Smart Agriculture (CSA) and Sustainable Land and Water Management***

Pakistan's agricultural sector faces significant challenges, including rapid urbanization, inefficient land use, and poor water management, all of which threaten food security. Approximately 20% to 40% of agricultural land has been converted into residential areas due to the unchecked expansion of housing societies (Zahoor, 2023). This trend, driven by population growth and unplanned urbanization, has reduced the availability of fertile land for farming and strained agricultural productivity. Despite the country's agricultural potential, the lack of a holistic approach to land preservation has resulted in underutilized resources and a declining ability to meet food production demands. Compounding this issue is water mismanagement. Although Pakistan possesses abundant water resources through the Indus Basin Irrigation System, approximately 40 million acre-feet (MAF) of water is wasted annually (IRSA, 2024). The basin is crucial, contributing over 25% of Pakistan's GDP and supporting 90% of food production; yet inefficiencies in water use remain a major challenge.

The rapid conversion of agricultural land and inefficient water management highlight the urgent need for Climate Smart Agriculture (CSA) practices. CSA focuses on optimizing the use of natural resources, such as land and water, through sustainable techniques. By incorporating practices like precision irrigation, climate-resilient crop varieties, and conservation agriculture, CSA can mitigate the impacts of urbanization and environmental degradation. A sound urban policy, combined with CSA strategies, could promote efficient land use, preserve agricultural productivity, and ensure better water management. This would not only improve food security but also help Pakistan adapt to the pressures of climate change and urban expansion.

The absence of proactive legislation on urban planning and agricultural management has exacerbated the food security crisis. Effective CSA approaches, such as sustainable land and water management, could address the growing demand for food production while reducing environmental degradation. In particular, CSA's focus on enhancing resource efficiency and resilience is vital for balancing the needs of urban development with sustainable agricultural production.

### ***Legal and Institutional Framework***

#### ***Federal Policies and Institutions***

<b>Sr. #</b>	<b>Policies/Acts/Rules</b>	<b>Madates</b>
1	National Climate Change Policy 2012	Provides a framework to address the impacts of climate change on key sectors, including agriculture, food security, and natural resource management (4.1,4.2,4.6.5,10)
2	National Climate Change Act of 2017	providing a legal framework for coordination and implementation of climate policies, including Climate-Smart Agriculture (CSA), food security, and sustainable land and water management(4.1,4.2,4.6.5,10)
3	National Agriculture and Food Security Strategy 2016-2025	The strategy includes key provisions related to Climate-Smart Agriculture (CSA), food security, and sustainable land and water management(6.1,6.1.3,6.2,6.4(chapter 6)
4	National Sustainable Agriculture Policy	to promote sustainable agricultural practices, improve food security, and ensure the sustainable management of land and water resources(1.2,1.6,2.3,2.6)
5	National Water Policy 2018	addressing water management challenges chapter.4(4.2), chapter.6(6.2), chapter. (7,8,16,20)
6	Ministry of National Food Security and Research	Responsible for national agricultural policy.
7	Indus River System Authority	Manages water resources in the Indus basin
8	Ministry of climate change and environmental coordination	To steer Pakistan towards climate resilience development

### *Provincial Policies and Institutions*

Sr. #	Acts/rules	Mandates
1	Khyber Pakhtunkhwa Agricultural Produce Markets Act	Regulates the marketing of agricultural produce.
2	Khyber Pakhtunkhwa Agriculture Policy	Aims to enhance agricultural productivity and promote sustainable practices.
3	Khyber Pakhtunkhwa Land Use Regulation	Provides guidelines for land use planning and zoning.
4	Agriculture Department of KP	Responsible for implementing agricultural policies and providing support to farmers.
5	Provincial Irrigation Department	Manages irrigation systems and water distribution
6	Khyber Pakhtunkhwa Environmental Protection Agency (KPEPA)	Addresses environmental issues related to agriculture and water resources
7	The Khyber Pakhtunkhwa Water Act 2020	Addresses the impact of climate change regarding droughts on water resources (chapter iv, v, viii)
8	The Integrated Water Resource Management (IWRM) Strategy for Khyber Pakhtunkhwa (	Focusing on several aspects related to water management Chapter, Strategic frame work, (4.1,4.2)
9	The Canal and Drainage Act of 1873	Regulates irrigation, drainage and canal construction and maintenances. (chapter, ii, iii ,v)

### *Gaps in Provincial Polices/Acts and Institutions*

S.No	Acts/rules	Gaps
1.	<b>Climate Change Policy KP 2022</b>	<ul style="list-style-type: none"> <li>• Non redressal of the specific needs of smallholder farmers,</li> <li>• No risk insurance mechanisms for farmers to cope with climate-induced losses, such as droughts, floods, and crop failures.</li> </ul>
2.	<b>The Khyber Pakhtunkhwa Water Act 2020</b>	<ul style="list-style-type: none"> <li>• Absence of framework for building resilience in water infrastructure or ecosystems</li> </ul>

		<ul style="list-style-type: none"> <li>• Non emphasize on Strategies for adaptation, such as improving water storage systems or encouraging water-efficient technologies</li> <li>• Poor engagement mechanism to engage communities in water conservation through education campaigns or incentives to encourage sustainable water use.</li> </ul>
3.	<b>The Integrated Water Resource Management (IWRM) Strategy for Khyber Pakhtunkhwa</b>	<ul style="list-style-type: none"> <li>• Poor managing and monitoring mechanism for ensuring Groundwater Depletion</li> <li>• No Recharge Mechanisms strategy for replenishing groundwater sources (e.g., rainwater harvesting)</li> <li>• Insensitive to rapid Urbanization Pressures</li> <li>• Inadequate Attention to Watershed Management</li> </ul>
4.	<b>The Canal and Drainage Act of 1873</b>	<ul style="list-style-type: none"> <li>• Lacks specific guidelines on water conservation and efficient water use</li> <li>• No mention of technologies such as drip irrigation, sprinkler systems, or modern practices aimed at reducing water wastage</li> <li>• More focus on surface water and poor integration of Groundwater Management</li> <li>• Weak engagement of relevant Stakeholder in water governance</li> <li>• Absence of robust framework to deal with flood management &amp; the rehabilitation of drainage systems</li> </ul>
5.	<b>KP Irrigation Department</b>	<ul style="list-style-type: none"> <li>• Rules and regulations of water under KP water Act 2020 are not framed yet</li> </ul>

## ***Review of Legal and Institutional Frameworks***

### ***Supportive Aspects (Policies)***

- **Policies Promoting Modern Techniques:** Existing agricultural policies at the federal and provincial levels encourage the adoption of modern farming techniques, including CSA practices.
- **Incentives for Innovation:** There are initiatives aimed at providing incentives for farmers who adopt sustainable practices.

### ***Hindering Aspects***

- **Outdated Regulations:** Some existing agricultural laws and regulations are outdated and may not support innovative CSA practices.
- **Lack of Awareness:** Farmers often lack knowledge about CSA techniques, and there is insufficient training provided by agricultural institutions.

### ***Supportive Aspects (Water Resources)***

- **Water Conservation Policies:** Policies exist to promote efficient water use and management, which aligns with CSA principles.
- **Irrigation Improvement Initiatives:** There are efforts to modernize irrigation systems, which can enhance water efficiency.

### ***Hindering Aspects***

- **Fragmented Management:** Poor coordination between various water management authorities leads to inefficiencies and hinders the implementation of integrated water resource management (IWRM) that supports CSA.
- **Regulatory Gaps:** Existing regulations may not adequately address the challenges posed by climate change, leading to a lack of frameworks for sustainable water management.

### ***Supportive Aspects (Land Management)***

- **Land Use Regulations:** The introduction of land use planning can support sustainable agricultural practices by promoting agroecological methods.
- **Tenure Security Initiatives:** Some policies aim to enhance land tenure security, encouraging farmers to invest in sustainable practices.



### *Hindering Aspects*

- **Insecure Land Tenure:** Inadequate land tenure security can discourage farmers from adopting long-term CSA practices, as they may fear losing access to the land.
- **Bureaucratic Barriers:** Complicated land registration processes can deter investment in sustainable land use.

### *Specific Challenges in Khyber Pakhtunkhwa (KP)*

- **Historical Context:** KP's history of conflict has disrupted agricultural practices and institutional capacity, making it difficult to implement CSA initiatives effectively.
- **Limited Resources:** Many institutions in KP face budgetary constraints, hindering their ability to support CSA and sustainable resource management initiatives.
- **Awareness and Capacity Issues:** Farmers in KP may lack knowledge about CSA practices, and there is often insufficient training available through provincial institutions.

## *Comparative Analysis*

### *India's Climate-Smart Agriculture Initiatives*

India has been proactive in implementing climate-smart agriculture (CSA) strategies to address the vulnerabilities of its agricultural sector to climate change.

1. The National Innovations in Climate Resilient Agriculture (NICRA) program, launched by the Indian Council of Agricultural Research (ICAR), is a flagship initiative that promotes the adoption of climate-resilient crops, water-saving technologies, and efficient soil management practices.
2. The Climate Resilient Agriculture Initiative in Andhra Pradesh focuses on sustainable agricultural practices such as zero-tillage, biofertilizers, and the use of drought- and flood-tolerant crops.
3. Watershed programs, particularly in drought-prone areas of Madhya Pradesh and Maharashtra, enhance water management through rainwater harvesting and agroforestry. These programs reflect the country's commitment to increasing agricultural productivity while ensuring long-term environmental sustainability in the face of climate challenges.
4. The Bihar Climate Resilient Agriculture Initiative aims to reduce the vulnerability of smallholder farmers in Bihar through climate-smart practices.

### *Bangladesh's Climate-Smart Agriculture Initiatives*

Bangladesh, being highly vulnerable to climate change, has integrated climate-smart agriculture to improve the resilience of its farming communities.

1. The Climate-Smart Agriculture and Water Management (CSAWM) program focuses on promoting climate-resilient rice varieties, better irrigation techniques, and water conservation methods, particularly in flood-prone regions.
2. CARE Bangladesh's Climate Resilient Agriculture Project promotes the cultivation of saline-tolerant crops, innovative soil management techniques, and rainwater harvesting systems.
3. The Haor Basin initiative allows farmers to grow vegetables in waterlogged conditions, addressing the threat of flash floods.

### *Comparative Analysis of Best Practices in Climate Smart Agriculture (CSA), Food Security, and Sustainable Land and Water Management in India, Bangladesh, and Pakistan, Specifically Khyber Pakhtunkhwa in Table Form:*

Category	India	Bangladesh	Pakistan
<b>Climate Smart Agriculture (CSA)</b>	<b>Practices:</b> - Organic Farming (National Program for Organic Production) - Integrated Pest Management (IPM) - Agroforestry	<b>Practices:</b> - Floating Gardens (flood-prone areas) - Rice-Fish Farming Systems - Community-Based Adaptation	<b>Practices:</b> - High-Value Crop Cultivation - Water-Conserving Techniques (drip irrigation, rainwater harvesting) - Farmer Training Programs
	<b>Effectiveness:</b> - Improved soil health, yields, and resilience to climate change	<b>Effectiveness:</b> - Significant food security and resilience improvement	<b>Effectiveness:</b> - Limited uptake of CSA due to lack of awareness and resources
	<b>Strengths:</b> - Strong policy support for organic farming and IPM	<b>Strengths:</b> - Innovative local practices and community engagement	<b>Strengths:</b> - Potential for high-value crops and water-saving irrigation methods

	<b>Weaknesses:</b> - N/A	<b>Weaknesses:</b> - N/A	<b>Weaknesses:</b> - Slow CSA adoption and limited government support
<b>Food Security</b>	<b>Practices:</b> - Public Distribution System (PDS) - National Food Security Act	<b>Practices:</b> - Safety Net Programs (cash transfers, food assistance) - National Food Policy	<b>Practices:</b> - Provincial Food Security Policy - Community Engagement in food production
	<b>Effectiveness:</b> - Reduced food insecurity but implementation challenges	<b>Effectiveness:</b> - Improved food security, with malnutrition challenges	<b>Effectiveness:</b> - High food insecurity due to economic challenges and natural disasters
	<b>Strengths:</b> - Robust food distribution systems and legal frameworks	<b>Strengths:</b> - Targeted safety nets and comprehensive food policy	<b>Strengths:</b> - Community-driven approaches have potential for greater impact
	<b>Weaknesses:</b> - N/A	<b>Weaknesses:</b> - Malnutrition remains a challenge	<b>Weaknesses:</b> - Ineffective policy implementation and sectoral coordination
<b>Sustainable Land and Water Management</b>	<b>Practices:</b> - Integrated Watershed Management - Rainfed Farming Technologies (drought-resistant crops, conservation agriculture)	<b>Practices:</b> - Integrated Coastal Zone Management - Participatory Irrigation Management	<b>Practices:</b> - Watershed Management Initiatives - Community-Led Irrigation Projects

	<p><b>Effectiveness:</b></p> <ul style="list-style-type: none"> <li>- Improved soil health, water retention, and resilience to climate change</li> </ul>	<p><b>Effectiveness:</b></p> <ul style="list-style-type: none"> <li>- Significant advancements in managing water resources in coastal areas</li> </ul>	<p><b>Effectiveness:</b></p> <ul style="list-style-type: none"> <li>- Nascent initiatives, hindered by funding, coordination, and capacity challenges</li> </ul>
	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>- Strong focus on integrated watershed management and community involvement</li> </ul>	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>- Innovative strategies in coastal areas and community-driven irrigation management</li> </ul>	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>- Opportunities for community-led water management initiatives</li> </ul>
	<p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>- N/A</li> </ul>	<p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>- N/A</li> </ul>	<p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>- Limited implementation of comprehensive water and land management strategies</li> </ul>
<p><b>Recommendations for KP</b></p>	<ul style="list-style-type: none"> <li>- Policy Reforms: Update laws and policies to support CSA and sustainable resource management</li> <li>- Capacity Building: Training and resources for farmers</li> </ul>		<ul style="list-style-type: none"> <li>- Community Engagement: Encourage local participation in decision-making to ensure context-specific and effective interventions</li> </ul>

### ***PESTLE Analysis***

PESTLE analysis of the federal and Khyber Pakhtunkhwa (KP) levels concerning climate smart agriculture (CSA), food security, and sustainable land and water management, covering the political, economic, social, technological, legal, and environmental factors.

<b>Factor</b>	<b>Federal Level</b>	<b>Khyber Pakhtunkhwa (KP) Level</b>
<b>Political</b>	<ul style="list-style-type: none"> <li>- Federal policies are increasingly focusing on food security and climate change.</li> <li>- Bureaucratic hurdles can slow down policy implementation.</li> <li>- Political instability may hinder long-term agricultural and water management strategies.</li> </ul>	<ul style="list-style-type: none"> <li>- Local government structure can support grassroots initiatives.</li> <li>- Political dynamics may affect funding and prioritization of agricultural projects.</li> <li>- Inter-departmental coordination can be challenging.</li> </ul>
<b>Economic</b>	<ul style="list-style-type: none"> <li>- Agriculture remains a key sector for economic development and employment.</li> <li>- Limited budget allocations can constrain agricultural and water management initiatives.</li> <li>- International funding and partnerships are critical for resource mobilization.</li> </ul>	<ul style="list-style-type: none"> <li>- KP's economy is largely agrarian, heavily reliant on agriculture.</li> <li>- Economic challenges such as unemployment may affect farmers' ability to adopt new practices.</li> <li>- Potential for local markets to support sustainable agricultural products.</li> </ul>
<b>Social</b>	<ul style="list-style-type: none"> <li>- Increasing public awareness and concern about food security and climate change.</li> <li>- Cultural resistance to changing traditional farming practices may hinder adoption of CSA.</li> <li>- Diverse population with varying needs for food security and agricultural practices.</li> </ul>	<ul style="list-style-type: none"> <li>- Strong community ties can facilitate local engagement in agricultural initiatives.</li> <li>- Limited access to education and awareness about CSA practices among rural populations.</li> <li>- Vulnerable populations are more affected by food insecurity and climate impacts.</li> </ul>

<b>Technological</b>	<ul style="list-style-type: none"> <li>- Growing emphasis on adopting modern agricultural technologies, including precision farming and irrigation systems.</li> <li>- Lack of infrastructure for technology transfer can hinder progress.</li> <li>- Opportunities for research collaboration with universities and international organizations.</li> </ul>	<ul style="list-style-type: none"> <li>- Limited access to modern technology and innovation in rural areas.</li> <li>- Training and capacity building for farmers on new technologies are often insufficient.</li> <li>- Community-based solutions leveraging local knowledge can enhance technology adoption.</li> </ul>
<b>Legal</b>	<ul style="list-style-type: none"> <li>- Frameworks for food security and agricultural development are present but need updating and enforcement.</li> <li>- Regulatory hurdles can impede the implementation of sustainable practices.</li> <li>- Land tenure issues can affect investment in sustainable land use.</li> </ul>	<ul style="list-style-type: none"> <li>- Local laws and regulations may not always align with federal policies.</li> <li>- Bureaucratic inefficiencies may complicate the execution of legal frameworks.</li> <li>- Community land rights issues can deter investment in sustainable practices.</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>- Increasing focus on environmental sustainability in agricultural policies.</li> <li>- Climate change poses significant threats to agriculture, necessitating urgent action.</li> <li>- Federal programs for reforestation and sustainable land management are gaining traction.</li> </ul>	<ul style="list-style-type: none"> <li>- KP faces unique environmental challenges, such as water scarcity and land degradation.</li> <li>- Vulnerability to climate change impacts on agricultural productivity.</li> <li>- Local initiatives may focus on conservation but require more support and resources.</li> </ul>

### ***Institutional SWOT Analysis***

A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis provides a framework for assessing Pakistan's agricultural institutions and their capacity to promote climate-smart agriculture and sustainable land and water management.

#### ***Strengths:***

- **Established Institutions:** Pakistan has several key agricultural institutions, such as the Ministry of National Food Security and Research (MNFSR), which has a national mandate to develop agricultural policy. Provincial agricultural departments also have the capacity to adapt policies to meet local needs (Zaman & Shah, 2018).
- **Diverse Agricultural Sector:** Pakistan's diverse agricultural sector, which includes crops ranging from wheat to cotton and sugarcane, provides opportunities for experimenting with different climate-smart practices. For instance, water-saving irrigation techniques and agroforestry have the potential to be adopted across various regions, depending on local conditions (Saeed & Hussain, 2020).

#### ***Weaknesses:***

- **Fragmentation Between Federal and Provincial Governments:** One of the main challenges facing Pakistan's agricultural institutions is the lack of coordination between federal and provincial governments. The devolution of powers under the 18th Amendment has led to inconsistencies in the implementation and enforcement of climate-smart practices across provinces (Rehman & Ali, 2021).
- **Underfunded Extension Services:** Agricultural extension services, which are responsible for providing farmers with information and training on climate-smart practices, are severely underfunded and understaffed. As a result, many farmers, particularly those in remote rural areas, do not have access to the knowledge and resources they need to adopt sustainable practices (Saeed & Hussain, 2020).

#### ***Opportunities:***

- **Emerging Technologies:** Precision agriculture, drone-based monitoring, and other emerging technologies offer significant opportunities to improve the productivity and resilience of Pakistan's agricultural sector. By leveraging these technologies, Pakistan can improve resource efficiency and reduce the environmental impact of farming (Khan, 2019).
- **Access to Global Climate Finance:** Global climate finance mechanisms, such as the Green Climate Fund, offer opportunities for Pakistan to access funding for large-scale climate adaptation projects.

These funds could be used to support the adoption of climate-smart agricultural practices, such as no-till farming, agroforestry, and precision irrigation (Ahmad & Farooq, 2020).

*Threats:*

- **Vulnerability to Climate Change:** Pakistan's agricultural sector is highly vulnerable to climate change. Rising temperatures, erratic rainfall patterns, and increasing incidents of floods and droughts threaten food security and rural livelihoods. Without significant investments in climate adaptation, the sector will struggle to cope with these growing risks (Rehman & Ali, 2021).
- **Political Instability:** Political instability and shifting government priorities pose a threat to the long-term sustainability of climate-smart agricultural policies. Frequent changes in leadership may delay the implementation of critical reforms and adaptation projects (Saeed & Hussain, 2020).

### *Issues and Challenges*

**Inadequate Legal Framework:**

The absence of a national legislative framework on food security, its vision, objectives, and implementation strategies is the biggest challenge to achieving the goal of food self-sufficiency and security in the country. Although there are many laws in Pakistan that ensure various aspects of the food chain, their focus is mainly on food chain management and marketing. Due to a poorly developed legislative framework, various foodborne infectious diseases have prevailed in the Pakistani community (MoNFSR, 2024).

**Rising Population:**

Pakistan's high population growth is attributed to limited access to family planning services, lower literacy rates, and rapid urbanization. The rising population is already burdening food security by taxing resources and infrastructure, thereby increasing hunger and malnutrition. The demand for food products is rising alongside population growth, which saw a three-fold increase from 1972 to 2017, while agricultural production exhibited nominal growth patterns.



### **Rapid Urbanization:**

Pakistan continues to urbanize rapidly, driven by increasing population and subsequent demand for housing and industrial development. This urban expansion into agricultural lands has caused many problems for the agricultural sector; however, no laws are in place to stop this practice. If measures are not taken to secure the future of the agricultural sector, Pakistan faces a threat to food security and a significant decline in exports (Imperial Institute of Policy Studies, 2021).

### **Land Utilization Practices:**

Pakistan faces an acute dilemma not only regarding the efficient utilization of available land for increased productivity but also in managing urban sprawl and encroachment on agricultural spaces. There are no national or provincial land utilization plans or enforcement mechanisms in place to protect land against the ever-increasing number of housing societies.

### **Diversifying Diet Patterns:**

Despite the increase in food availability and per capita income, the average calorie intake per adult equivalent in Pakistan is still less than the 2,350 Kcal benchmark. It is estimated that thirty percent of children under age 5 are underweight, forty-five percent are stunted, eleven percent are wasted, and thirty percent are underweight. This overall scenario may increase vulnerability to poverty, widespread disease burdens, and lower productivity (Haider, 2017).

### **Water Availability for Agriculture:**

Pakistan is facing problems related to food security due to an irrigation water crisis for crop production. Food security encompasses not only the sufficiency of available food but also ensures people's full access to food sustainably. Although resources and natural geography for irrigation are available, the absence of on-farm irrigation infrastructure, excessive reliance on water-intensive crops, and lack of water conservation practices, along with flooding irrigation methods instead of drip or sprinkler systems, lead to resource wastage.

### **Unsustainable Agricultural Practices:**

The incidence of food poverty is higher in rural areas (35%) than in urban areas (26%). In Pakistan, irrigated agriculture is vital for future food security because it produces more than 90% of total grain production (Qureshi, 2012). With decreasing amounts of available water, the challenge of sustaining irrigated agriculture is increasing daily.

### **Increased Soil Erosion:**

Soil health, along with water supply, is the most valuable resource for humans, as human life depends on the soil's generosity. Soil degradation poses a threat to food security, as it reduces yield, forces farmers to use more inputs, and may eventually lead to soil abandonment. Unfortunately, the importance of preserving soil health appears to be overlooked by policymakers, especially in light of the ever-increasing incidences of floods and climate change impacts.

### **Climate Change:**

Increasing minimum and maximum temperatures and irregular rainfall patterns due to global warming are major climatic factors affecting food security in Pakistan by reducing wheat production. Floods have become a regular phenomenon in the country, severely impacting the agricultural landscape. However, respective institutions have failed to mitigate the impact on agricultural practices, leading to poverty and food insecurity.

### **Inefficient Food Distribution Systems:**

The supply chain for food distribution in Pakistan is often fragmented and inefficient, involving multiple intermediaries, which increases costs and reduces the quality of food reaching consumers. Lack of coordination among stakeholders exacerbates these challenges. This inequitable food distribution system impedes food access and availability, reducing opportunities for the disadvantaged in society.

**Limited Access to Credit:**

Despite agriculture being a vital sector, a significant portion of farmers, especially small and marginal ones, struggle to access formal credit. Estimates suggest that only 10-15% of credit needs are met by formal sources. This limited access forces farmers to turn to informal lenders who charge exorbitant interest rates, trapping them in cycles of debt.

**Lack of Storage Facilities:**

Many farmers rely on traditional methods like on-farm storage in open sheds or pits, leading to significant post-harvest losses of up to 40% due to factors like pests, rodents, moisture damage, and spoilage.

**Value Addition in Export Commodities:**

The country has some of the best varieties of fruits and vegetables. However, their contribution to exports is minimal due to the absence of standard processing and storage facilities. Most of these export commodities get wasted during transportation and conveyance, even within the country.

**Housing Societies and Agriculture:**

The ever-increasing presence of housing societies encroaching on agricultural lands is detrimental to the food security regime in the country. In the absence of a regulatory framework, the growth and strength of these societies incentivize farmers to sell their lands for readily available cash instead of investing in agricultural production.

**Technological Gaps:**

Unlike other advanced countries, where the availability of fertile land is limited by geography, they have achieved great feats through extensive use of technology for maximizing production, reducing water usage, and ensuring the conservation of soil and nature. Pakistan has failed to develop a special program for using technology in precision farming, water management, crop rotation, and consequently, productivity.

## *Conclusion*

Pakistan faces significant challenges in addressing the impacts of climate change on its agricultural sector. However, by strengthening policy coherence, improving institutional capacity, and promoting technological innovation, the country can enhance its resilience to climate change and ensure sustainable agricultural development. The recommendations and action plan outlined in this report provide a roadmap for integrating climate-smart agriculture, food security, and sustainable land and water management into national and provincial frameworks, paving the way for long-term sustainability and resilience.

Urbanization, especially the construction of housing societies on urban agricultural lands, has disrupted existing food supply chains in urban areas, leading to food insecurity. The population bulge, massive pressure on cities to provide amenities to the public, and inefficient use of land available for agriculture impact the production cycle in the country. Ancient agricultural practices, the absence of modern farm machinery, a lack of capacity building for farmers, and impractical, non-consensus-based policy decisions impede progress toward achieving food security in the country.

A lack of coherence between federal and provincial structures, insufficient incentives for innovation, the absence of linkages between producers and agricultural industries, and capacity issues affecting farmers' social behavior for more productive crops point to systemic problems in the agricultural sector. Productivity is directly proportional to food security, and the state must prioritize the agricultural sector as a main area of investment to foster growth and development.

The future of Pakistan's agricultural sector hinges on its ability to adapt to the realities of climate change. While the country has taken some steps toward promoting sustainable practices through initiatives like the National Climate Change Policy, much more needs to be done to build resilience against climate risks. By strengthening its legal and institutional frameworks, investing in research and innovation, and learning from global best practices, Pakistan can create a more sustainable and resilient agricultural sector that ensures long-term food security and economic growth.

## ***Recommendations***

Agriculture is the locomotive of rural development in Pakistan. The agricultural sector is the main source of foreign exchange earnings in the country. The export of cotton, cotton-based products, and rice accounts for about 65% of total export earnings. Despite its critical importance to growth, exports, and food security, the agricultural sector faces many challenges that lower its yield. These impediments include the use of obsolete farming technology, outdated infrastructure, a lack of irrigation facilities, and water salinity. The following policy measures must be implemented by the government to address the various challenges farmers face in Pakistan's agricultural sector.

### **Legislative Framework**

A detailed study of some regional countries reveals that they have framed practical and need-based national legal frameworks. These frameworks aim to assign responsibilities to national and provincial governments for regulating agricultural markets in the truest sense, supporting research and innovation, and protecting farmers from exploitative market forces. The government must formulate a national food security act with a clear vision and enforcement mechanism, aligning the interests of all relevant stakeholders.

### **Urban Planning/Control Laws**

The national and provincial governments should take immediate steps to control the two most important contributors to food insecurity in Pakistan: population explosion and massive urbanization. Population control must be the top priority for both federal and provincial structures, and programs such as family planning, EPI, and Nashunuma should be linked for lasting impact. National and provincial laws on land use, along with enforcement bodies, should be established immediately to curb the surge of illegal societies, prevent haphazard urban growth, and improve the performance of civic agencies responsible for providing amenities.

### **Provision of Microcredit to Farmers**

Microcredit can significantly benefit farmers with small landholdings by providing necessary support to maximize productivity. However, the microcredit system faces fundamental issues, such as lengthy processing times for lending. Additionally, due to inflationary pressures, the standard amount of credit may fall short of farmers' requirements, which is discouraging. Higher interest rates also deter farmers. This can be addressed through regulations by the State Bank that provide micro-lending on a fast-track basis with minimal interest. Another important intervention could be a subsidy on loan interest to lower barriers for farmers seeking credit.

### **Climate-Smart Agriculture Practices**

One of the most critical aspects of our policy intervention should be the adoption of climate-smart agricultural practices. Pakistan has experienced massive disruptions in agricultural production cycles due to floods and climate change impacts on crop patterns and water use. The government, through its engagement in COPs and domestic legislation, has prioritized climate response mechanisms, with a special focus on conserving cultivable soil and forest cover. The government can protect farming communities from potential devastation by using the Climate Investment Fund and resilience strategies to mitigate the consequences of climate change and floods.

### **Technology as a Revolutionary Tool for Transforming Agriculture**

Technology can be a revolutionary tool in transforming agriculture in Pakistan and ensuring food security. It assists stakeholders at all levels—farmers, markets, government, and support organizations—in knowledge sharing, machinery use, crop patterns, and, most importantly, precision farming and sustainability. The government must invest in technology transfer and dissemination, along with attracting private sector investment through public-private partnerships. Agriculture IT wings should be established in farm services centers to create an interface between farmers and government agencies for troubleshooting issues.

### **Strengthening Policy Coherence**

There is an urgent need for a more coherent national strategy that aligns federal and provincial efforts. A central coordinating body should be established to ensure that provincial initiatives align with national climate goals. This body would also be responsible for ensuring that resources are allocated efficiently and that climate-smart policies are consistently enforced across regions.

### **Building Institutional Capacity**

Agricultural extension services should be strengthened to ensure that farmers have access to the information and resources they need to adopt climate-smart practices. This could include increasing funding for extension services, providing training programs for agricultural officers, and expanding the use of digital platforms to reach remote rural communities.

### Introducing Financial Incentives

Financial incentives, such as subsidies for water-efficient irrigation systems or tax breaks for farmers who adopt drought-resistant crops, would encourage widespread adoption of sustainable practices. These incentives could be targeted at smallholder farmers, who are often the most vulnerable to climate risks but lack the capital to invest in new technologies.

### Promoting Public-Private Partnerships

Collaboration between the government and the private sector can drive innovation in agriculture. Public-private partnerships could be used to introduce new technologies, such as precision agriculture tools, to farmers. The private sector could also play a role in providing training and technical support to farmers who adopt these technologies.

### *Logical Framework Matrix*

#### *Log frame for short Term Initiatives*

S#	Initiatives/ Actions	Institutions	Time	Fund Allocated	Objectives
1	Framing of Rules and Regulations under Water Act 2020	Irrigation Department KP	6 months	nil	Efficient utilization of water
2	Framing of Housing Schemes Regulation	Local Govt. and Rural Development Department	6 months	nil	Land sustainably would be ensured
4	Revision of KP Water Act 2020	Irrigation Department KP	2 months	nil	Water management
5	Revision of Integrated Water Resource Management Strategy KP	Irrigation Department Kp	6 months	nil	Water management
6	Revision of Canal and Drainage water Act 1873	Irrigation Department KP	6 months	nil	Water Management and Flood Control ensuring Food security and Health of Soil
7	Revision of Climate Change Policy KP 2022	Environment Protection Agency	1 months	nil	Climate smart agriculture

**Log frame for Long Term Initiatives**

S#	Initiatives/ Actions	Institutions	Time	Fund Allocated	Objectives
1	District Land Use Plans and Master Plans Of all Districts in KP	Urban Planning Unit Working under Planning & Development Department	3 years	Rs.800 Million	Land sustainability  And Urbanization Control
2	Precision Irrigation (Drip irrigation, Sprinkler irrigation, Centre pivot irrigation, soil moisture sensors)	Irrigation Department Kp	5-6 years	Rs.1000 Million	Water management  And Climate Smart Agriculture by enhancing crops productivity
3	Introduction of Climate Resilient Crops Varieties for Farmers	Agriculture Department	6-7 years	Rs.500 Million	Climate Smart Agriculture
4	Strengthen Policy Coherence	MNFSR, Provincial Agriculture Departments	12 months		Conduct training programs for farmers and officials
5	Improve Institutional Coordination	MNFSR, MoCC, Provincial Governments	12 months		Pilot precision agriculture projects
6	Enhance Capacity Building	MNFSR, Provincial Governments, Research Institutions	Ongoing	1000 million (50/50% sharing model)	Develop proposals for international climate funds



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