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Assessing the Impact of Climate Change on Food Security in Pakistan: Challenges and Solutions

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Abstract: Climate change presents a profound threat to global food security, with its impacts felt acutely in Pakistan—one of the most climate-vulnerable nations in the world. As a country where agriculture remains the backbone of the economy, providing livelihoods for a significant portion of the population, the consequences of climate change are severe. This paper delves into the intricate relationship between climate change and food insecurity in Pakistan, where rising temperatures, erratic rainfall patterns, and an increase in extreme weather events have compounded the already fragile agricultural system. The research explores how climate-induced factors, such as droughts, floods, and heatwaves, intensify food insecurity, particularly in rural areas reliant on agricultural production.

The paper focuses on three key dimensions: agricultural water management, the impacts of climate-related disasters on crops and livestock, and the implementation of climate-smart agricultural practices. Firstly, the study investigates the water issues that plague Pakistan's agricultural sector, including inefficient irrigation systems and depleting groundwater resources. Secondly, it examines the economic and social losses caused by repeated disasters, such as floods and droughts, which devastate crops and livestock, leaving millions at risk of hunger. Lastly, it highlights the role of climate-smart agriculture in mitigating these challenges by promoting practices that increase resilience and productivity under changing climate conditions.

By synthesizing insights from reports, empirical data, and case studies from international organizations, government agencies, and academic research, the paper provides a comprehensive analysis of the multifaceted impacts of climate change on food security in Pakistan. The findings underscore the critical need for improved water management systems, investment in climate-resilient agricultural infrastructure, and the promotion of sustainable farming practices to ensure long-term food security in the face of climate adversity.

Keywords: Climate Change, Food Security, Agriculture, Water Management, Climate-Smart Agriculture

1. Introduction

Climate change represents one of the most pressing global challenges which is fundamentally altering weather patterns and increasing the frequency and severity of extreme weather events [1]. These changes pose significant threats to food security, which is essential for human well-being and socio-economic stability. As a country where agriculture is deeply intertwined with both the economy and societal fabric, Pakistan faces profound vulnerabilities to the impacts of climate change.

These changes disrupt global food security through several interconnected pathways:

1. **Altered Crop Yields**: Changes in temperature and precipitation significantly affect growing seasons and crop productivity. While higher temperatures can accelerate the maturation of some crops, they often lead to reduced yields and lower nutritional quality. Crops such as wheat, rice, and maize, which are staples in many diets, are particularly vulnerable to these changes, affecting global food supply chains [2].
2. **Increased Pest and Disease Incidence**: Warmer temperatures and changing weather patterns expand the range and prevalence of pests and diseases that impact crops and livestock. This not only reduces the quality and quantity of agricultural outputs but also increases the costs of pest management for farmers [3].
3. **Water Scarcity**: Altered precipitation patterns contribute to droughts and reduced water availability, which are critical issues for agriculture, particularly in water-stressed regions. With agriculture being the largest consumer of freshwater globally, the reduced availability of water for irrigation poses a direct threat to food production [4].

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4. **Climate-related Disasters**: The increased frequency and intensity of climate-related disasters such as floods, droughts, and storms disrupt agricultural systems, causing losses in crops and livestock. These disasters have long-term implications, including soil degradation, loss of arable land, and displacement of farming communities [5].

These impacts have the potential to destabilize food systems, drive up food prices, and exacerbate hunger and malnutrition, especially in vulnerable regions like South Asia, sub-Saharan Africa, and small island developing states.

1.1. Pakistan's Agricultural Economy

Agriculture is the backbone of Pakistan's economy, contributing approximately 24% to the Gross Domestic Product (GDP) and employing nearly 50% of the labour force [6]. This heavy reliance on agriculture makes Pakistan particularly vulnerable to climate change impacts. Key aspects of Pakistan's agricultural landscape include:

1. **Dependence on the Indus River System**: The Indus River system irrigates about 80% of Pakistan's cultivated land and is primarily fed by glacial melt from the Himalayas [7]. However, these glaciers are increasingly threatened by rising temperatures, which could lead to altered water flow patterns and impact water availability for agriculture.
2. **Crops and Livestock**: Pakistan's agriculture revolves around major crops such as wheat, rice, sugarcane, cotton, and maize, while livestock, including cattle, sheep, and goats, are crucial to rural livelihoods [8]. These sectors are highly sensitive to climatic changes, which can directly affect productivity and economic stability.
3. **Reliance on Water-Intensive Crops**: A significant portion of Pakistan's agricultural output comes from water-intensive crops such as wheat, rice, and sugarcane [9]. In a country already facing water scarcity, the cultivation of these crops puts additional strain on water resources.
4. **Low Productivity**: Pakistan's agricultural sector is characterized by lower yields compared to regional and global averages [10]. This low productivity, exacerbated by climate change and frequent natural disasters, has resulted in Pakistan becoming a net food importer, thereby increasing its vulnerability to global market fluctuations.

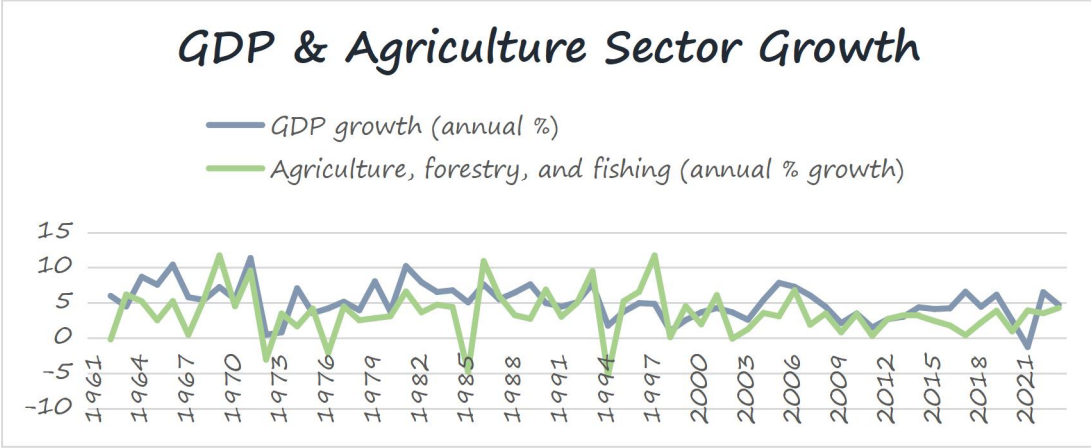

Figure 1: Correlation between GDP growth and Agriculture growth [11].

1.2. The Impacts of Climate Change on Food Security in Pakistan

Pakistan faces a multitude of climate-related challenges that exacerbate food insecurity:

1. **Glacial Melt and Water Availability**: The melting of glaciers due to rising temperatures has led to unpredictable water flows in the Indus River, affecting irrigation and reducing crop yields [12]. The erratic water supply complicates the planning and management of agricultural resources, impacting food production.
2. **Erratic Monsoon Patterns**: Irregular monsoon rainfall contributes to both floods and droughts, which can destroy crops, damage agricultural infrastructure, and cause water shortages [13]. These disruptions reduce agricultural productivity and affect the livelihoods of millions of farmers.
3. **Natural Disasters**: Repeated natural disasters, including floods and droughts, have caused extensive damage to crops, livestock, and agricultural infrastructure. The 2022 floods, for instance, affected around 33 million people and led to significant losses in agricultural production, compounding food insecurity [14].

1.3. Food Insecurity in Pakistan

Food insecurity in Pakistan is characterized by inconsistent access to sufficient and nutritious food, driven by various socio-economic and environmental factors:

1. **Poverty**: A substantial portion of the population lives in poverty, making it difficult for many households to afford adequate food. Approximately 20.5% of Pakistan's population is undernourished, with high rates of stunted growth among children, reflecting chronic food insecurity [15].

2. **Nutritional Quality**: Food insecurity in Pakistan also encompasses the quality of food available. Poor agricultural practices, food adulteration, and limited access to diverse diets contribute to malnutrition, affecting overall health and productivity.

1.4. Research Question

The research question explores how climate change affects food security in Pakistan and examines how improved water management and climate-smart agriculture (CSA) can mitigate these impacts. The study focuses on agricultural water issues, crop and livestock losses, and CSA, aiming to provide evidence-based recommendations for enhancing food security.

1.5. Objectives of the Paper

This paper aims to analyse the complex interplay between climate change and food insecurity in Pakistan by:

- Examining agricultural water issues and management challenges.
- Assessing losses to crops and livestock from repeated natural disasters.
- Evaluating the adoption and effectiveness of CSA practices.

2. Impact of Climate Change on Agriculture in Pakistan

Pakistan's agriculture sector is a cornerstone of the country's economy. However, it is also one of the most vulnerable sectors to climate change due to its heavy reliance on natural resources like water and fertile land. Climatic variability, including changes in temperature, precipitation patterns, and the frequency of extreme weather events, is disrupting agricultural productivity, threatening food security, and affecting millions of farmers across the country [16].

2.1. Rising Temperatures and Heatwaves

Over the past century, Pakistan has experienced a significant warming trend, with the average temperature rising by approximately 0.63°C [17]. This increase, combined with the growing frequency and intensity of heatwaves, has detrimental effects on agricultural output, particularly during the critical growing seasons of major crops like wheat and rice.

1. **Effects on Crop Yields:**

   Wheat: According to the Pakistan Agricultural Research Council (PARC), a 1°C increase in temperature during the wheat-growing season can lead to yield reductions of up to 15% [18]. For instance, the heatwaves of 2018 resulted in a 7% decrease in wheat yields compared to the previous year, highlighting the sensitivity of wheat production to temperature extremes [19].

   Rice: High temperatures during the flowering stage can induce sterility in rice plants, significantly reducing grain yields [20]. The Indus Basin, a key area for rice cultivation, has experienced temperatures surpassing optimal ranges, adversely impacting crop output.

2. **Impact on Livestock:** Heat stress also affects livestock, reducing feed intake, milk production, and reproductive efficiency [21]. Dairy cows, for instance, produce significantly less milk when exposed to prolonged high temperatures, directly impacting food supply and farmers' incomes.

2.2. Erratic Rainfall Patterns

Rainfall patterns in Pakistan have become increasingly erratic, with some regions experiencing intense downpours that cause flooding, while others endure prolonged dry spells that hinder agricultural activities [22]. These unpredictable rainfall trends pose significant challenges to the agricultural sector.

1. **Statistical Data and Trends:**

   Increased Intensity of Monsoon Rains: The monsoon season, vital for rice and other crops, has become highly unpredictable. Some years witness up to 20% more rainfall than average, causing floods, while others suffer severe deficits, leading to drought conditions [23].

   Droughts: Provinces such as Sindh and Balochistan are frequently affected by recurring droughts, some lasting several years, which severely impact crop production and water availability for irrigation [24].

2. **Impacts on Agriculture:**

   Floods: Intense rainfall often results in flash floods and riverine floods, damaging crops, infrastructure, and soil fertility. The 2010 super flood, the worst in Pakistan's history, submerged over 2 million hectares of farmland and caused agricultural damages worth $5 billion [25].

   Droughts: Persistent droughts reduce water availability for key crops like cotton and sugarcane, leading to crop failures and soil degradation. The recurring droughts in Tharparkar have plunged many families into food insecurity, with significant livestock losses exacerbating the crisis [26].

2.3. Melting Glaciers and Water Scarcity

Pakistan's agriculture heavily depends on the Indus River system, which is primarily fed by melting glaciers in the Himalayas. Rising temperatures are causing these glaciers to recede rapidly, threatening long-term water availability, especially during the dry season.

1. **Statistical Data:**

Glacier Retreat: A recent report from the International Centre for Integrated Mountain Development (ICIMOD) highlights accelerated glacier mass loss in the Himalayas and the Karakoram range [27]. Initially, this process increases river flows, but over time, it is expected to lead to significant water scarcity.

Decreased River Flows: Projections indicate that by 2050, the flow of the Indus River could decrease by up to 15% due to reduced glacial melt, significantly impacting irrigation-dependent agriculture [28].

2. **Impacts on Agriculture:**

Water Shortages: Reduced river flows diminish water availability for irrigation, forcing farmers to rely on depleting groundwater resources, which are often unsustainable.

Salinity and Soil Degradation: Over-extraction of groundwater and improper irrigation practices have led to widespread soil salinity, affecting 5.7 million hectares of arable land and making farming increasingly unviable [29].

2.4. Increased Susceptibility to Pests and Diseases

Climate change is altering pest populations and disease prevalence, further threatening Pakistan's agriculture. Warmer temperatures and shifting precipitation patterns create favourable conditions for pests and diseases that can devastate crops.

- **Locust Infestations:** The 2019–2020 locust outbreak, exacerbated by unusually wet weather, caused severe damage to crops across Sindh, Punjab, and Balochistan, resulting in billions of dollars in losses [30].
- **Crop Diseases:** Higher temperatures and humidity levels have increased the prevalence of diseases like rusts in wheat and blights in rice, further reducing crop quality and yields.

2.5. Socioeconomic Impacts

The consequences of climate change extend beyond agricultural productivity, impacting the socioeconomic fabric of rural communities. Climate-induced agricultural damages are estimated to cause annual GDP losses exceeding $4 billion [31]. Smallholder farmers, who form the majority of agricultural producers, face reduced incomes, increased poverty, and heightened food insecurity. Additionally, recurrent floods, droughts, and soil degradation are forcing rural families to migrate to urban areas in search of work, worsening urban poverty and social pressures.

3. Agricultural Water Issues

Water scarcity presents a significant challenge for agriculture in Pakistan, profoundly affecting food security and rural livelihoods. As a water-stressed nation, Pakistan’s per capita water availability has plummeted from about 5,000 cubic meters per year in 1950 to less than 1,000 cubic meters today, crossing the critical threshold of water scarcity [32]. This drastic decline is driven by multiple factors, including rapid population growth, inefficient water management practices, and the impacts of climate change. The agricultural sector, which consumes approximately 90% of the country’s water resources, [33] is particularly vulnerable, with water shortages threatening food production, economic stability, and overall food security.

3.1. Key Issues

1. **Inefficient Irrigation Practices**

Traditional irrigation methods, such as flood irrigation, dominate Pakistan’s agriculture. These techniques are not only outdated but also inefficient, resulting in significant water losses. Up to 60% of the water used in flood irrigation does not reach the crops effectively, being lost to evaporation and runoff [34]. This inefficiency contributes to the overall scarcity of water and undermines the productivity of the agricultural sector, making it critical to modernize irrigation practices to conserve water.

2. **Poor Water Infrastructure**

Pakistan’s extensive canal system, one of the largest in the world, is plagued by age and poor maintenance [35]. Decades of neglect have led to substantial water losses through seepage, leakage, and siltation. The crumbling infrastructure fails to deliver water efficiently, exacerbating the already strained water resources. Addressing this issue requires significant investment in repairing and upgrading the existing canal system to reduce wastage and improve water delivery.

3. **Mismanagement of Water Resources**

Mismanagement of water resources, particularly in the allocation and pricing of water, further compounds the problem. Water allocation disputes between provinces, such as Punjab and Sindh, often lead to tensions and inefficient use of

available resources [36]. The lack of effective water pricing mechanisms also contributes to overuse and wastage, as water remains undervalued and misallocated. Implementing sound governance and regulatory frameworks is essential to ensure equitable distribution and efficient use of water resources.

3.2. Climate-Induced Water Variability

Pakistan's water variability is increasingly driven by climate-induced changes. The Indus River, dependent on melting Himalayan glaciers, faces erratic flows due to rapid glacial melt, heightening flood risks in the short term and long-term water scarcity. Changing rainfall patterns disrupt water supply during crucial crop seasons, affecting agricultural productivity. Irregular monsoons and prolonged droughts further disturb traditional farming cycles, causing crop failures and economic losses. Extreme weather events, exacerbate these challenges, damaging crops, eroding topsoil, and stressing water availability, making agriculture less sustainable and more unpredictable.

3.3. Groundwater Depletion

To cope with unreliable surface water supplies, farmers have resorted to over-extracting groundwater, causing alarming depletion rates. In some agricultural regions, groundwater levels are dropping by more than a meter annually, threatening long-term water availability and the sustainability of agricultural activities. Overuse of tube wells have exacerbated salinity problems, degrading groundwater quality and making it unsuitable for agricultural and drinking purposes [37]. Saline intrusion not only reduces the quality of the water but also damages soil health, further undermining agricultural productivity.

4. Losses to Crops and Livestock from Repeated Disasters

Pakistan’s agricultural sector, which is a primary source of livelihood for millions, is increasingly vulnerable to climate-induced disasters. The country has experienced devastating events, including floods, droughts, heatwaves, and locust infestations, which have severely impacted crops, livestock, and food security. These recurring calamities have created a vicious cycle of poverty and food insecurity, particularly affecting rural communities dependent on agriculture.

4.1. Economic Impact of Climate-Induced Disasters

Climate-induced disasters have inflicted extensive economic damage on Pakistan’s agriculture sector, disrupting rural economies and undermining national food security. Key events have highlighted the sector’s vulnerability and the broader economic consequences.

1. **2010 Floods:** One of the most catastrophic events in Pakistan’s history, the 2010 floods affected over 20 million people and caused estimated damages of $43 billion. The agricultural sector suffered immensely, with millions of acres of farmland inundated, leading to significant losses in major crops such as wheat, rice, and sugarcane. The floods also resulted in the loss of over 1.2 million livestock, exacerbating economic strain on rural households that rely on livestock for income and nutrition [38].
2. **Droughts in Sindh and Balochistan:** Prolonged droughts in Sindh and Balochistan, Pakistan’s arid regions, have led to repeated crop failures and livestock deaths. The scarcity of water has made it difficult for farmers to sustain agricultural activities, forcing many to migrate to urban areas in search of employment. This migration disrupts rural economies and contributes to urban poverty and unemployment, highlighting the interconnectedness of environmental and socioeconomic challenges.
3. **2022 Floods:** The 2022 floods were particularly devastating, affecting 33 million people and causing an estimated $13 billion in damages [39]. Key crops like cotton, rice, and sugarcane were extensively damaged, severely impacting the livelihoods of millions of smallholder farmers and the broader textile industry. The scale of destruction underscored the urgent need for improved disaster preparedness and climate-resilient agricultural practices.
4. **Locust Infestations:** The 2020 locust infestation, one of the worst in decades, affected 61 districts and caused crop damage estimated at approximately $3.4 billion [40]. Swarms of locusts ravaged essential crops, including wheat, maize, and pulses, leading to reduced food supply and higher market prices. The economic losses for farmers, combined with increased food prices, worsened food insecurity, particularly in already vulnerable communities.

4.2. Impact on Crops and Livestock

Repeated natural disasters have drastically affected both crop production and livestock health, leading to significant reductions in agricultural output, food supply, and farmer incomes.

1. **Floods:** Flooding causes severe soil erosion, nutrient depletion, and waterlogging, which collectively reduce crop yields and degrade soil health. The 2022 floods destroyed around 4.4 million acres of agricultural land, [41] impacting soil fertility and long-term productivity. These changes not only reduce immediate crop yields but also affect future agricultural potential, posing a long-term threat to food security.
2. **Droughts:** Persistent droughts lead to water stress, hindering crop growth and increasing susceptibility to pests and diseases. Water scarcity forces reliance on inefficient irrigation methods and diminishes fodder and water

availability for livestock, leading to poor health and lower productivity. The socioeconomic impact of droughts is particularly pronounced in arid regions, where farming communities face heightened economic distress.

3. **Heatwaves:** Extreme heatwaves, which are becoming more frequent due to climate change, cause heat stress in both crops and livestock. For crops, heat stress accelerates growth stages, often leading to reduced yields. In livestock, heat stress results in decreased milk production, weight loss, and higher mortality rates. The 2021 heatwaves in Sindh and Punjab led to significant livestock losses, [42] illustrating the severe impact of rising temperatures on agricultural productivity.

4. **Locust Infestations:** The locust swarms of 2019-2020, driven by climate-induced changes in weather patterns, damaged crops significantly, leading to losses of up to 40% in wheat yields and nearly 70% in vegetables [43]. The infestations worsened food insecurity and increased economic losses for already struggling farmers.

5. **Livestock Losses:** Repeated disasters have led to substantial livestock losses, particularly in vulnerable regions. For instance, the 2018 drought in Tharparkar [44] resulted in high livestock mortality rates due to disease and lack of resources, causing severe economic distress for pastoral communities reliant on animal husbandry for their livelihoods.

5. Climate-Smart Agriculture Practices

CSA represents an innovative approach that seeks to address the dual challenges of climate change and food security. As a strategy, CSA aims to transform agricultural systems by enhancing food security while adapting to climate variability and reducing greenhouse gas emissions [45]. In Pakistan, where agriculture is the backbone of the economy and provides livelihoods to millions, recurrent climatic shocks such as droughts, floods, and extreme heat pose significant threats. CSA practices, therefore, present a critical opportunity for adaptation, ensuring sustainable food security and resilient agricultural systems.

5.1. Key CSA Practices

1. Conservation Agriculture (CA): Conservation Agriculture emphasizes soil management techniques that minimize disruption to the soil's structure and biodiversity, thereby enhancing sustainability and productivity [46].

- **Minimum Tillage:** By limiting ploughing, this practice helps maintain soil structure, improves moisture retention, and reduces erosion. It also contributes to lower greenhouse gas emissions by preserving soil organic matter.
- **Crop Rotation:** Sequentially growing different crops enhances soil fertility, reduces pest and disease risks, and improves soil resilience. Crop rotation is essential in Pakistan, where monocropping of wheat and rice has led to soil degradation [47].
- **Cover Cropping:** Planting cover crops protects the soil from erosion, suppresses weeds, and enhances soil organic matter. This practice significantly improves water infiltration and retention, which is crucial for rain-fed agriculture.

2. Drought-Resistant Crops: With Pakistan's increasing vulnerability to drought and extreme heat, the development of drought-resistant and heat-tolerant crop varieties is vital. These crops, such as heat-tolerant wheat and maize and salinity-tolerant rice, help maintain productivity under adverse weather conditions, reducing the risk of food insecurity.

3. Agroforestry: Integrating trees into agricultural landscapes offers multiple benefits, including improved biodiversity, carbon sequestration, and enhanced soil fertility.

- **Windbreaks and Shelterbelts:** Trees and shrubs act as barriers against strong winds, protecting crops from damage and reducing soil erosion.
- **Fruit Trees in Farmlands:** Incorporating fruit trees alongside crops or livestock diversifies income sources, providing sustainable food, timber, and fuel. This practice enhances resilience by creating a diversified farming system.

4. Improved Water Management: Efficient water management is crucial in Pakistan’s water-scarce environment. Techniques such as drip irrigation, rainwater harvesting, and micro-irrigation systems improve water-use efficiency.

- **Drip Irrigation:** This method delivers water directly to the roots of plants, minimizing wastage and enhancing crop yield.
- **Rainwater Harvesting:** Collecting and storing rainwater for use during dry periods can significantly mitigate the impact of water scarcity.

5. Integrated Pest Management (IPM): IPM combines biological, cultural, mechanical, and chemical methods to control pests with minimal environmental impact [48]. This approach reduces reliance on synthetic pesticides, protecting beneficial insects, soil, and water resources.

5.2. Benefits of CSA Practices

1. **Stabilization of Yields:** CSA practices help stabilize crop yields even under extreme weather conditions, sustaining livelihoods and food supply despite climatic challenges.

2. **Improved Soil Health:** Conservation agriculture improves soil structure, enhances organic matter, and promotes nutrient cycling. By preventing soil erosion and improving fertility, these practices are critical for long-term agricultural productivity.
3. **Enhanced Resilience to Climatic Shocks:** CSA builds adaptability to changing weather patterns. For example, agroforestry not only enhances biodiversity but also modifies microclimates, making agricultural landscapes more resilient to extreme weather.
4. **Sustainable Resource Use:** Techniques like drip irrigation and rainwater harvesting optimize water use, reducing agriculture's environmental footprint and enhancing resource efficiency.
5. **Reduced Greenhouse Gas Emissions:** By minimizing soil disturbance, enhancing soil carbon storage, and optimizing resource use, CSA practices contribute to carbon sequestration and lower emissions.

5.3. Challenges to CSA Adoption in Pakistan

Despite its potential, CSA adoption in Pakistan faces several challenges:

1. **Low Farm Mechanization Levels:** The level of mechanization in Pakistan is very low, making it difficult for farmers to adopt modern CSA technologies that often require advanced machinery.
2. **Financial Constraints:** Smallholder farmers, who form the majority in Pakistan, face significant financial barriers to adopting CSA practices due to the high initial costs associated with seeds, irrigation systems, or agroforestry saplings.
3. **Limited Access to Technology and Knowledge:** Many farmers lack access to the latest agricultural technologies and extension services, which limits their ability to implement CSA practices effectively.
4. **Low Awareness and Capacity:** Traditional farming practices are deeply rooted in Pakistan, and there is limited awareness about the benefits of CSA among rural communities.
5. **Policy and Institutional Gaps:** There is insufficient policy support for CSA in Pakistan, and a lack of targeted incentives complicates the transition to climate-smart practices.
6. **Lack of Developed Markets:** The government's role as the largest buyer for major crops suppresses market development, impeding price discovery and a market-based incentive structure that would otherwise drive innovation and adoption of CSA practices.

6. Conclusion

Climate change poses a significant threat to food security in Pakistan, profoundly affecting agriculture, water resources, and rural livelihoods. As one of the most climate-vulnerable countries, Pakistan faces extreme weather events like floods, droughts, and heatwaves, which severely disrupt agricultural productivity. The 2022 floods, for instance, submerged vast farmlands, destroyed crops, and caused significant livestock losses, leading to immediate food shortages and long-term impacts such as soil degradation and disrupted planting cycles. Water scarcity, worsened by erratic rainfall and melting glaciers, further strains agriculture, with projections indicating potential absolute scarcity by 2025. Inefficient water management and regional disputes exacerbate these issues, threatening rural livelihoods, increasing food insecurity, and driving poverty and displacement.

To address these challenges, Pakistan needs a comprehensive strategy focusing on water management, CSA, disaster response, and social protection. Effective water management is crucial and can be achieved by modernizing irrigation systems, such as adopting drip and sprinkler technologies, enhancing governance, and promoting water conservation practices like rainwater harvesting. Strengthening water management policies, revising outdated agreements like the Water Apportionment Accord (WAA), [49] and introducing water pricing mechanisms can ensure equitable distribution and efficient use. Building resilient infrastructure, such as flood barriers and reservoirs, is also vital for mitigating extreme weather impacts.

Promoting CSA is another critical element, involving the adoption of drought-resistant crops, sustainable farming techniques, and providing farmers with training and access to climate information. Enhancing research and development of locally adapted CSA technologies, coupled with financial incentives, can encourage farmers to embrace sustainable practices. Integrating CSA into national agricultural and climate strategies will further create a supportive environment for farmers, boosting resilience and productivity.

Strengthening disaster response mechanisms is essential for managing climatic shocks and protecting vulnerable populations. This includes enhancing early warning systems, improving disaster management infrastructure, and involving local communities in preparedness planning. These measures will ensure that relief efforts are timely, effective, and tailored to local needs, reducing the adverse impacts of extreme weather events.

Enhancing social protection systems is also crucial for safeguarding vulnerable populations from climate change impacts. Expanding access to social safety nets, such as cash transfers and food assistance programs, can provide critical support to those facing food insecurity and economic disruptions. Encouraging livelihood diversification and skills development helps rural populations build resilience and reduce dependency on agriculture, thus enhancing socio-economic stability.

Specific recommendations for building resilience include improving water use efficiency through modern irrigation technologies, lining canals to reduce seepage, and implementing integrated water resource management approaches to strengthen governance. Investing in climate-resilient infrastructure and raising public awareness about sustainable practices can further enhance the adaptive capacity of communities.

In conclusion, tackling food insecurity in the face of climate change in Pakistan demands a coordinated and multi-faceted approach. By prioritizing water management, CSA, disaster response, and social protection, Pakistan can build resilience against climate change, ensuring a secure and sustainable future for its population.

Abbreviations

Gross Domestic Product: GDP
Climate-Smart Agriculture: CSA
Pakistan Agricultural Research Council: PARC
Conservation Agriculture: CA
International Centre for Integrated Mountain Development: ICIMOD
Integrated Pest Management: IPM
Water Apportionment Accord: WAA

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Conflicts of Interest

The authors declare no conflicts of interest.

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