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The Impact of Climate Change on Food Security in Pakistan: Challenges and Adaptive Opportunities

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Abstract

Climate Change (CC) is taken as most crucial issue across the globe. It has been influencing each and every sphere of life, to which Pakistan is not an exception. Pakistan is suffering from Climate change at a very large scale and is the fifth most vulnerable nation due to high number of glaciers and mountain ranges. Floods of 2022 and 2025 are example of alarming climate catastrophe. Pakistan is not just facing the Climate change in form of floods but severe heat waves and droughts are also the changing weather patterns. Climate change essentially means the slow and irreversible change in the weather conditions, precipitation patterns, melting of ice caps, and other such natural phenomena. This shift is creating increasing sea levels, irregular bouts of flood and drought resulting in national and global calamities. Due to the alteration of climatic conditions, most of the urgent issues are arising out of which one is food insecurity. With increased temperatures, rainfall patterns become unpredictable, and climatic events intensify, the fragile equilibrium of Pakistan's agricultural sector gets destabilized, and its capacity to provide a stable and secure food supply to the people is greatly challenged. Pakistan's path to achieving food security is tainted with challenges emanating from natural and man-made sources. The agricultural sector, which is the pillar of the nation's economy, is threatened by vulnerabilities such as water shortage and ageing practices in agriculture to the effects of Climate Change. These and a burgeoning population and economic inequalities lead to a scenario where a large percentage of the population lacks access to a sufficient and nourishing diet.

Key Words: Climate Change, Food Security, Food Supply Chain, Droughts, Famine.

Introduction

Food insecurity is expressed in varied forms, from chronic hunger and malnutrition to occasional shortages of food, which are frequently caused by more than one of the above factors. Climate change is one of the leading environmental factors causing food insecurity. Pakistan, especially, has gained prominence because it is highly prone and poorly resilient against climate catastrophes. Even though Pakistan is one of the lowest emitters of carbon in the world, it is one of the most vulnerable countries. It is causing a ripple effect on the food value chain right from the productivity of agriculture for staple foods like wheat and rice to comparatively more varied food resources like livestock, fruits, etc.; all the time being an agrarian economy. Not only Pakistan, but most of the developing nations are going through the same problems with climate change on their agricultural produce and associated food security. Brazil, India, Vietnam and Bangladesh have been ahead of the curve in coming up with strategies on how to mitigate the negative effects of climate change. These nations have registered encouraging outcomes with their climate resilient infrastructure programs. Considering the above channels, this study focuses on how generally the altered weather conditions hinder agriculture and food production in the nation. This study also

explores the prominent reason/ cause of Pakistan's susceptibility to climate-related calamities. Additionally, it also delves into the solutions for constructing disaster-resilient infrastructure. The research seeks to provide policy advice for reducing the impacts of climate change on food security. Since Climate Change and the resultant environmental issues have been area of concern for the past few years this study examines the rationale for Pakistan's increased susceptibility to climate-induced disasters and by analyzing the causes for such vulnerabilities, this research addresses the primary question first, which is are the environmental threats to Pakistan a creation of its own, or are they external in nature? Then examining the direct and indirect effects of Climate Change on food insecurity and agriculture during the recent years, this study sets up a causality relationship that Climate Change had on the worsening scenario of the availability of food resources. Considering the impacts of Climate Change, a careful study on disaster resilient infrastructure and risk avoidance methods is necessary in order to estimate what amount of resources and what course of action will be necessary for the same. The study goes beyond the immediate issues of crop production and cattle rearing, looking at the various factors that lead to food insecurity in the context of Pakistan. Excessive population growth, poverty, and poor infrastructure further increase the challenge, requiring an integrative approach that looks not just at environmental factors but also the social, economic, and political factors involved. Through detailed analysis of the implications of Climate Change for food security vis-a-vis crop production, land supply and food supply chain in Pakistan, this study contributes to the global literature on climate adaptation and mitigation measures, providing insights that can be used to guide policy in the country to prevent malnutrition and food insecurity in the country at large and lower classes in particular.

Literature Review

The agricultural sector in Pakistan heavily relies on the country's climatic conditions, making it highly vulnerable to the changing climate. Studies indicate that CC has made the agricultural industry particularly susceptible, with unpredictable weather patterns endangering global food production and availability. This poses a substantial risk to countries that rely significantly on agriculture for economic as well as productivity support. “The world’s crop production is also highly vulnerable to these global temperature-changing trends as raised temperatures will pose severe negative impacts on crop growth.”[1] Studies have also revealed that human actions like burning coal, forests, and using oil have increased the number of heat-absorbing gases in the atmosphere, which has led to a major increase in Earth's temperature. “The increased atmospheric GHGs produced by the intensive use of fossil fuels are warming the planet due to CC. Global surface temperatures have increased by 0.13 °C on average per decade since 1950.”[2]This increase in the average temperature results in different natural catastrophes like severe draughts, melting of glaciers, heavy monsoons to which Pakistan is no exception. Climate Change has a direct impact on the food production and availability which has been researched thoroughly over the years. The available data indicates that the main climatic factors affecting Pakistan's food security by lowering wheat production are rising minimum and maximum temperatures as well as erratic rainfall patterns brought on by global warming. “CC can be more devastating in the regions that are already vulnerable and hungry”.[3] Since Pakistan ranks 102nd out of the 125 in the 2023 Global Hunger Index, this shows that the country is susceptible to risk of food insecurity evermore. It has been stated that about 33 million people were affected by one of the worst floods to ever hit Pakistan in August of 2022. Due to abnormally heavy monsoon rainfall, the floods caused considerable agricultural losses in the fertile Indus plains, increasing the likelihood of food shortages. “1.1 million hectares of agriculture out of 2.5 million hectares or 18% of Sindh's total area were submerged under water.”[4]

1. Pakistan – A Vulnerable State for Climate Disasters

(Oxford academic) Vulnerability means the quality or state of being exposed to the possibility of being attacked or harmed. Pakistan is ranking 8th on the list of countries most vulnerable to the aftereffects of climate change according to the Global Climate Risk Index 2021.

1.1 Vulnerabilities

Pakistan is considered a more vulnerable country to climate disasters due to a combination of geographical, socio-economic, and environmental factors along with its location. The country relies heavily on agriculture, with a significant portion of the population employed in this sector. CC has led to shifts in precipitation patterns, causing erratic monsoons and increased frequency of extreme weather events, which negatively impact crop yields and disrupt the agricultural cycle.

1.1.1. Geographical Diversity

Pakistan's geographical diversity is a double-edged sword, marked by an extensive river network while the topography exposes the country to the recurrent threat of devastating floods. During heavy monsoon rains, these rivers act as conduits for excess water, aggravated by the melting snow from the Himalayas and cyclones in the Arabian Sea. Pakistan suffered devastating floods in 2022, causing food shortages and outbreaks of waterborne diseases. *(Pakistan's Flood Problem Is Supercharged by Climate Change. Recovery Means Going Beyond Damage Control).*The event led to a $16.3 billion reconstruction bill and raised questions about Pakistan's ability to incorporate climate resilience into its recovery.

1.1.2. Agriculture and Water Scarcity

Pakistan's agriculture sector contributes 24% to the country's gross domestic product and is heavily reliant on agriculture yields. CC has altered precipitation patterns, leading to changes in water availability which creates water scarcity, exacerbated by reduced snowfall and glaciers in mountainous regions. Pakistan heavily relies on glacial meltwater for its rivers, particularly for sustaining its agricultural sector. However, the accelerated melting of glaciers in the Himalayas due to global warming poses a significant threat to water availability. Disruptions in the regular flow of glacial meltwater directly impact agriculture and food security, as evidenced by events like the Shisper Glacier surge in the Karakoram Range, posing challenges to agricultural practices. Furthermore, the reliance on outdated irrigation techniques and inefficient water management practices further compounds these issues. Insufficient water for crops directly impacts agricultural productivity and contributes to food insecurity. Agriculture-related losses are estimated at $3.84 billion and total economic damage at $30 billion[8]. The onset of the winter season has led to downsized production of the staple winter crop, wheat, which contributes 72% of the nation's daily caloric intake.

1.1.3. Extreme Weather Events

The increased frequency and intensity of extreme weather events, such as floods and heatwaves, pose immediate threats to crops. Floods destroy standing crops, erode topsoil, and contaminate water sources. Heatwaves lead to heat stress in crops, affecting their growth and productivity. Such events not only reduce current yields but also have long-term effects on the fertility of agricultural land. Intense heatwaves particularly in urban areas, where rising temperatures, exacerbated by CC, contribute to prolonged and severe implications to life. The country is consistently being ranked among the top 10 most vulnerable countries on the Climate Risk Index, with 10,000 fatalities and financial losses of $4 billion from 173 extreme weather events in the past 20 years.[9]

1.1.4. Changing Rainfall Patterns

Irregular rainfall patterns and shifting monsoon dynamics disrupt agricultural cycles in Pakistan, leading to crop failures and impacting livelihoods. Variations in monsoon onset and withdrawal directly influence planting and harvesting seasons, thus affecting crop yields. The changes in precipitation patterns also contribute to water scarcity, amplifying the vulnerability of communities' dependence on agriculture. An illustrative example is the 2019 locust attack, which

followed unseasonal rainfall, causing widespread crop damage. [10]Over 33 million people were affected by devastating floods in Pakistan in August 2022 due to human-caused CC.

1.1.5. Water Level Rise and Coastal Vulnerability

Coastal areas in Pakistan, especially in Sindh, face threats from sea level rise and storm surges. Cyclones, such as the 1999 Arabian Sea cyclone, have led to coastal flooding and infrastructure damage. The intrusion of saltwater into arable land jeopardizes agriculture, exacerbating challenges for coastal communities. The vulnerability of these areas is evident in the devastating impact of past cyclones on coastal regions, underscoring the need for adaptive measures. Therefore, haphazard rainfall seasons and intensive cyclones are aggravating the situation. The majority of Pakistan's population lives around the river Indus and are at imminent risk of drowning due to the river's swollen levels of water. The floods have been described as a "monsoon on steroids."[11]

1.1.5. Lack of Adaptive Capacity

Pakistan is facing a national security emergency due to a heatwave that has caused flooding, infrastructure damage, and water shortages. Pakistan faces a critical challenge in adapting to and recovering from climate-related disasters due to its limited resources and large population. Every passing year and disaster has exposed the risk of vulnerabilities arising from inadequate urban planning and weak disaster management systems. The large population density exacerbates the impact of climate-related disasters, placing immense pressure on the already strained resources and infrastructure. The country struggled to cope with the sheer scale of displacement, damage to infrastructure, and the disruption of essential services. The lack of adaptive capacity is further compounded by economic constraints, limiting the investment in resilient infrastructure and comprehensive disaster preparedness programs.

1.1.7. Overpopulation

Overpopulation in Pakistan compounds vulnerability to climate-related disasters through various interconnected mechanisms. The substantial population pressure places tremendous stress on natural resources and agricultural produce, contributing to environmental degradation and reducing ecosystem resilience. Rapid urbanization, driven by population growth, results in unplanned settlements in hazard-prone areas, heightening the vulnerability of urban populations to floods and other disasters. The expansion of agriculture to meet the demands of a growing population leads to deforestation and soil degradation, rendering the sector more susceptible to climate impacts. Addressing the complex interplay between overpopulation and climate vulnerability necessitates comprehensive strategies that include sustainable population management, equitable economic development, and integrated climate resilience planning.

1.1.8. Political Economic and Administrative Limitations

Weak governance, inadequate planning, and limited capacity to enforce regulations pose significant hurdles to effective CC mitigation and adaptation strategies in Pakistan. The International Monetary Fund estimates that the nation owes its creditors around $77 billion, which must be paid back over the course of the next three years. This has increased inflation in Pakistan. The last year has seen a sharp increase in energy tariffs that have impacted industry and exports, a record high in inflation that reached 38 percent earlier this year, and a more than 50% decline in the value of the currency relative to the US dollar[12]. In that scenario, people belonging to low-income households who mostly rely on agriculture, small-scale industry, and construction are nevertheless susceptible to political and economic shocks that leads to food insecurity in Pakistan.

1.2. Pakistan's Climate risks: A Mix of Local and Global Practices

Pakistan, although only contributing 0.9% to global greenhouse gas (GHG) emissions[13], is one of the most vulnerable countries to the impacts of CC. An amalgamation of practices mainly by the industrially developed countries and minor by Pakistan itself, leads to the climatic risks Pakistan suffers from.

1.2.1. Role Played by Global Community

The international community bears a significant share of responsibility for the climate crisis in Pakistan, primarily due to historical emissions that originated from the industrialization processes of developed countries. Over the years, these nations have been the largest contributors to GHG's, leading to a substantial accumulation of these gases in the Earth's atmosphere. The consequences of these historical emissions, such as global warming and CC, are pervasive and transcend national borders, affecting countries worldwide, including Pakistan. The disparities in per capita emissions highlight the disproportionate impact of industrialized nations on the global climate, underscoring the interconnectedness of the issue. While countries like Pakistan may have lower per capita emissions, the cumulative effect of the sustained high emissions from major industrialized nations has far-reaching consequences for the entire planet. The interconnected nature of the Earth's climate system implies that climate-related challenges faced by Pakistan and other nations are, to a significant extent, a consequence of the collective emissions from the international community. International trade and supply chains further contribute to the climate crisis in Pakistan. The production and transportation of goods over long distances involve significant energy consumption and emissions. The carbon footprint associated with the entire life cycle of products, from production to consumption, extends globally. As Pakistan participates in these global trade networks, emissions associated with international trade indirectly contribute to the overall carbon burden, contributing to climate-related challenges within the country.

1.2.2. Pakistan's Share in Its Climate Risks

Despite contributing minimally to global GHG's emissions, Pakistan bears a disproportionate burden of the impacts caused by emissions from industrialized nations. Pakistan's contribution to its own climate challenges stems from local practices, policy decisions, and broader socio-economic dynamics. The nation's substantial reliance on fossil fuels, particularly coal and natural gas, for energy generation has resulted in significant GHG's. Energy sector is the largest contributor of GHG emissions accounting for 46% of the total national Green House Gas Emission Inventory.[14] Additionally, deforestation, spurred by factors like agricultural expansion and urbanization, has led to a reduction in the carbon sequestration capacity of forests, amplifying environmental degradation and intensifying climate-related issues. Water mismanagement represents another critical aspect. Inefficient irrigation practices, coupled with over-extraction of groundwater, have contributed to water scarcity having far-reaching consequences for agricultural productivity and overall environmental health. Rapid urbanization and infrastructure development, while essential for economic growth, often occur without sufficient consideration for environmental impact. This has led to the urban heat island effect in cities and increased susceptibility to extreme weather events. Agricultural practices, such as the burning of crop residues and the reliance on water-intensive crops, contribute not only to local environmental issues but also to global greenhouse gas emissions. Inadequate waste management exacerbates the problem, with improper disposal and limited recycling leading to environmental pollution and the emission of methane—a potent greenhouse gas—from decomposing organic waste in landfills. Pakistan faces severe land degradation issues due to heavy deforestation and intensive use of agricultural land[15]. Unsustainable practices, such as excessive use of fertilizers and pesticides, degrade soil quality and compromise agricultural sustainability. Industrial activities emit GHG's, intensifying the greenhouse effect and cause global warming resulting in erratic weather patterns, rising sea levels, loss of carbon sink and extreme events, all of which adversely impact food production, water resources, and ecosystems. Societal and economic disruptions, including food insecurity, displacement, and heightened vulnerability to natural disasters, underscore the interconnectedness of human activities and environmental risks, emphasizing the urgent need for concerted global action to mitigate CC and protect our shared future.

2. Climate Disasters - Impact on Agriculture and Pakistan's Preparedness

Pakistan, along with most of the developing nations, is facing the brunt of CC to the utmost extent. It has been impacting Pakistan in all walks of life. However, this has not been giving the due

attention and the country lacks preparedness measures to counter the sporadic occurrences of Climate related disaster.

2.1. Climate Disasters in Pakistan

Some of the major climate related disaster that have occurred in recent past having devastating impacts are delineated in the following sections;

2.1.1. Floods

Over the past few years, floods have been responsible for more than 30 percent of natural disasters. These led to a lot of damage including loss of human lives and valuable assets of human beings. Developing countries, in particular, are at a higher risk because they are unable to handle such disasters. Inadequate infrastructure and lack of capacity to handle such disasters makes the underdeveloped countries vulnerable to climate change. Floods, whether characterized as flash or riverine, have affected the country in a broader spectrum. Over the few years, the country has witnessed rise in frequency, duration, and severity of floods. Notably, Pakistan has witnessed an average occurrence of flood every three years between the years 1950 and 2011, with 12 instances of extreme flood events. This has resulted in the loss of around 8,887 human lives with an indirect impact of $19 billion on economy[16]Pakistan witnessed unprecedented challenges on agriculture due to flood. Crops were destroyed, livestock swept away in flood water, and people lost their homes. Owing to the impact of flood, the country has faced severe nutrition crisis, with around 10.5 million people who faced food insecurity. As of 18 November 2022, the Pakistan National Disaster Management Authority reported that over 1,700 people having lost their lives and at least 12,867 people injured.[18] "Floods plunged vulnerable population of a country into food insecurity".[19]

Province	Death toll	Fully damaged	Injured	Economic loss
Punjab	188	16,590 houses	2023	Agricultural
Baluchistan	253	17,608 houses	164	Agricultural
Sindh	422	307,306 houses	1101	Agricultural
KPK	264	30,233 houses	327	Agricultural

Figure 1: Province Wise Agricultural Losses in Recent Floods[17]

2.1.2. Drought

A drought is a prolonged period of low precipitation in a particular location that results in scarcity of water. According to the Pakistan Meteorological Department, southern Pakistan experiences extreme draught condition. It has been reported that there were severe drought issues in eight districts of Sindh: Qambar Shahdad Kot, Shikarpur, Jacobabad, Sanghar, Khairpur, Sukkur, Tharparkar, and Umerkot. Droughts have historically affected Sindh; significant ones have occurred in 1871, 1881, 1899, 1931, 1942, 1999, 2003, 2020, 2021, and 2022. About 1.4 million people, 5.6 million livestock, and 12.5 million acres of cropland were impacted by the 1999–2002 drought in Pakistan.

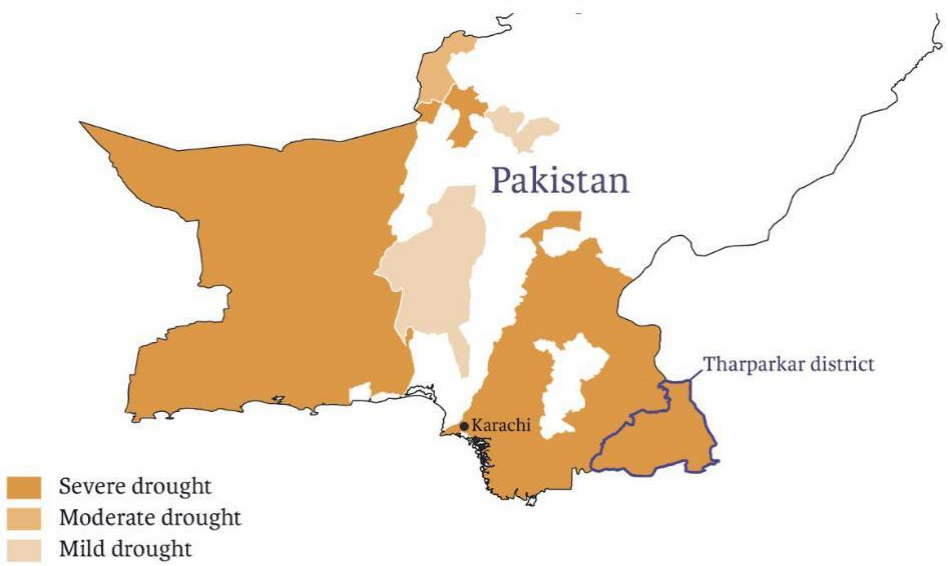

Figure 2: Droughts Across Pakistan Districts[20]

According to the estimate, numerous cattle perished and hundreds of acres of crops were destroyed as a result of the drought. Farmers in Pakistan suffered short-term financial losses as a result, but there were also long-term effects on agricultural production. "Compared to 2016-17 seasons, cultivation area (measured in acres) for wheat reduced by 17% in 2017-18."[21] This reduction in the cultivable land implicates that the food production also decreased in the same proportion resulting in even more insecurity. About 2 million cattle affected as a result of draught. This directly affected the supply of meat and dairy products, which increased the risk of malnutrition and health issues among children. Due to the limited availability of food products and restricted supply, draught ultimately leads to the increase in prices. This aspect reduced people's purchasing power and increased the likelihood of food insecurity in the country.

2.1.3. Locust Infestation

Locusts are one of the kind of pests that attack all sorts of crops. The migration of these pests is a result of changing climate conditions to which they are accustomed. In the recent years, Pakistan has faced the worst attack of these locusts after nearly 3 decades. This is due to heightened temperatures resulting in lowered atmospheric pressure has attracted these pests towards the central and southern regions of Pakistan affecting around 60 districts. "By late 2018, swarms that developed in Saudi Arabia's Rub al Khali began moving west across the Red Sea to the Horn of Africa, south into Yemen, and east to Iran."[22]The damage that spread across Pakistan in all the provinces can be gauged by the fact that it harmed over three million hectares of crops, resulting in losses of around $3 billion. This loss is not only related to the production capacity of the cultivable land but also diminished the buying capacity of the famers who owned those farms. The food security ministry stated in a case study that the locusts have already reduced agricultural yields in 2019 by over fifteen percent. Gauging from the quantum of losses, it is seen that these locust attacks have caused a considerable damage to the vegetation and hence the overall food security of the country.

2.1.4. Irregular Shower Patterns

Global temperatures are continuously rising, which is altering precipitation patterns and monsoon season in Pakistan. Agribusiness infrastructure, farm livelihoods, and agricultural productivity are all impacted by these factors, which puts rural communities at risk for food instability. This change in precipitation occurrences along with hail storms have caused reasonable damage to the yield of different crops such as mangoes, sugarcane, wheat, etc. which form the staple food. Survey across the country have revealed that these irregular rains and hailstorms have destroyed nearly 75% of

crop harvested by small farmers.[23]Taking into account that over 60% of Pakistan's population is either directly or indirectly dependent on rain-fed agriculture, the kind of damage that the same rain is causing is alarming. The impact of crop destruction can be seen on multiple aspects; from agribusiness infrastructure, to farm livelihood, from agricultural productivity to economic subsistence. "Agricultural growth and household income which are estimated to decrease on average by 5.1 and 2pc, respectively, on an annual basis,"[24] viz the economic cost of this change in climate.

2.2. Pakistan's Preparedness Towards Climate Disasters

Pakistan's current state in terms of climate related disaster resilience, amidst heightened vulnerabilities and challenges, underscores the urgent need for strategic improvements. This is particularly crucial for enhancing food security and overall well-being, necessitating a comprehensive approach to achieve resilience in the face of potential disasters.

2.2.1. Contextualizing Climate Change Resilience

Climate change resilience represents the capacity of ecosystems, communities, and socio-economic systems to anticipate, adapt to, and recover from the adverse impacts of climate change. It encompasses a dynamic and multi-dimensional approach to building the ability of these systems to withstand and respond effectively to climatic disturbances. Resilience involves not only the ability to absorb and recover from shocks but also the capability to transform and adapt in the face of evolving climate conditions. This concept recognizes the interconnectedness of political, environmental, administrative, social, and economic factors, emphasizing the need for holistic strategies that integrate mitigation and adaptation efforts. Climate change resilience extends beyond mere resistance to climatic stressors; it involves fostering sustainable practices, enhancing community engagement, and implementing policies that promote long-term viability in the face of an increasingly unpredictable climate[25]. As a crucial aspect of climate change mitigation and adaptation, resilience serves as a foundation for building a more sustainable and robust future in the face of ongoing environmental challenges.

2.2.2. Analysis of Pakistan's Current Climate Resilience Infrastructure

Pakistan faces heightened vulnerabilities, including water scarcity and more frequent and intense heatwaves, floods, and cyclones. The most severe episode of flooding in Pakistan in 2022 for instance impacted around 20 million individuals, leading to significant economic and infrastructural devastation nationwide[26]. These vulnerabilities to climate change disasters are exacerbated by the absence of disaster-resilient infrastructure, which leaves communities ill-prepared to cope with and recover from the impacts of such events. Also, despite having multiple authorities, departments and ministries working to lower the cost of such disasters or devising ways to avoid it altogether there has been an absence of tangible frameworks for the same. The insufficient resilience of infrastructure is evident in various sectors, contributing to increased human and economic losses during climate-related disasters. One glaring issue is the inadequacy of flood management infrastructure. The absence of well-maintained embankments, flood protection walls, and drainage systems leaves communities susceptible to inundation, resulting in displacement, loss of life, and extensive damage to property and agriculture. According to the World Bank, the 2010 floods alone caused economic losses equivalent to 4.7% of Pakistan's GDP.[27] Furthermore, the absence of climate-resilient agricultural infrastructure compounds the challenges faced by farmers. Inefficient water management systems, lack of weather-resistant storage facilities, and outdated irrigation methods contribute to reduced agricultural productivity during extreme weather events.

3. Global Best Practices and Ways Forward for Pakistan on Climate Resilience

Through the adoption of climate-resilient technologies, the nations across the globe have successfully mitigated the impact of environmental stressors on their agricultural systems, ensuring food security. Each case study delves into specific strategies, technologies, and

international standards that have played a crucial role in achieving sustainable and resilient food production.

3.1.Brazil

Brazil, a global agricultural powerhouse, has confronted the challenge of food shortage owing to climate change. The country's response involves the strategic integration of the climate sturdy technologies to bolster agricultural productivity and mitigate environmental concerns. The Brazilian Agricultural Research Corporation (EMBRAPA) has played a pivotal role in this initiative.[28] One noteworthy example is Brazil's emphasis on precision agriculture, which harnesses advanced technologies like satellite imagery, sensors, and data analytics to optimize resource management. This approach not only enhances crop yields but also minimizes the environmental footprint of agriculture, aligning with international standards advocated by the International Standards Organization (ISO). Additionally, Brazil has implemented sustainable land management practices, addressing deforestation through initiatives such as the Forest Code. Agroforestry, has also demonstrated remarkable success in addressing climate change impacts. One key aspect is its role in carbon sequestration. Studies conducted by environmental research organizations reveal a significant increase in carbon sequestration levels within agroforestry systems as compared to conventional agricultural practices. For instance, recent data indicates a 30% higher carbon sequestration rate in agroforestry systems, contributing significantly to Brazil's commitment to reducing carbon emissions. Moreover, the implementation of agroforestry practices in Brazil have shown tangible benefits in terms of improved water retention. Recent field studies indicate an impressive 25% improvement in water retention, ensuring a more stable water supply for crops and enhancing the overall sustainability of Brazil's agricultural landscapes.[29]

3.2. India

India, a country with a substantial agricultural-dependent population, has been grappling with the challenge of food shortage intensified by climate change impacts. In response to this, it has strategically incorporated technology-based methods to enhance agricultural productivity and mitigate environmental risks. Notably, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), a flagship program, focuses on sustainable water management through the adoption of precision irrigation methods.[30] These practices not only optimize water use efficiency but also align with international standards, as promoted by organizations such as the Food and Agriculture Organization (FAO), emphasizing the importance of sustainable water management in agriculture.[31] Moreover, India's National Mission for Sustainable Agriculture (NMSA) plays a crucial role in promoting climate-resilient agricultural practices like the combined system of farming by promoting location specific integrated /composite farming systems; soil and moisture conservation measures; comprehensive soil health management; efficient water management practices and mainstreaming rainfed technologies. NMSA serves as a comprehensive framework, providing guidance and support for sustainable agriculture initiatives. By aligning with NMSA, India strengthens its commitment to fostering sustainable practices and enhancing the adaptive capacity of its agriculture sector.

3.3. Vietnam

Vietnam, a nation susceptible to extreme weather events and rising sea levels, has proactively addressed food shortage challenges due to climate change through the adoption of climate adaptation technologies. One notable initiative involves the implementation of weather forecasting technology to empower farmers with timely and accurate information. By integrating this technology into agricultural practices, farmers can make informed decisions, reducing vulnerability to climate-related uncertainties. This aligns with international efforts to enhance the capacity of nations to adapt to climate change, as highlighted in frameworks like the Sendai Framework for Disaster Risk Reduction.[32] Also, the establishment of marine protected areas (MPAs) stands out as a key pillar in Vietnam's sustainable fisheries management strategy. These designated zones act as havens for marine life to recover and thrive, safeguarded from the pressures

of commercial fishing. Recent data reveals a notable increase in fish populations within these MPAs, reaching up to a 25% augmentation compared to adjacent areas. This emphasizes the effectiveness of MPAs in nurturing marine biodiversity, providing a resilient foundation for fisheries and ensuring sustained livelihoods for coastal communities. The success of MPAs underscores the importance of spatial planning and conservation measures in the quest for sustainable fisheries.

3.4.Bangladesh

Bangladesh, a low-lying delta region prone to frequent floods and cyclones, faces significant challenges in ensuring food security amid the impacts of climate change. The country has taken proactive measures by adopting various technologies to mitigate the effects of environmental related issues and overcome food shortage. Notably, Bangladesh has embraced the cultivation of stress-tolerant crop varieties, such as flood-resistant rice varieties developed in collaboration with the International Rice Research Institute (IRRI). These resilient crops withstand waterlogged conditions and have contributed to increased yields, aligning with international standards for sustainable and climate-smart agriculture.[33] In addition to crop resilience, Bangladesh has implemented water management strategies to cope with changing climate patterns. The adoption of innovative water-saving technologies, including drip and sprinkler irrigation, helps optimize water use efficiency in agriculture. Such practices resonate with global initiatives like the Food and Agriculture Organization (FAO)'s guidelines on sustainable water management in agriculture. By integrating climate-resilient technologies and aligning with international standards, the country demonstrates a holistic approach to address food shortages and build resilience in its agricultural sector amid the challenges posed by climate change.[34] Pakistan can learn valuable lessons from Bangladesh's successful approach to climate-resilient agriculture.

3.5.Future of Climate Resilience in Pakistan

In light of the work done by global players on Climate Resilience front, Pakistan is in dire need to do the same to cope up with the adverse and far-reaching impacts of CC. The strategies that Pakistan needs to follows in developing climate resilient infrastructure are delineated.

3.5.1. Strategies

Keeping in view the current position of disaster resilience in Pakistan with respect to climate change, it is pertinent for the country to adopt measures to improve the current position. Achieving comprehensive disaster resilience in Pakistan demands a multifaceted and collaborative strategy. Conducting a thorough risk assessment, considering the diverse natural hazards and climate change impacts, will provide a foundation for targeted resilience strategies. Strengthening early warning systems through investments in advanced technologies and communication channels is crucial for timely alerts and community awareness[35]. Resilient infrastructure development, incorporating climate-resilient designs and retrofitting existing structures, is a key aspect of enhancing resilience.

3.5.2. Enhancing Food Security Through Climate Change Resilience

Disaster resilience holds paramount significance for Pakistan, especially in the context of enhancing food security and elevating overall quality of life. In the agricultural sector, fostering resilience involves practices like crop diversification, which enhances adaptability to variable climatic conditions and mitigates the risk of complete crop failure during disasters. Implementing water-efficient irrigation systems and sustainable water management practices becomes crucial for agricultural resilience, given Pakistan's susceptibility to droughts and water scarcity. Adding on, effective early warning systems are imperative for Pakistan to ensure timely responses to potential threats, allowing communities to evacuate or protect agricultural produce, thereby minimizing losses and securing food supplies. Resilience at the community level further strengthens Pakistan's ability to implement preparedness measures, securing food stocks and fortifying infrastructure against potential disasters. Community engagement and social resilience initiatives play a vital role in bolstering disaster resilience and food security in Pakistan. Localized efforts, such as community gardens and farmers' markets, contribute to reducing dependence on external sources

during disruptions. Furthermore, strong social support networks aid in recovery efforts, minimizing the long-term impacts of disasters on communities and improving overall quality of life.

3.5.3. Climate Resilient Infrastructure in Pakistan

Infrastructure resilience plays a pivotal role in ensuring food security in the face of climate change by creating a robust framework that can withstand, adapt to, and recover from climatic stressors. In Pakistan, where climate change poses a significant threat to agriculture, a sector vital for food production, building resilient infrastructure becomes imperative. Investing in resilient water infrastructure is fundamental for agricultural resilience. The Indus Basin Irrigation System, a critical component of Pakistan's agricultural landscape, can benefit from upgrades and modernization to optimize water use efficiency. According to the International Water Management Institute (IWMI), efficient water management can contribute to a substantial increase in crop yields. Weather-resilient agricultural infrastructure is equally vital. The deployment of greenhouses, net houses, and climate-controlled storage facilities can protect crops from extreme weather events, ensuring year-round production. The Food and Agriculture Organization (FAO) emphasizes that such infrastructure investments contribute to reducing post-harvest losses, which are currently estimated at 15-20% for major crops in Pakistan. Moreover, transportation infrastructure plays a crucial role in connecting farmers to markets. Climate-resilient roads and transportation networks can facilitate the timely and efficient movement of agricultural produce, minimizing losses and ensuring food reaches consumers in a timely manner. The Asian Development Bank reports that inadequate transportation infrastructure can result in post-harvest losses of up to 40% in some cases. It is therefore pertinent for Pakistan to focus on improving its infrastructure resilience to tackle the food insecurity challenge arising due to climate change.

3.6.Lessons on Climate Resilience from Global Best Practices

Countries such as Brazil, India, Vietnam, and Bangladesh, aforementioned, have successfully addressed food security challenges amid climate change by integrating climate-resilient technologies and sustainable practices. These nations serve as valuable models for Pakistan, showcasing effective approaches in precision agriculture, sustainable land management, agroforestry, technology adoption, weather forecasting, and conservation strategies to enhance agricultural productivity and environmental sustainability. Brazil, a global agricultural powerhouse, has successfully addressed food shortage challenges due to climate change by integrating climate-resilient technologies and sustainable practices. Notably, precision agriculture, utilizing advanced technologies like satellite imagery, has optimized resource management, enhanced crop yields and aligning with international standards. Brazil's commitment to sustainable land management, exemplified by initiatives such as the Forest Code, offers Pakistan an answer in addressing deforestation and promoting environmental conservation. Agroforestry in Brazil, with its focus on carbon sequestration and improved water retention, provides a valuable model for Pakistan to reduce carbon emissions and ensure a stable water supply for crops. Similarly, Pakistan can learn valuable lessons from India's strategic approach to tackling food shortages exacerbated by climate change. India's emphasis on technology-based solutions, particularly through initiatives like the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), showcases the efficacy of precision irrigation methods in optimizing water use efficiency. This aligns with international standards advocated by organizations like the Food and Agriculture Organization (FAO), emphasizing the importance of sustainable water management in agriculture. Pakistan could benefit from implementing similar technology-driven approaches to enhance its own water-use efficiency in agriculture. Pakistan can draw valuable insights from Vietnam's proactive measures to address food security challenges and climate disasters. Vietnam's use of weather forecasting technology for farmers showcases the importance of integrating advanced technology to provide timely and accurate information. Vietnam's establishment of marine protected areas (MPAs) stands out as a successful strategy for sustainable fisheries management. Designated zones for marine

conservation have led to a significant increase in fish populations, emphasizing the effectiveness of MPAs in nurturing marine biodiversity. Pakistan could benefit from implementing similar spatial planning and conservation measures to ensure sustainable fisheries, safeguarding marine life and supporting the livelihoods of coastal communities. Bangladesh's success in cultivating stress-tolerant crop varieties, particularly flood-resistant rice developed in collaboration with the International Rice Research Institute (IRRI), demonstrates the importance of investing in resilient crop breeding programs. Pakistan could benefit from similar initiatives to enhance agricultural productivity in the face of changing climate patterns. Moreover, Bangladesh's adoption of water-saving technologies like drip and sprinkler irrigation aligns with global initiatives for sustainable water management in agriculture. Pakistan can learn from Bangladesh's innovative approaches to optimizing water use efficiency, particularly in regions prone to water scarcity and irregular precipitation.

Conclusion

In Pakistan, the substantial repercussions of climate change on food security underscore the nation's vulnerability to a list of challenges arising from shifting climatic conditions. The complex phenomena of climate change when boiled down within the lens of Pakistan presents series of ambiguities related to the sensitivity towards climate change and highlights the fault lines in the existing structure of the country. The most prominent among such challenges is the nexus of rapid population growth, economic volatility, and political instability which exacerbates the looming threat of climate change in the country. This climatic upheaval has brought about a critical juncture for food security in Pakistan, demanding urgent attention and strategic interventions to address the systemic vulnerabilities. Recognizing the inherent correlation between climatic patterns and food production, it becomes imperative to not only comprehend but also proactively mitigate these challenges to safeguard the nation's long-term food supply. Strategic measures such as ecosystem-based adaptation, the formulation of climate-smart policies, fostering international collaborations, and implementing effective water management strategies are significant in fortifying Pakistan against the multifaceted challenges posed by climate change. In addition to these efforts, building resilient agricultural systems, embracing innovative technologies, promoting sustainable farming practices, and investing in climate-resilient crop varieties are integral components of a holistic strategy to enhance food security in the face of a changing climate. Although Pakistan is not a significant contributor to climate change, yet certain actions can be taken at national level: creating avenues to foster awareness and education regarding climate change; empowering local communities with knowledge and resources enables them to adopt adaptive measures and build resilience against climate-induced disasters. Similarly on international level practical measures such as collaborative efforts, international partnerships, the exchange of best practices and prioritizing sustainable development goals can contribute to a collective response that transcends national boundaries and ensures a coordinated approach to mitigate the impacts of climate change on global food security. Therefore, by understanding, acknowledging, and actively addressing the complex interplay between climatic shifts and food production, coupled with strategic interventions at local, national, and international levels, one can perceive a more secure and resilient food future for Pakistan and beyond.

Recommendations

In the context of Pakistan's vulnerability to climate change and its profound impact on food security, several practical recommendations, drawing inspiration from national and international models are proposed as follows;

At Micro Level

Since the impacts of CC are exacerbated due our own practices on the agricultural front. It is therefore necessary to bring about changes not only in those practices but also the policies which are listed below;

1. **Ecosystem-Based Adaptation (EbA)**
   Implement ecosystem-based adaptation strategies, drawing inspiration from successful national models like China's "Grain for Green" program, which focuses on ecological restoration and sustainable land management.[36]
2. **Water Management Strategies**
   Develop and adopt effective water management strategies, emulating successful national initiatives like Australia's Murray-Darling Basin Plan, focusing on sustainable water use in agriculture.[37]Murray-Darling Basin Authority. (2019). Murray-Darling Basin Plan 2019.
3. **Collaborative Enforcement: District Administration and NDMA Initiatives in Implementing Stringent Land-Use Regulations**
   To restrict people from developing habitats on riverbeds and associated areas, the district administration in collaboration with the National Disaster Management Authority (NDMA) of Pakistan should implement and enforce stringent land-use planning regulations. Drawing inspiration from the successful model of Japan's River Law and associated disaster risk reduction strategies, the government of Pakistan should establish and enforce clear guidelines prohibiting human settlements in vulnerable riverbed areas.[38]
4. **Innovative Technologies and Sustainable Farming**
   Promote the adoption of innovative technologies and sustainable farming practices, inspired by countries sharing similar climate vulnerabilities for instance, India’s National Mission for Sustainable Agriculture (NMSA)[39]
5. **Climate-Resilient Infrastructure for Crops in Pakistan**
   Given the shared agroecological context between India and Pakistan, a pertinent recommendation for climate-resilient infrastructure in terms of crops can be drawn from India's National Mission for Sustainable Agriculture (NMSA) which focuses on enhancing climate resilience in agriculture through measures such as the promotion of climate-resilient crop varieties, efficient water management, and the adoption of sustainable farming practices. By incorporating similar principles into its infrastructure development, Pakistan can fortify its agricultural systems against the impacts of climate change, ensuring the resilience and sustainability of crop production.
6. **Community Empowerment and Education**
   Establish community empowerment and education programs, drawing inspiration from both national initiatives, such as Pakistan's own climate education efforts, and international models like the Climate Reality Leadership Corps.

At Macro Level

Climate related disasters faced by Pakistan are not just its own creation or naturally induced but all the developed countries across the globe had a significant impact by their relentless use of fossil fuel. In light of this, steps need to be taken in collaboration with international players to mitigate the food security concerns related to Pakistan.

1. **Climate-Smart Policies**
   Formulate and implement climate-smart policies, using the framework exemplified by the Climate-Smart Agriculture Sourcebook by the Food and Agriculture Organization (FAO) of the United Nations.[40]

Resilient Agricultural Systems

Build resilient agricultural systems, following the example of the United Nations International Fund for Agricultural Development's (IFAD) initiatives, such as the Adaptation for Smallholder Agriculture Program (ASAP).[41]

3. **Climate-Resilient Crop Varieties**

   Invest in and adopt climate-resilient crop varieties, leveraging international initiatives like the Consultative Group on International Agricultural Research (CGIAR) and their Crop Trust's work on preserving and utilizing crop diversity for climate resilience.[42]

4. **International Collaboration and Sustainable Development Goals (SDGs) -**

   Advocate for international collaboration and prioritize Sustainable Development Goals (SDGs) related to climate and agriculture, aligning with global efforts such as the United Nations Framework Convention on Climate Change (UNFCCC).[43]

By integrating these recommendations, Pakistan can embark on a comprehensive and synergistic approach at the national and international levels to fortify itself against the multifaceted challenges posed by climate change and ensure a resilient food future.

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