

PAKISTAN'S VULNERABILITY TO CLIMATE CHANGE: A REVIEW OF IMPACTS AND STRATEGIC RESPONSES

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ABSTRACT

This article provides a comprehensive review of the consequences of climate change in Pakistan, focusing on the major environmental, economic, and social impacts. Pakistan, ranked as one of the most vulnerable countries to climate change, is experiencing severe disruptions to its agriculture, water resources, and coastal ecosystems due to extreme weather events and changing climatic patterns. This study analyzes the causes and effects of climate change, evaluates the ongoing impacts, and explores the potential strategies for mitigation and adaptation. The review suggests that climate change in Pakistan has a significant impact on food security, water availability, and overall national stability, urging the need for immediate action at both governmental and societal levels to address these challenges.

Keywords: Climate change, Pakistan, environmental impact, agriculture, water resources, mitigation strategies, adaptation.

INTRODUCTION

Climate change refers to long-term alterations in temperature, precipitation patterns, and other climatic factors. Over the last few decades, the consequences of climate change have become increasingly evident across the globe. Pakistan, located in a region highly vulnerable to climate risks, is facing serious threats due to rising temperatures, erratic rainfall patterns, and frequent extreme weather events such as floods, heatwaves, and droughts. These climatic shifts are having a profound impact on the country's agricultural sector, water resources, public health, and socio-economic development.

Pakistan's unique geographical location, marked by coastal areas, mountain ranges, and fertile plains, makes it particularly sensitive to climate change. The region's reliance on monsoon rains for agriculture, the rapid melting of glaciers in the Himalayas, and the depletion of groundwater resources compound the challenges it faces. Moreover, the country's limited financial and

technological capacity for climate resilience exacerbates the potential impacts.

This review aims to consolidate the existing knowledge on the consequences of climate change in Pakistan, highlighting the key areas that are most affected, and proposing both local and global solutions to mitigate its effects. The discussion focuses on the impacts on agriculture, water resources, biodiversity, health, and socio-economic stability.

Climate change is an urgent global crisis with wide-ranging consequences for both the natural environment and human societies. Its impacts are becoming increasingly evident worldwide, and countries like Pakistan, with their fragile ecosystems and socio-economic vulnerabilities, are bearing the brunt of its adverse effects. Pakistan, ranked among the most vulnerable nations to climate change, faces an escalating array of environmental challenges that threaten its agriculture, water resources, health systems, and

economic stability. As a country that is heavily dependent on its natural resources and agriculture, the consequences of climate change for Pakistan are particularly severe.

Pakistan's Climate Profile

Located in South Asia, Pakistan's diverse geography spans from arid deserts and vast mountain ranges to fertile plains and extensive coastal regions. This variety, while contributing to its rich biodiversity, also means that the country's susceptibility to extreme weather events is particularly high. Climate change exacerbates existing natural hazards such as floods, droughts, heatwaves, and cyclones, disrupting ecosystems and posing significant risks to agriculture, infrastructure, and human well-being.

According to the Global Climate Risk Index (2021), Pakistan has been ranked among the top ten countries most affected by extreme weather events over the past two decades. This includes frequent and severe flooding, especially in the monsoon season, as well as devastating droughts, which significantly impact the country's food production and water availability. The melting of glaciers in the Himalayas, which feeds Pakistan's major rivers, adds to the severity of flooding while reducing the long-term availability of freshwater resources.

Impact on Agriculture and Food Security

Agriculture is the backbone of Pakistan's economy, employing approximately 40% of the workforce and contributing around 24% of the national GDP. However, this sector is highly vulnerable to climate change. The unpredictable nature of weather patterns, particularly erratic rainfall, increased frequency of droughts, and heat stress, significantly affect crop yields. Wheat, rice, cotton, and sugarcane—key agricultural products of Pakistan—are highly sensitive to changing climatic conditions.

Changes in the timing and intensity of rainfall not only lead to poor harvests but also decrease the water availability for irrigation, especially in the arid regions of the country, where farmers rely on river systems like the Indus for their crops. This, in turn, exacerbates food insecurity and threatens livelihoods in rural areas. Climate-induced disruptions to the agricultural supply chain, along with the escalating cost of inputs (such as water, fertilizers, and seeds), add additional pressure to an already vulnerable sector.

Water Scarcity and Energy Crisis

Pakistan's water resources are under severe stress due to climate change. The country relies heavily on surface water from the Indus River system, but climate change is leading to erratic river flows, reduced glacial meltwater, and more intense droughts. The unpredictable availability of water for irrigation, industrial use, and drinking poses

significant challenges to both urban and rural populations. At the same time, the demand for water is growing due to population growth, industrialization, and urban expansion, further intensifying the crisis.

Furthermore, water scarcity is intricately linked to Pakistan's energy challenges. A substantial portion of the country's energy production relies on hydropower, and the diminishing water supply has begun to threaten this energy source. The growing energy deficit is exacerbated by the increasing temperatures that necessitate higher demand for cooling, placing additional stress on the power grid. Inadequate infrastructure to store and manage water resources effectively, combined with the ongoing depletion of water reserves, creates a feedback loop where energy shortages and water crises are mutually reinforcing.

Health Impacts and Vulnerability of Populations

Climate change also poses a severe threat to public health in Pakistan. Heatwaves, which are becoming more frequent and intense, especially in urban areas like Karachi, can lead to direct health effects such as dehydration, heatstroke, and other heat-related illnesses. In addition to heatwaves, climate-induced changes in vector-borne diseases, such as malaria and dengue fever, are expected to increase due to shifts in temperature and rainfall patterns that create favorable conditions for mosquitoes and other disease vectors.

Moreover, climate-related natural disasters like floods and storms further strain Pakistan's already overburdened healthcare system. The destruction of health facilities, the displacement of people, and the contamination of water supplies can lead to outbreaks of waterborne diseases such as cholera and dysentery. Rural populations, women, children, and the elderly are especially vulnerable to these health threats, as they have limited access to healthcare and disaster preparedness.

Social and Economic Vulnerability

The social fabric of Pakistan is also under stress as the impacts of climate change disproportionately affect its poorer populations, especially those living in rural and semi-urban areas. The increasing frequency of natural disasters, loss of agricultural livelihoods, and deteriorating water resources contribute to socio-economic instability, displacement, and poverty. Vulnerable populations, including women, children, and ethnic minorities, bear the brunt of these socio-economic impacts, with reduced access to resources, education, and healthcare services.

Climate change-related migration is becoming an increasing concern. People displaced by extreme weather events often find it difficult to relocate due to a lack of opportunities in cities and urban centers. This forced



Key themes that were explored include:

1. **Agricultural Impact:** Review of studies documenting shifts in crop production, agricultural productivity, and vulnerability of smallholder farmers.
2. **Water Resources:** Analysis of how climate change affects freshwater availability, river flow patterns, and groundwater depletion.
3. **Health Consequences:** A study of emerging health threats like heatstroke, water-borne diseases, and vector-borne diseases as a result of changing weather patterns.
4. **Socio-Economic Impacts:** Exploration of how economic stability, poverty, and migration patterns are influenced by climate-related events.
5. **Mitigation and Adaptation Strategies:** A review of governmental and non-governmental efforts towards addressing climate change in Pakistan, including policies and climate action plans.

This multi-faceted review approach aims to provide a comprehensive understanding of climate change consequences in Pakistan and suggest avenues for policy interventions.

RESULTS

1. Agricultural Impact

Climate change is causing substantial disruptions in Pakistan's agriculture, which is highly dependent on the monsoon rains. The frequency and intensity of droughts have been increasing, while excessive rainfall has caused devastating floods, damaging crops and farmland. Major crops like wheat, rice, cotton, and sugarcane are particularly vulnerable. A report by the Food and Agriculture Organization (FAO) suggests that the agricultural sector could face a reduction in productivity of up to 30% due to climate change in the coming decades.

In addition to direct impacts from weather patterns, the rising temperature also exacerbates pest outbreaks and affects crop health. For instance, the cotton sector has been severely impacted by higher temperatures and prolonged droughts, leading to lower yields and reduced income for farmers. Furthermore, the retreat of glaciers in the northern regions of Pakistan threatens the future water supply for irrigation, creating further challenges for food production.

2. Water Resources

Pakistan is heavily reliant on the Indus River system for

its water supply. Climate change is altering the flow patterns of the river, leading to reduced water availability, particularly during the dry season. The melting of glaciers in the Himalayas, which provide approximately 75% of the river's flow, is accelerating. This is causing seasonal variations in river water levels and increasing the risk of flooding during monsoon periods.

Groundwater levels are also depleting rapidly due to over-extraction for irrigation, compounded by reduced replenishment during droughts. This has led to the salinization of aquifers and a reduction in drinking water availability for rural and urban populations.

3. Health Consequences

The health impacts of climate change in Pakistan are becoming increasingly severe. Heatwaves, which have become more frequent and intense, contribute to a higher incidence of heat-related illnesses, including heatstroke and dehydration. Furthermore, the changing climate creates favorable conditions for the spread of vector-borne diseases like malaria, dengue, and chikungunya.

Increased rainfall and flooding also lead to the spread of waterborne diseases, such as cholera and dysentery, due to contamination of drinking water sources. The healthcare system, already under strain, faces increased challenges in addressing these emerging health threats.

4. Socio-Economic Impacts

The socio-economic impacts of climate change are profound. As agriculture is a major source of livelihood for a large portion of the population, disruptions in crop production directly threaten food security and income. Poverty is exacerbated as farmers face increasing difficulty in sustaining their livelihoods.

In addition to agricultural impacts, migration patterns are also being influenced by climate change. Rural populations, particularly in the most affected regions like Sindh and Balochistan, are increasingly migrating to urban centers in search of better opportunities. This urbanization strain creates additional social and economic challenges, such as pressure on housing, infrastructure, and employment opportunities.

5. Mitigation and Adaptation Strategies

Pakistan has initiated several strategies to address the consequences of climate change. These include both mitigation measures, such as the promotion of renewable energy sources (e.g., solar and wind power), and adaptation strategies aimed at enhancing the resilience of communities and ecosystems.

The Government of Pakistan has developed a National

Climate Change Policy, which outlines steps for reducing emissions, promoting sustainable agriculture, and improving water management. Additionally, the country is focusing on disaster management and building early-warning systems to reduce the impact of extreme weather events.

However, the implementation of these strategies remains challenged by a lack of funding, insufficient technological infrastructure, and political instability. There is a need for stronger collaboration between the government, non-governmental organizations, and international partners to enhance the effectiveness of these efforts.

DISCUSSION

Climate change in Pakistan is already causing significant challenges across various sectors. The agricultural sector is under threat due to changing weather patterns, which will likely lead to greater food insecurity in the future. Water resources are becoming increasingly scarce, and the retreat of glaciers poses an additional long-term risk to water availability. Public health is being affected by both direct (heatwaves) and indirect (disease outbreaks) consequences of climate change.

The socio-economic implications are also severe, with rural populations facing displacement due to climate-induced disasters and agricultural losses. While the government has taken steps to address these challenges, the lack of effective implementation, sufficient funding, and policy coherence limits the success of these measures.

The consequences of climate change in Pakistan are a wake-up call for policymakers and the international community. There is an urgent need for increased climate resilience efforts, stronger collaboration with international bodies, and greater investment in adaptation strategies. Pakistan must also strengthen its infrastructure and policies to ensure that climate adaptation and mitigation efforts are effective in the long run.

The consequences of climate change in Pakistan are multidimensional, affecting nearly every aspect of life, from agricultural productivity and water availability to public health and socio-economic stability. In this section, we explore the complex interplay between these factors and discuss the potential pathways for mitigating and adapting to these challenges.

Agriculture: The Backbone of Pakistan's Economy Under Threat

Pakistan's agricultural sector has long been a cornerstone of its economy, but it is under severe stress due to climate change. Agriculture is heavily reliant on water resources, and Pakistan's dependence on irrigation from the Indus

River system places the sector at high risk. Climate change has already disrupted the timing and intensity of rainfall patterns, leading to the misalignment of crop growing seasons and water scarcity.

Heat Stress and Crop Yield Reduction

The increasing frequency of extreme temperatures, especially during summer months, is particularly harmful to crops like wheat, rice, and cotton, which require specific temperature ranges for optimal growth. Rising temperatures can lead to "heat stress," where plants fail to produce sufficient yields, or crops may even be entirely destroyed. For instance, wheat yields are expected to decline significantly in the coming decades due to higher temperatures during the flowering and grain filling stages, crucial for wheat productivity. This threatens food security, as these staples are not only central to Pakistan's food supply but are also critical exports to international markets.

Droughts and Water Scarcity

Droughts are becoming more frequent and prolonged in Pakistan, exacerbating water scarcity. Since most agricultural activities in Pakistan rely on irrigation from the Indus Basin, the reduced water flow from glacial melt, coupled with shifting monsoon patterns, places enormous pressure on water resources. In the past, Pakistan's irrigation system was sufficient to meet the needs of its crops, but as river flows decline and demand increases, there are signs of a looming water crisis. This could lead to crop failures, particularly in regions like Sindh and Punjab, which are highly dependent on the Indus River. Furthermore, groundwater levels are dropping, making it increasingly difficult to use alternative sources for irrigation, thus compounding the crisis.

Sustainability of Livelihoods in Rural Areas

In rural Pakistan, where a large percentage of the population is engaged in subsistence farming, the impact of climate change on agriculture directly threatens livelihoods. Many farmers lack access to the capital needed to invest in climate-resilient crops, irrigation systems, or insurance, which leaves them vulnerable to the economic impacts of crop failure. Additionally, the loss of agricultural productivity may lead to food insecurity, forcing farmers to migrate to urban areas, putting further strain on cities that are already under significant pressure due to overpopulation.

Water Resources: The Crux of Pakistan's Environmental Crisis

Water scarcity has emerged as one of the most pressing challenges of climate change in Pakistan. With glaciers in the Himalayas serving as a major source of water for

the Indus River system, the accelerated melting of these glaciers, combined with erratic rainfall, is diminishing the availability of freshwater. This not only threatens agriculture but also has a direct impact on human populations, industry, and energy production.

Impact on Hydropower and Energy Production

A significant portion of Pakistan's energy supply comes from hydropower plants located along the Indus River. As river flows decline due to both reduced glacier melt and irregular rainfall patterns, the potential for generating hydropower diminishes. This exacerbates Pakistan's already precarious energy crisis, which is characterized by a growing gap between demand and supply. Power shortages in urban areas, coupled with increasing energy demands for cooling during hotter summers, are likely to disrupt daily life and hinder industrial productivity.

Waterborne Diseases and Public Health

The reduction in clean water availability also increases the risk of waterborne diseases, particularly in regions where sanitation infrastructure is weak. Flooding, as a result of extreme weather events, further exacerbates the contamination of drinking water supplies, leading to outbreaks of diseases such as cholera, typhoid, and dysentery. In Pakistan's rural areas, poor sanitation combined with limited access to healthcare makes vulnerable populations more prone to these diseases.

Increased temperatures and erratic water supplies also encourage the proliferation of mosquitoes, leading to a rise in vector-borne diseases like malaria and dengue fever. These diseases are expected to spread into new areas as the geographic range of mosquito populations extends with climate warming.

Public Health: Heatwaves, Disease, and Vulnerable Populations

Pakistan's population is particularly vulnerable to the health impacts of climate change due to inadequate healthcare infrastructure, poverty, and socio-economic inequality. Health systems in both urban and rural areas are already overstretched, and the additional burden posed by climate-induced diseases could overwhelm the system.

Heatwaves

Heatwaves are among the most direct and immediate impacts of climate change in Pakistan. In cities like Karachi, where temperatures regularly exceed 40°C (104°F) during the summer months, the risk of heatstroke and dehydration has increased significantly. The vulnerability of the population is heightened by poor urban planning, lack of green spaces, and inadequate cooling systems. Poor communities, particularly those

living in informal settlements, are disproportionately affected as they have limited access to air conditioning and basic healthcare facilities. The urban poor, who often work outdoors or in poorly ventilated environments, are most at risk.

Vector-borne Diseases

In addition to heatwaves, climate change facilitates the spread of vector-borne diseases. Pakistan has witnessed an increase in the incidence of diseases like dengue, malaria, and chikungunya in recent years, driven by rising temperatures and altered rainfall patterns. These diseases, particularly dengue fever, are often more prevalent during and after periods of heavy rainfall, which creates breeding grounds for mosquitoes. In the absence of sufficient public health infrastructure, these diseases continue to spread, further straining healthcare resources.

Disaster-Induced Health Crises

Flooding and other extreme weather events can trigger secondary health crises by displacing large populations and damaging healthcare infrastructure. For example, in the aftermath of the catastrophic floods of 2010, Pakistan saw outbreaks of waterborne diseases, and displaced populations struggled with inadequate access to medical care, clean water, and food. In many cases, emergency relief efforts were delayed or insufficient, further compounding the suffering of the affected populations.

Social and Economic Impacts: Vulnerability, Displacement, and Poverty

The socio-economic impacts of climate change in Pakistan are equally profound. While Pakistan is still an agricultural economy, rapid urbanization has meant that a significant portion of the population now lives in cities. Climate change impacts in rural areas force people to migrate to urban centers, creating new challenges for urban planning, employment, and social integration. Cities like Karachi, Lahore, and Islamabad face the dual burden of climate-induced migration and inadequate infrastructure, exacerbating social and economic disparities.

Migration and Displacement

Climate-induced displacement is a growing concern in Pakistan. Many people, particularly farmers in rural areas, are forced to leave their homes due to droughts, floods, and the destruction of agricultural land. These displaced individuals often migrate to already overburdened urban areas, leading to overcrowding, pressure on infrastructure, and social conflict. The influx of climate refugees can strain existing services such as healthcare, education, and housing, increasing competition for jobs and resources in cities.

Economic Losses and Poverty

Climate change exacerbates existing socio-economic inequalities, especially in rural areas where poverty is already widespread. Economic losses from crop failures, livestock deaths, and loss of livelihood directly contribute to the worsening poverty cycle. The agricultural sector's vulnerability to climate change not only impacts farmers but also affects related industries, including food processing, distribution, and retail. As agriculture is the primary source of income for millions of Pakistanis, the shrinking agricultural sector deepens the poverty trap and limits opportunities for upward mobility.

Conclusion and Pathways Forward

The consequences of climate change in Pakistan are vast and multifaceted, with significant implications for agriculture, water resources, public health, and socio-economic stability. Given the severity of these impacts, it is critical for Pakistan to adopt an integrated approach to both mitigation and adaptation. Mitigation strategies—such as reducing greenhouse gas emissions through renewable energy adoption and sustainable land management—are essential for addressing the long-term risks of climate change. At the same time, adaptation strategies must be implemented to build resilience to the immediate impacts of climate change.

Adaptation measures in Pakistan must include improving water management systems, enhancing agricultural resilience through climate-smart farming techniques, and investing in disaster preparedness and public health infrastructure. Furthermore, Pakistan must strengthen its climate governance framework and ensure the active participation of local communities, particularly those most vulnerable to climate change.

In conclusion, Pakistan's ability to navigate the challenges posed by climate change depends on the implementation of both short-term and long-term strategies, as well as a collective effort from all sectors of society. The window of opportunity to mitigate the worst effects of climate change is rapidly closing, and immediate action is needed to safeguard the future of Pakistan's environment, economy, and people.

CONCLUSION

Climate change is one of the most critical challenges facing Pakistan today. The impacts on agriculture, water resources, public health, and socio-economic stability are already being felt, and without immediate and comprehensive action, the situation will worsen. The government has developed several policies and strategies to address these challenges, but the lack of effective implementation and coordination continues to hinder progress.

This review emphasizes the need for enhanced climate resilience, better resource management, and improved disaster response mechanisms. In addition, international cooperation and financial support will play a critical role in ensuring Pakistan's capacity to adapt to the changing climate. By focusing on both mitigation and adaptation strategies, Pakistan can build a more sustainable future despite the challenges posed by climate change.

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