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ANALYZING THE EFFECTS OF CLIMATE CHANGE ON WATER RESOURCES IN AZAD JAMMU AND KASHMIR: FARMERS' PERCEPTION, AWARENESS, AND ADAPTATION PRACTICES

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Abstract:
A significant source of freshwater on Earth is the Himalayan area. It is anticipated that climate change would lead to a rise in the frequency and severity of the present severe weather events as well as new vulnerabilities with varying socioeconomic and geographical implications on populations. For developing nations like Pakistan, the effects would be more catastrophic. The primary sources of freshwater in Azad Jammu and Kashmir (AJ&K) are glacier melt, snowfall, and monsoon rains, all of which are very vulnerable to climate change. Both the monsoon rains' pattern, regions, and intensity as well as the snowfall season are evolving. This project has the potential to influence both academic discourse and practical policymaking, ensuring that the water resources in AJK is better equipped to withstand the challenges posed by climate change. It is designed not only to address immediate knowledge gaps but also to lay the foundation for future research on climate resilience in similar rural and mountainous contexts.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) asserts that the effects of climate change are extensive, permeating every region of the world and having a significant impact on both natural and human systems (IPCC, 2014). The consequences of these shifts are extensive, impacting not only water resources but also agricultural output, ocean acidity, and biodiversity loss. (Ahmed *et al.* 2020) Furthermore, there are serious risks to people's health, safety, and way of life due to the increased frequency and severity of catastrophic climate changes including storms, floods, and droughts (Dars *et al*. 2021)

Pakistan is ranked fifth among the nations most susceptible to climate change. This ranking is based on the Global Climate Risk Index. Pakistan saw 152 extreme weather events, 9,989 fatalities, and $3.8 billion in economic losses between 1999 and 2018. Based on these statistics, the think tanks came to the conclusion that Pakistan is becoming more vulnerable to climate change over time (David Eckistein *et al*. 2021).

There is a close connection between water and climate change. The effects of climate change on water across the globe are complicated (Gadiwala and Burke 2019). The majority of climate change's effects are related to water, including variable rainfall patterns, melting ice sheets, increasing sea levels, floods, and droughts (Ahmed *et al.* 2020).

Climate change poses significant threats to water resources globally, with Pakistan being particularly vulnerable (Dars *et al*. 2021). The country's water supply heavily relies on the Indus River, which is sensitive to climate-induced changes in glacial melt and precipitation patterns (Dars *et al.* 2021). Rising temperatures and altered rainfall patterns are expected to impact water availability, with projections ranging from -12% to +24% by 2050. These changes will likely affect agricultural production, increasing food imports (Zhu *et al*. 2013). Pakistan's per capita water availability has drastically decreased from 5140 m3 in 1950 to 1000 m3 currently, approaching water scarcity levels. The country has experienced severe floods and droughts in recent decades, further straining water resources (Hussain & Mumtaz, 2014). To address these challenges, experts recommend implementing integrated water management

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strategies, improving water-use efficiency, and developing climate change adaptation measures (Dars *et al*. 2021; Zhu *et al*. 2013; Ahmad *et al*. 2020; Hussain and Mumtaz 2014).

The state of Azad Jammu & Kashmir is a delicate area that is susceptible to the adverse effects of climate change. Landslides, floods, and drought in regions receiving precipitation are examples of how climate change is affecting the environment (Ali 2024). The State's physical infrastructure and natural resources are under jeopardy as a result of these climate effects, which is concerning for the economy.

The research gap for this study lies in the limited understanding of how farmers in Azad Jammu and Kashmir (AJK) perceive, are aware of, and adapt to climate change, particularly in a geographically diverse region. While global and regional studies have explored farmers' adaptation strategies and awareness in response to climate variability (e.g., Adger *et al*. 2018; Poteete, Janssen, & Ostrom, 2010), specific insights into AJK, a region with unique socio-economic and environmental challenges are scarce. Existing research often generalizes findings across larger areas, neglecting the localized barriers faced by farmers in AJK, such as financial constraints, limited access to information, and institutional weaknesses. Moreover, there is insufficient empirical evidence on how these farmers' perceptions shape their adaptive behaviors. This study aims to fill this gap by employing robust econometric analysis to explore the interplay between climate change awareness, perception, and adaptation strategies among AJK's farming communities, contributing to targeted policy interventions.

Review of literature

Climate change poses significant threats to water resources in Azad Jammu and Kashmir (AJ&K) and surrounding regions. Rising temperatures are accelerating glacier melt, increasing the risk of Glacial Lake Outburst Floods and altering water availability patterns (Ali, 2024). These changes impact various sectors, including agriculture, ecosystems, and human health (Ameen *et al.* 2023). The decreased snowfall is affecting water supplies and agricultural practices in AJ&K and Gilgit-Baltistan (Ali 2024). Climate change is also expected to shift vegetation distributions, with some plant communities expanding while others contract (Akbar and Gheewala 2020). The region faces additional challenges such as pollution, freshwater scarcity, and conflict-related infrastructure damage (Zaman *et al.* 2023). Addressing these issues requires integrated strategies, including improved water resource management, infrastructure resilience, sustainable agriculture practices, and enhanced early warning systems. Collaboration across sectors, investment in climate science, and community empowerment are essential for mitigating climate change impacts and ensuring sustainable water resource management in the region (Ali 2024; Zaman *et al*. 2023).

Farmers in the Himalayan regions generally perceive climate change as increasing temperatures, decreasing precipitation, and more erratic weather patterns (Kaushal 2019). These perceptions align with observed climate data showing warming trends and decreasing rainfall (Mahdi *et al*. 2021). The impacts of climate change on agriculture include altered farming seasons, reduced crop yields, and increased pest incidence (Wani *et al*. 2020). However, some areas have experienced benefits, such as extended growing seasons allowing for increased cropping intensity (Wani *et al*. 2020). Farmers' adaptation strategies include changing cropping patterns, using resistant crop varieties, and modifying agronomic practices (Mahdi et al. 2021). The perception of climate change impacts varies among farmer types, with low-resource subsistence farmers experiencing stronger effects on food security and income. Many farmers lack awareness of climate change causes and face constraints in implementing adaptation measures (Shukla *et al.* 2019).

Research indicates widespread awareness of climate change among farmers in Pakistan, with 58-75% of surveyed farmers recognizing its impacts (Abid *et al*. 2016). Farmers perceive

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changes in temperature, rainfall patterns, and shifting seasons as key climate change indicators (Sharma et al. 2018). These changes significantly affect water resources, prompting farmers to adopt various adaptation strategies. Common adaptations include changing crop varieties, adjusting planting dates, crop diversification, and modifying irrigation practices (Fahad and wang 2020). Factors influencing farmers' awareness and adaptation choices include education, farming experience, land ownership, access to information, and extension services (Mehmood *et al*. 2022). However, adaptation efforts are constrained by lack of information, financial resources, and water scarcity (Abid *et al*. 2016). These findings underscore the need for improved farmer education and institutional support to enhance climate change adaptation in Pakistan's agricultural sector.

Farmers in Pakistan are increasingly aware of climate change impacts on agriculture, including temperature fluctuations, droughts, shifting rainfall patterns, and severe floods (Ullah et al. 2019). To adapt, farmers employ various strategies such as changing crop varieties, adjusting planting dates, diversifying crops, modifying fertilizer use, planting shade trees, and altering irrigation methods (Khoso *et al*. 2024). Factors influencing adaptation include education, farm experience, land ownership, access to information, and institutional support. However, farmers face barriers like lack of information, financial constraints, and limited access to resources (Saddique *et al*. 2022). The impacts of climate change vary across regions, with wetland areas experiencing less volatility than arid regions. Improved understanding of climate change impacts and adaptation strategies is crucial for enhancing farmers' resilience and protecting their livelihoods (Ullah et al., 2019).

Climate change intensifies extreme weather events including droughts, floods, heat waves, and storms. Sea levels are rising, posing a serious threat to coastal towns, as seen by the melting of ice caps and glaciers brought on by rising global temperatures (World Health Organization 2019). The North Atlantic is seeing a rise in the frequency of severe storms, which puts people, infrastructure, and economies at serious danger (Kossin *et al*. 2020). Every year, severe weather events lead to significant disruptions in the supply of food and water, damage to property, and significant financial losses totaling billions of dollars. Moreover, worldwide agricultural production is significantly impacted by changes in climatic patterns. Changes in temperature and precipitation can negatively impact agricultural productivity and food security in regions that rely heavily on agriculture (Lobell *et al*. 2011). This increases the price of food globally and favors poverty and hunger, particularly in developing countries. Most people understand climate change based on their own knowledge, experiences, and the accompanying costs and benefits (Lorenzoni and Pidgeon 2006).

The World Health Organization (WHO) projects that between 2030 and 2050, the death rates from heat stress, diarrhea, malnutrition, and malaria would significantly increase due to climate change (World Health Organization, 2019). This highlights how urgently a comprehensive plan is needed to address the wide-ranging and significant effects. Pakistan is particularly vulnerable to the consequences of climate change. Extreme weather events are becoming more frequent, monsoon patterns are changing, and the Himalayan glaciers are melting, among other climate-related issues facing the nation. Pakistan's water supplies, agriculture, and general socioeconomic stability are all seriously threatened by the changes (Khan *et al*. 2020).

Pakistan's glaciers are essential to the nation's supply of freshwater. They provide the Indus River system, which is necessary to meet millions of people's needs for drinking water and agriculture. Communities downstream are at serious risk of sudden and catastrophic flooding due to the increased probability of glacial lake outburst floods (GLOFs) brought on by the acceleration of glacier melting brought on by rising temperature (Immerzeel *et al*. 2020).

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Pakistan's agriculture sector, which employs a sizable portion of the labor force, is particularly susceptible to the effects of climate change. Crop productivity and food security are negatively impacted by changes in precipitation patterns, increased frequency of droughts, and unusual weather events. Rainfall variations create a susceptible ecosystem by generating catastrophic floods or severe droughts (Shahzad *et al*. 2019). The coastal areas of Pakistan are also under risk from increased cyclonic activity and sea level rise. Cities with dense populations and significant economies, like Karachi, are particularly susceptible to the risks presented by storm surges and shoreline erosion. This disrupts infrastructure and economic operations in addition to endangering human life (Rizvi *et al*. 2015). Climate change has serious socioeconomic repercussions in Pakistan. Disasters brought on by climate change exacerbate the nation's already high rate of poverty by displacing people, reducing food yields, and taxing available resources. Health risks associated with climate change also include the potential for vector-borne illnesses like dengue fever and malaria to spread more widely as a result of altered precipitation and temperature patterns (Khan *et al*. 2020). Therefore, human activity is the primary driver of climate change, a worldwide issue with significant social, economic, and environmental repercussions. Addressing this issue requires thorough knowledge, sensible legislation, and international action. When determining the degree of understanding and the scope of action done to address climate change, the impact of public perception is crucial. A research to better understand views regarding climate change was carried out in a worldwide comparison comprising 19 nations. Given this, Pakistan's values are centered in the middle. According to a research done in Pakistan, eight out of ten people, or a sizable portion of the population, are concerned about the implications of climate change (Asad *et al*. 2023). It's interesting to note that the study also shows that women and those with more education exhibit higher degrees of worry. More than 80% of parents in Pakistan who participated in a survey said they were concerned about how climate change might affect their kids, although this was not always their top worry. It was ranked as one of the top three problems confronting the nation by less than 25% of parents (Asad *et al*. 2023). The attitudes, beliefs, and values of people have a significant impact on their behavior, according to behavioral science and psychology studies (Steg and Vlek 2009). People who care about climate change, are more likely to engage in pro-environmental behaviors like cutting back on energy use, taking public transit, and supporting renewable energy projects (Bamberg and Moser 2007). Furthermore, opinions polls and political outcomes can be influenced by popular views of climate change, which can then have an impact on policy decisions. Policymakers and politicians usually modify their goals in reaction to popular sentiment, particularly in democracies where public opinion is very influential (Jagers and Matti 2010). Therefore, making educated decisions, finding solutions, and addressing policy concerns all depend on having a solid grasp of climate threats. With the use of surveys and response analysis, this study seeks to uncover the complex variables that affect people's perceptions and understandings of climate change in various parts of Pakistan.

Climate changes scenario in Pakistan

The impacts of climate change are widely apparent, especially as a result of global warming. In the future, climate change's harmful consequences are probably going to be more severe (Shahvari *et al*. 2019). The repercussions of climate change vary around the world, but they are particularly bad in developing nations (Rahman and Lateh 2017), due to a variety of factors, including inadequate institutional capabilities, a lack of awareness and understanding of effective measures, a lack of resources and their improper use, and unfavorable economic conditions (Ullah et al. 2019). In the upcoming years, the Intergovernmental Panel on Climate Change (IPCC) has forecast that it would have detrimental effects on natural resource

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depletion, human-caused activities, and natural disasters. Globally, the hydrologic reserves and biological systems were altered by El Nino and La Nina. The temperature increased by 0.4 °C between 1895 and 1995. Heat waves and relatively hotter days and nights are examples of extreme weather conditions brought on by the skyrocketing temperatures (Meehl and Tebaldi 2004; Rauf *et al*. 2017). Pakistan will also be particularly affected by climate change because of its rapidly melting glaciers, droughts, floods, and declining hydrological reserves (Chaudhry *et al*. 2009). Temperatures in Pakistan are expected to increase from 0.9 to 1.5 °C between 2020 and 2050. The worst droughts ever experienced by Pakistan occurred in 1998 and 2004 (Hussain and Mumtaz 2014), and its largest province Baluchistan was badly affected, 84% of its population was directly affected, killing 76% of livestock; similar to provincial effects, the whole country suffered greatly by massive floods displacing a large number of people in its northern as well as central parts (Chang 2014; Ullah *et al*. 2018). In the upcoming years, there will probably still be hot weather, extreme droughts, insect infestations, health issues, and changing lifestyles (Hussain *et al*. 2018). Climate change will have dangerous effects on many regions of the world, including increased mercury, more frequent famines, altered rainfall patterns (IPCC 2014b, c), and agricultural damage (Rosenzweig *et al*. 2014). Climate change will have devastating repercussions on agricultural nations like Pakistan, where per capita income is already low and there is inadequate capacity building (Balkhair *et al*. 2018). Pakistan's economy depends heavily on agriculture, which produces 80% of its exports and has a lot of arable land. Northern snowfall and glacier melting provide the water for two-thirds of Pakistan's arable land. The agricultural industry employs over two-thirds of Pakistan's population, yet the country still lacks the appropriate infrastructure needed to adapt to and mitigate the consequences of climate change (World Bank 2013). Pakistan's geographic position, increased reliance on agriculture, high dependency on water resources, and lack of preparedness for climate emergencies put the country at risk of experiencing the consequences of climate change (Balkhair et al. 2018; Malik et al. 2012). Furthermore, not all regions will likely be affected uniformly by climate change (Malik et al. 2012), and there is a worrying concern that it will have a more severe impact on poor farmers in rural areas (Ali and Erenstein 2017). The 2010–2011 floods are a sign of the vulnerabilities that farmers in rural areas face as a result of climate change (Gorst et al. 2015). The majority of people in mountainous regions of developing nations rely on natural resources for their livelihoods. Climate change is therefore a serious threat to the country's economy and rural livelihoods (Mukwada and Manatsa 2018). The majority of people in mountainous regions of developing nations rely on natural resources for their livelihoods. Climate change is therefore a serious threat to the country's economy and rural livelihoods. According to Hussain et al. (2020), the majority of the population has been hampered by floods, droughts, and excessive temperatures, and the average number of affected individuals has grown since 2010. More than a million people were impacted by floods alone in 2012 and 2014, which left the populace in disarray. Because to the ongoing efforts of people, non-profits, and environmentalists to mitigate and adapt to climate change, the number has decreased below one million since 2015 (Hussain et al 2020).

Natural calamities and socio-economic impacts of climate change

The effects of climate change include water shortages and threatened food security, which lead to social unrest and political unrest as well as global migration (Ellison et al. 2017; Kelley et al. 2015). Thousands of millions have been affected by uneasy access to drinkable water (Mekonnen and Hoekstra 2016) and severe heat strokes (Fischer and Knutti 2015). Continental interior regions are probably going to be impacted by rising temperatures (Dimri et al. 2018; Mannig et al. 2018). Many planted species are projected to go extinct as a result of climate change brought on by rising mercury, increased glacier melting, and a shortage of water

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supplies (Gampe et al. 2016; Shaffril et al. 2018). However, the rising sea level is threatening to destroy the coastal ecology (Perera et al. 2018; Phillips 2018). Climate change, insect infestations, health problems, and seasonal and lifestyle shifts are all stubbornly happening and are likely to continue in the future (Hussain et al. 2018). Pakistan is being particularly hard hit by a lack of adequate infrastructure and a lack of adaptability (IPCC 2013). Along with the above listed problems, the general public's concerns are being quickly exacerbated by a lack of environmental education and awareness, traditional consumer behavior, a lack of incentives, a lack of legislation, and a lack of government attention to climate change.

By 2050, there might be serious consequences from a 2–3% rise in mercury and a notable shift in rainfall patterns (Gorst et al. 2015). Pakistan has suffered significant financial losses as a result of environmental and natural disasters, including lower agricultural yields, system restoration, and the reconstruction of essential infrastructure (Ali and Erenstein 2017). In addition, Punjab has experienced a rise in traffic accidents as a result of poor visibility and eye and skin illnesses brought on by pollution during the last three to four years.

Climate change impacts on Agriculture, Livestock, and Forestry

Climate change is predicted to worsen the agricultural sector's problems (Rosenzweig et al. 2014), as much of the world—including Pakistan (Habib et al. 2018)—is projected to experience extreme weather events including skyrocketing temperatures and changes in rainfall patterns (IPCC 2014b, c). Climate change in agricultural regions interacts with the effects of agricultural production-boosting activities, impacting crop yields and productivity in many ways that vary depending on the agricultural systems' practices (Abrahão and García-garizábal 2015). Since crops in tropical nations have already reached the point at which they can withstand heat and drought, the consequences of climate change, such as rising temperatures, may result in decreased agricultural yields (Agriculture Development 2008).

Lowlands are expected to be harmed by regular floods, rising sea levels, and salinization of subsurface water. The decrease in snowfall and quick melting of glaciers are anticipated to generate drought-like conditions due to the lack of water for agricultural crops (IFAD 2013). The climatic conditions are generated by an arid and hot environment, which is the major source of floods and droughts, severely reducing agricultural production (Yu et al. 2013). Agriculture is the sector that has high sensitivity to climate change, since it both influences and is affected by climate change concurrently (Balkhair et al. 2018).

Changes in rainfall patterns and rising mercury levels in the Indus Basin may reduce fresh water supplies, affecting the agriculture sector and Pakistan's whole economy. Furthermore, the Indus Basin's indigenous genetic crop types are on the edge of extinction. Water waste has also resulted from a lack of sophisticated irrigation systems for agriculture areas (Hussain et al. 2016). Local populations of the Upper Indus Basin also observed an increase in drought-like conditions between 2001 and 2011, resulting in contraction of agrarian area, degradation of soil quality, and loss in agricultural output as well as animals (Hussain et al. 2016). Rural livelihood and cash crops such as cotton, wheat, rice, and sugarcane have been affected throughout the years due to harsh weather and climatic changes (Abid et al. 2015). Keeping this in mind, it is necessary to examine farmers' vulnerabilities and the extent to which they are affected by climate change. A thorough plan should be developed to raise farmers' knowledge of climate change.

Livestock is critical in Pakistan for providing a living for locals, and climate change is having a significant impact on this industry. Climatic upheavals have a significant influence on animals, creating contagious and potentially lethal infections. Climate change has an impact on feed, water, fodder, and rangeland for livestock grazing, resulting in a significant decrease in meat and dairy output. Disease vectors, feed quality and quantity, and biodiversity all have a

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significant impact on cattle (Hamid 2015; Melissa et al. 2017). Rising temperatures and massive CO2 concentrations in the atmosphere have led to the extinction of many plant and animal species (Abas et al. 2017).

Many man-made problems, including drought, floods, land sliding, and global warming, are affecting Pakistan's forests. Insect assaults on the dying trees were shown to manifest as wood fragments and mud mixed rubble in stem-eaten voids. In Pakistan's Punjab province, certain tree species, including oak and rosewood, have been shown to dry up to the point of extinction between 1999 and 2008 (Abas et al. 2017).

Impacts of climate change on Food and Energy Security

Like the rest of the world, Pakistan is suffering greatly from climate-related issues related to food, water, and energy security (Imran et al. 2016). Due to the effects of climate change, a number of factors are hurting poverty and food security, and these problems will only increase in frequency in the days ahead (Panel et al. 2007). South Asia is home to more than 300 million undernourished people, making it the area with the highest rates of food insecurity worldwide (FAO 2012). Since climate change and weather changes affect Pakistan's major economic sector, they are to blame for the country's rising rates of poverty and lack of food security (Ali and Erenstein 2017).

The possible threat of water scarcity worldwide and atmospheric temperature variations are two current effects of climate change that are getting worse. With colder winters, hotter summers, drier deserts, and more rain and snowfall, many parts of the world are experiencing greater weather and climatic variability. A minimum of 1° increase in temperature is predicted for 2040–2059, which might lead to river overflow and the melting of ice glaciers in Pakistan's central area. Because of this rise in temperature, the southern region is vulnerable to droughts and resource shortages. According to Hussain et al (2020) the thermal increase in the country in May will lead to warmer summers and decrease in temperature in October could result in colder winters. The country's average temperature will rise by a disastrous 2.5 percent between 2040 to 2059 if present GHG emissions continue. Additionally, the impact of climate change on cereal output has a significant negative influence on Pakistan's food security.

Food crops may be severely impacted by changes in mercury levels and water availability. Unexpected precipitation during the planting and harvesting seasons has a significant negative influence on Pakistan's primary food crops. Although Pakistan's hilly regions are endowed with an abundance of natural resources, they are not adequately managed in terms of both agricultural production and activities. Farmers' suffering is being made worse by floods, dry spells, and unpredictable precipitation. Another problem is the rise in crop pests. Because of the threatened food security, people living in mountainous regions have become more reliant on plain areas (Hussain et al. 2016). To ensure food security and rural livelihood, appropriate mitigation and adaptation strategies must be implemented at the farm level (Abid et al. 2015). The fact that farmers, who are the primary constituents, will be responsible for covering the adaptation expenses alone, however, presents a significant obstacle at the local level. To guarantee food security, effective solar energy technology and contemporary local water management strategies may be required (Hussain et al. 2016) as well as a reduction in CO2 emissions. When farmers embraced modern farming methods, their levels of food security increased (8–13%) and poverty decreased (3–6%) (Ali and Erenstein 2017). It was shown that more methods were adopted by the more knowledgeable and experienced farmers than by the relatively less knowledgeable and inexperienced ones (Abid et al. 2016a).

Rapid economic growth, industrialization, and urbanization forced the government to take short-term steps to meet its energy needs using thermal energy. This short-term approach is

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having a lot of effects on the balance of payments, energy security, and environmental damage. However, because there is a 3000 MW electrical shortage, the administration is still having difficulty handling the energy issue (Lin and Ahmad 2017). Loopholes in planning deepened the demand-supply gap (GoP 2014). However, many experts have noted that the rise in urbanization has increased energy demand, which in turn is causing carbon emissions (Ali and Nitivattananon 2012; Cole and Neumayer 2004;York2007).

The problem is particularly bad in Pakistan because of the nation's lengthy history of uncontrolled development, which has had a detrimental effect on the socioeconomic structure of the nation, particularly in metropolitan areas (Hussain et al. 2018). Energy consumption is rising due to an increase in vehicle use, which eventually threatens the environment and energy security. However, in the study publications about Pakistan, the idea of GHG emissions and energy security from road transportation is overlooked. Pakistan urgently needs to strike a balance between increasing economic growth and enhancing energy security and environmental sustainability (Lin and Ahmad 2016). It is also a fact that, in comparison to conventional renewable energy resources, Pakistan's natural renewable energy resources have enormous potential (Sheikh 2010), as Pakistan is situated in a natural rich energy zone which has a capacity to generate 2.9 million MW of electricity from wind and solar. Moreover, the reduction in emissions must be the main agenda in the formulation of policies to curb CO2 emissions and their impactsThe idea of smart grids, smart cities, and smart buildings has been introduced in an effort to reduce everyday greenhouse gas emissions and provide energy security. Rice, wheat, cereals, vegetables, spices, and grains are among the crops in Pakistan that are sensitive to the climate. Rising temperatures, decreased crop yield, and altered rainfall patterns are all contributing to issues with food security (Li and Yap 2011).

Impacts of climate change on Society

Climate change has several consequences for the environment as well as in socioeconomic fabric and affects society in many ways, and society must pay the price of these implications in the socioeconomic sectors, i.e., health, clean air, food, water, housing, and diseases. Untimely deaths, human health problems, and food are directly affected by the changes in climate in the twenty-first century (Li and Yap 2011). Every year, natural disasters including earthquakes, heat waves, floods, and droughts claim lives all across the world, including in Pakistan. The population's health is negatively impacted by climate change in a number of ways, particularly due to the ongoing yearly temperature increases that cause global warming and the highest temperature ever recorded in Pakistan's southern areas. Due to its proximity to the equator, the southern region of Pakistan is widely thought to be at risk of negative heat consequences from global warming. However, with a modest yearly temperature increase, Punjab (in the central part of Pakistan) is experiencing extreme heat and humidity waves. Additionally, the duration of heat waves rose by 31 days between 1980 to 2007 (Sultana et al. 2009). The central and northern parts of Pakistan are expected to be the most sensitive to the negative effects of climate change, with potential temperature increases of up to 4% in the center area, over 3% in the northern region, and around 1% in the southern region by 2050 (Hussain et al 2020).

It is anticipated that rising unemployment and a restrictive labor market will soon be the economic effects of climate change in developing nations. Almost one billion people work in agriculture, making it one of the oldest professions in human history and the second most human capital-intensive industry after the services sector. Unpredictable rainfall patterns, rising temperatures, frequent floods and droughts, deforestation, and unpredictable weather patterns are all predicted to pose threats to the agriculture industry in the future. It is anticipated that the perilous circumstance would have a detrimental effect on the farm industry and its

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workforce (Olsen 2009). Migration, which may be described as the reallocation and displacement of a race owing to dangerous conditions for life and employment due to natural or human causes, is one strategy for mitigating and adapting to climate change (IOM 2014). It is evident that climate change has affected schooling in addition to location. The population's education is impacted by the temporary disruptions to everyday life brought on by extreme weather events, such as hurricanes, flash floods, and unexpected rains and storms. It is widely held that calamities like regular floods are more likely to occur if the current climatic trends continue (Kara and Yucel 2015). Long-term effects of climate change on education include food shortages and crop scarcity brought on by famines, droughts, and extreme heat waves (C. Change 2017). Similar to worldwide issues, Pakistan is experiencing the effects of climate change through increased illness incidence, mass migration, and competition for daily-wage jobs. These effects are caused by severe weather events such heat waves, droughts, floods, and storms. Migration-induced changes in the economic balance can lead to high unemployment rates, which can worsen child malnutrition, raise the poverty level, and cause food shortages.

One of the biggest threats to emerging nations is heat waves. In 2015, over 65,000 people were admitted to hospitals in Karachi for treatment of heat stroke due to the city's widespread heat wave (Glum 2015). Over 100 heat-related deaths have been reported in Pakistan's plain areas throughout the summer, which are also experiencing extreme heat waves (Sheikh and Tunio 2013). The lack of adequate medical facilities in the nation is making the consequences of heat waves worse (Rauf et al. 2017). Around the world, climate change is leading to more frequent disasters and more severe flooding. Disasters involving flooding may have negative health repercussions, such as dermatological problems. Following floods, both viral and noninfectious dermatological problems are on the rise. The primary causes of morbidity among flood victims are infectious disorders with dermatological symptoms, including leptospirosis, measles, dengue fever, impetigo, tineacorporis, malaria, and leishmaniasis. Among the most common dermatological disorders are inflammatory ones, such as irritating contact dermatitis (Dayrit et al. 2018).

Moreover, climatic factors and weather alterations can have outbreak dangers of dengue hemorrhagic fever (DHF) (Banu et al. 2014; Ebi and Nealon 2016). Alterations in the weather have contributed in the spread of Aedes mosquitoes through various channels. Increased precipitation with favorable temperature has a strong likelihood for the spread of DHF. There are also some causes associated with DHF, i.e., humidity and vapor pressure (Bhatt et al. 2013; Estallo et al. 2015). Several districts of Punjab province suffered in terms of morbidity and mortality. Over 300 citizens were killed by DHF in the Faisalabad district and affected 14,000 in 2011 only in two big cities including Faisalabad (Bakhsh et al. 2018).

The latter may result in serious consequences including health problems, stress, worry, missed school days, sleep deprivation, and several more innumerable losses and consequences (Chan et al. 2016). Notably, the frequency of earthquakes and seismic activity has increased dramatically, and the temperature cycle in South East Asia—especially in Pakistan—is deteriorating owing to global warming, with winter temperatures dropping to -19°C and summer temperatures rising to +53°C during the past ten years. Numerous diseases, including dengue, avian flu, and swine flu, are affecting Pakistani citizens. Health policymakers must immediately concentrate on outbreak awareness campaigns rather than lowering the negative health effects of climate change through media promotion, expanding access to healthcare facilities, and expanding Pakistan's healthcare network.

Impacts of climate change on the pattern of weather

The Earth's average temperature has increased by 0.6±0.2 °C since 1990. Rapid melting of glaciers and sea ice, an increase in heat waves, warming seas, a nearly 10- to 20-cm rise in sea

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level, and changes in weather patterns with intense rains and droughts in different parts of the world are all contributing factors to this temperature increase. By 2010, the global temperature reportedly increased by 4 °C in just ten years due to altered precipitation and weather patterns. Typically, changes in humidity and temperature patterns impact the borders between species. Approximately 160 kilometers of latitude or longitude can be impacted by a 1 °C temperature change in natural zones (Ali and Qureshi 2011). Warmer days and nights are expected to be rising globally, whereas colder days and nights are expected to be decreasing (Abbas et al. 2018). The development and production of annual crops have been put in jeopardy due to rising mercury and changes in rainfall patterns. Raining patterns, energy availability, agriculture, and irrigation needs have all been impacted by atmospheric deterioration.

In hilly areas, natural water supplies are likely to be impacted by rising temperatures and its environmental repercussions (Akhter et al. 2017). The greatest drought in history occurred in the Horn of Africa as a result of altered rainfall patterns, which led to food shortages throughout East Africa (Williams and Funk 2011). The northwest region of India has seen climate damage, much like Africa, and Pakistan is presently witnessing comparable changes as a result of climate change. Spatial variations in rainfall patterns, along with variations in the normal rotation of the atmosphere in this region, were the main cause of climate change and environmental deterioration (Rodo 2003).

The southern region of Pakistan is considered an arid region with immediate risks of droughts and water scarcity due to its geographic position and historical climate. While the average precipitation predicted nationwide is less than 40 mm per year, some regions are predicted to receive very little rainfall—less than 10 mm—which will negatively impact the population and economic structure of an agrarian nation like Pakistan (Hussain et al 2020).

The risks to future economic and social development posed by global warming have been acknowledged by the Pakistani government. Although contemporary technology, infrastructure, techniques, and rules for sustainable development are still missing in the nation, regulatory authorities have taken moves to invest a significant amount of money in climate change adaptation and mitigation. Rainfall is one of the key drivers of agricultural advancement. The production of livestock and the sustenance of agricultural crops depend on the natural occurrence of rainfall. Government officials should focus their efforts on obtaining funding for the construction of a dependable irrigation system so that it can handle future fluctuations in precipitation (Hussain et al 2020).

Since the last 20 years, the frequency and severity of severe climate changes have increased, and approximately 40% of the nation's population has experienced droughts, floods, storms, and changes in rainfall (Asif 2010). It is anticipated that fluctuating climatic conditions will continue to occur in terms of the frequency and magnitude of storms, cyclones, floods, and droughts (Ullah et al. 2018).

At the beginning of 2016, atmospheric fluctuations prompted cold waves to relocate from the United States to the United Kingdom, while heat waves have shifted from India to Pakistan from mid-2015. Heat and cold waves demand more energy to chill and reheat. A man must endure hypothermia below 58°F and hyperthermia over 53 °C; so, every living creature is impacted by these extreme waves (Pan et al. 2016). On the other hand, the combination of fog and snow cancels thousands of flights each year, as well as halting road transit during the frigid summer. If the same mix of hot weather and humidity continues in the coastal parts of Baluchistan for a few of decades, it will be difficult to undertake multi-billion developmental projects at the port city of Gwadar—a gateway to the Middle East for Chinese economic endeavors through Pakistan (Abbas et al. 2018).

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Adaptation and mitigation methodologies in Pakistan

Over the past few years, Pakistan has been affected by climate change, and social and economic advancement requires adaptation to these consequences. To bring the public into line with the national climate policy on mitigation and adaptation efforts, the Ministry of Climate Change has implemented a number of actions. Transportation, agriculture, livestock, energy, forestry, town planning, and the industrial sectors are all areas that need to be addressed in order to lessen the effects of climate change (Lin and Ahmad 2017). The use of power-efficient appliances and environmentally friendly, renewable energy sources must be guaranteed in order to offset the climate initiatives at the national level. The Intended National Determined Contributions (INDC) estimate that Pakistan needs between 7 and $14 billion annually to implement these mitigation strategies. Under the Green Pakistan Program, around 100 million trees have been planted nationwide to lessen the consequences of climate change (GOP 2017–18.).

Technological improvements in the domains of energy, forestry, and transport have been underlined in the report of the barrier analysis and enabling framework. Modern micro-hydropower plants and solar energy generating are examples of these environmentally beneficial energy technology breakthroughs. Along with energy, these technical developments in forestry include social forestry in response to carbon sinks and sustainable forest management (SFM) against deforestation, while innovations in transportation include sophisticated vehicle tune-up and a bus rapid transit (BRT) system (Ministry of Climate Change 2016). Additionally, the report identifies the two most susceptible sectors as being agriculture and water, and it discusses three adaption strategies for these industries. Rainwater collection, storm water management, and groundwater recharge are the three key technologies for the water industry. Climate predictions and projections, drought-tolerant crop varieties, effective irrigation systems (both drip and sprinkler), and the availability of an early warning system are recommended technology for the agriculture industry (Ministry of Climate Change 2017). It is important to make sure that locals actively participate in mitigation and adaptation plans since they are more knowledgeable than outside groups. It is imperative that the government curb its inconsistencies in planning and policy.

The Intergovernmental Panel on Climate Change (IPCC 2014, b, c, 2007) note that among several lacking phenomenon, knowledge is insufficient and is not adequate to drive the adaptive responses (IPCC Working Group II 2014). Due to these factors, the IPCC (2014, b, c) inferred that execution of policies and implementation has been comparatively restricted and faces numerous obstacles and challenges (Andersson and Keskitalo 2018); the conditions in Pakistan is worst in this regard. To address the micro-level effects of climate change, several sectors urgently need to develop comprehensive, multifaceted policies. Measures must be outlined to minimize interventions in forests, on glaciers, wetlands, and pastures in order to adapt to and offset the changes in the climate. Sorting and prioritizing the related processes—which are essential for adaptation and mitigation—is required to meet sustainable national developmental goals.

Climate change adaptation and mitigation with economic perspective

Pakistan has less exposure to receiving or disbursing global financial resources since it is a relatively young player in the global climate financing industry with limited institutional resources. The prime document on climate change in Pakistan is the National Climate Change Policy of 2012, which lays out the goals for achieving climate-resilient improvements for Pakistan by integrating climate change into the nation's most susceptible areas. Between 2010 and 2014, around 6% of Pakistan's government budget was approved for climate-related sectors, namely transportation and energy. With the help of foreign financial subsidies to cover

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the almost 40 billion US dollars in reduction expenses, Pakistan intends to cut about 20% of its total greenhouse gas emissions by 2030 as part of its National Determined Contribution to the Paris Agreement. Estimates of Pakistan's annual adaption needs range from $7 billion to $14 billion (ADB 2017).

International climate finance from the Asian Development Bank (ADB), Global Environment Facility (GFF), Adaptation Fund, and Japan's Fast Start Initiative has been made available to Pakistan. Between 2010 and 2015, the Asian Development Bank gave Pakistan a total of 389.8 million US dollars in investment and technical assistance. Just 13.9 million US dollars (3.6%) were used for adaptation, whereas 96.4% of this amount (375.9 million USD) was used for mitigation. Additionally, 12.5 million US dollars were awarded by the Global Environment Facility for mitigation efforts, and these funds have been fully distributed. Pakistan's anticipated yearly adaptation needs, which range from $7 billion to $14 billion, are still greater than the total amount of cash received from various sources (ADB 2017). Pakistan has had 141 climate-related severe events over the past 20 years, resulting in 500 annual fatalities and economic damage of up to $2 billion USD annually, making it one of the most impacted nations in the world, according to the Global Climate Risk Index (Harmeling and Eckstein 2012). With technical assistance from the People's Republic of China, the Pakistani government launched the "Carbon Neutral Pakistan" program in June 2015 to create a local carbon market to lower GHG emissions and attract international investment. This project is expected to cost $3.85 million USD in total, as indicated by the 2016 Public Sector Development Program (PSDP) (ADB 2017).

In Pakistan, including Gilgit Baltistan, Azad Jammu and Kashmir, and Federally Administrative Tribal Areas (FATA), the Ministry of Climate Change, in collaboration with the provincial Forest and Wildlife Departments, is implementing the Green Pakistan Program. The program will cost 3.652 billion Pakistani rupees and run for five years, from 2016–17 to 2021–22. This initiative will be carried out in 100 Pakistani districts (GOP 2017–2018). Just the transportation sector in Pakistan is responsible for over 21% of the country's overall GHG emissions. Metro Buses or BRT (Bus Rapid Transport) are now available in three Pakistani cities: Lahore, Islamabad, and Rawalpindi. Construction is also underway in more Pakistani cities: Faisalabad, Karachi, and Multan. BRT buses are equipped with energy-efficient diesel engines that are at least Euro-II/Pak-II compliant. These engines improve fuel efficiency and lower carbon emissions into the atmosphere. The construction of BRT, sometimes referred to as the metro bus in Pakistan, cost 1.99 billion Pakistani rupees per kilometer in Islamabad and 1.11 billion Pakistani rupees per kilometer in Lahore. This is significantly more expensive than traditional systems. These metros typically cost about 9100 Pakistani rupees every bus journey to operate, while the relevant authority only makes about 6500 Pakistani rupees in revenue, meaning that each trip costs 2600 Pakistani rupees (Ministry of Climate Change 2016). According to the SAP statistics, the federal government's 2017–18 budget was 4983 billion Pakistani rupees (not including debt payments), of which about 6.85% (341 billion Pakistani rupees) were approved for budgetary items relating to climate change. By the end of March 2018, the federal government has spent 3851 billion Pakistani rupees, spending 182 billion of those funds on climate impacts (Hussain et al 2020).

Given Pakistan's deficiencies in capacity building at the local, provincial, and national levels, it is imperative that politicians, businesses, and the general public update their assessments of climate change in terms of mitigation and adaptation strategies. Additionally, it is crucial to consider it by region (rural, urban, and peri-urban), since this network of climate change provides the foundation for developing policy frameworks for emerging trends. Reduction/Adaptation Data from the Mitigation Support area about the timing, severity of the

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climate impacts, and acceptability of anticipated response options (Hussain et al. 2018) which will also assist to cut the adaptation and mitigation costs. For tangible mitigation and adaptation measures to be implemented at the local and divisional levels in developing nations like Pakistan, people and all stakeholders need to be aware of the fundamentals of climate change challenges and their effects (Hussain et al. 2019b).

Conclusion and Future Prospects

In the past two decades, climate change has been a keen area of interest to researchers since the effects of climate change can be observed through global warming across the world. Due to increased greenhouse gas (GHG) emissions, the global temperature is rising, and the number of warm days and nights is elevating, resulting in intense heat waves causing numerous fatalities annually in several countries including Pakistan. The adaptive capacity of Pakistan is perceived to be low due to high poverty, lack of financial and physical resources. The effects of climate change in Pakistan are highly severe with frequent occurrences such as melting of Himalayan range glaciers at a rate faster than ever recorded in history, abrupt rainfalls, unpredictable flooding, droughts, varying temperature, lack of water sources, intense heat waves, saturation of lakes, storms, hurricanes, landslides, earthquakes, human healthcare issues, pest diseases, seasonal changes, and alterations in lifestyle.

The remedial actions against climate change include awareness building from the grassroots level, expanding environmental knowledge, and implementing government policies and regulations. A cooperated and coordinated effort among governmental institutes, policymakers, officials, environmental organizations, and community members should formulate strategies and approaches for climate change mitigation and adaptation. The outcomes of this review will provide a detailed understanding of climate change with a focus on climate change mitigation and adaptation approaches and its economic aspects as its cost reaches over 7 billion to 14 billion US dollars per annum.

The study provides a detailed understanding of current changes in climate and the threats it poses. Hence, the study presents some actionable future perspectives by taking into account effective measures for agriculture livestock and forestry, and food and renewable energy security, as well as, building and spreading awareness among the population about possible dangers and devastation of climate change:

Firstly, the role of government needs to be proactive by eliminating inconsistencies and ineffective techniques in planning, establishing, and executing policies.

Secondly, a laid out plan for national sustainable development should be formulated which aims at reviewing and prioritizing sustainable and ecofriendly processes leading to mitigation and adaptation.

Thirdly, apart from governmental interference, the local residents should come forth with their experience and understanding of the climatic situation which can contribute to the development of mitigation and adaptation strategies at a higher extent.

Fourthly, the governmental authorities, organizations, and population should pool their resources to generate and implement strategies for minimizing human interventions in natural sites such as forests, oceans, wetlands, pastures, and fertile lands.

Lastly, the review accounted for a large sum of literature on climate change effects in Pakistan; however, there was a shortage of qualitative studies with comprehensive analysis and explanations of climatic effects. Furthermore, it is suggested that a deeper evaluation of various sectors should be conducted that affects climate, since most of the current research focuses on specific aspects yet lacks detailed examination of sectorial causes and impacts of climate change.

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