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CLIMATE CHANGE AND HUMAN WELL-BEING: BRIDGING SUBJECTIVE AND OBJECTIVE PERSPECTIVES

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ABSTRACT

Climate change represents one of the most pressing global challenges of the 21st century, not only threatening ecological stability and economic systems but also profoundly influencing human well-being. This article examines the intricate relationship between climate change and both subjective and objective dimensions of well-being. Drawing from interdisciplinary literature, it explores the physical, psychological, economic, and social impacts of climate disruption. Key areas discussed include the physiological consequences of heat and pollution, psychological distress associated with environmental degradation, and disparities in vulnerability influenced by social, economic, and geographical contexts. The article emphasizes the importance of integrative frameworks that combine scientific assessments with community-centered and perception-based approaches to climate adaptation and mitigation. By bridging subjective and objective perspectives, the chapter advocates for a more holistic understanding of human resilience and sustainability in the era of climate change.

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INTRODUCTION

Causes of Climate Change

Heat-trapping gases like carbon dioxide have been increasing in the environment, likely resulting in a temperature increase, which has led to an average temperature rise of 1 to 3.5 degrees C. Furthermore, rising temperature retains more water, increasing precipitation levels by 10 to 15%. Global Circulation Models (GCMs) have revealed the potential impact of climate change on agricultural production, resulting in reduced agrarian productivity globally (Maffre et al., 2018). Deforestation, fuel burning, serious trade, automobile manufacturing, and the production of electronic items such as TVs, air conditioners, and computers all contribute to global climate change, which is not only unavoidable but also causes an increase in environmental temperature (Hill et al., 2013). According to the Fourth Assessment Report (AR4) issued by the Intergovernmental Panel on Climate Change (IPCC, 2007), the environment has changed as a result of human-induced anthropogenic activities such as fuel burning, agricultural waste, and deforestation, among others. According to the assessment study, if anthropogenic activity continues at its current rate, the global average

temperature is projected to rise by 1 °C to 5.5 °C by 2100. Climate change has already had an impact on agricultural productivity.

The agriculture sector is simultaneously a source and a recipient of greenhouse gases. Doyle (2007) studied the effects of around 17 to 32% of greenhouse gases on agricultural development. The key reason for the greenhouse effect is the combined contribution from both farming and non-farming sources. This contains nitrous oxides from the land utilized, enteric fermentation, dairy cattle methane, consuming biomass, corn, fertilizer, creation of manures and pesticides, water system, and broad field machinery. The sequestration of carbon, methane, and nitrogen mixes will decrease the greenhouse gas impact. A significant point of this investigation is that the adequacy of natural and inorganic products is often linked to environmental change. They inferred that natural items are the best for food creation, for example, wheat flour, fruits, and vegetables, whereas animal products, such as meat, eggs, and milk, are the best for poultry.

An increase in carbon dioxide levels will lead to a decrease in the global food supply, with poor countries bearing the cost of the consequences. They discovered a significant gap in climate change vulnerability between developed and developing countries. Changes in sowing dates, new varieties, alternative crops, and improved irrigation and fertilizer systems were all put to the test. If the carbon concentration imbalance is ignored, worldwide cereal production is expected to decline by 11 to 20%. However, considering the aggregate farm impact, the decline is projected to be 1 to 8% (Rosenzweig and Parry, 1994).

Stakeholder Perspectives and Climate Perception

People's perceptions of climate change play a crucial role in environmental issues, agricultural productivity, and potential adaptations (Weber, 2010). The effects of climate-related problems can be mitigated through the introduction of better land management, an improved farming system, and the adoption of integrated farming practices. The involvement of stakeholders in the adaptation process leads to better adaptation options and improved socioeconomic viability from planning, development, and application of projects. All stakeholders played a crucial role in the decision-making and policy development process. The interventions of community-based adaptation would be more effective in supporting poor development when we incorporate risk, uncertainty, institutional and political structures, multilevel policy adaptation options, and interlinkages between mitigation and adaptation options regarding climate change (Dodman and Mitlin, 2011).

Local people in mountainous areas have experienced attacks by insect pests and low crop yields, resulting in decreased agricultural production. However, due to the fragile nature of mountainous regions, which have been affected by climatic conditions and contour farming, generalizing the climatic forecast study results and all the potential negative or positive impacts of climatic changes carries a significant degree of uncertainty (Gbetibouo et al., 2010).

In developing countries, farmers have observed that temperatures have risen and rainfall has decreased over the past two decades, negatively impacting agricultural production (Mubaya et al., 2012). It was found that climate variability has a more profound influence on human health, food security, and biodiversity loss than other economic factors, such as business and natural hazards (Ishaya and Abaje, 2008). Farmers perceived that high temperatures and precipitation were directly proportional in the US Therefore, overall, there was a minimal impact of climate change on agricultural production in the United States (Schlenker and Roberts, 2006). The effects of climate change may vary from country to country, but overall, it is anticipated that global warming will have a significant negative impact on agriculture worldwide. Climate change may bring benefits to countries with longer latitudes, but for countries with low latitudes, its effect will be drastic (Stern, 2020).

Changes in the climate pattern also alter the distribution of agro-ecological zones, ultimately affecting the habitats of pests, diseases, plants, and beneficial microflora, which in turn have a significant impact on agriculture and food security (Wilby, 2010). Similarly, in a study, Ayanlade et al. (2017) found that changes in the timing and quantity of rainfall have a significant impact on agricultural production. The Intergovernmental Panel on Climate Change forecasted that by 2100, the Earth's surface temperature is expected to rise from 1.8 °C to 4.0 °C. There will be both positive and negative impacts of global warming on crop production. It was forecasted that with the temperature rise, the crop production would increase within the range from 1 to 30 ºC, and crop production would decrease with the increase of temperature above 30 ºC (IPCC) Fourth Assessment Report (2007).

The temperature rise is inversely proportional to wheat production. With only a 1°C rise in atmospheric temperature, there would be a reduction in wheat production by up to six million tonnes. If the temperature were to rise to 5°C, then there would be an estimated decrease of 27.5 million tons of wheat in India alone. It was also forecasted that due to current heat stress in different parts of the country, there would be a decline of 1.8 million tons of milk production. Aggarwal and Sivakumar (2010) also projected a shifting monsoon season due to climatic changes in the hilly areas of Nepal. The involvement of stakeholders in the adaptation process leads to better adaptation options and improved socioeconomic viability from the planning, development, and implementation of projects. All stakeholders played a crucial role in the decision-making and policy development process. When we incorporate risk, uncertainty, institutional and political structures, multilevel policy adaptation options, and interlinkages between mitigation and adaptation options regarding climate change, the interventions of community-based adaptation would be more potent in supporting development (Dodman and Mitlin, 2011).

Adaptation to climate change in the ecological system refers to the adoption or modification of the current system to mitigate the adverse effects of climate change and also to maximize the positive impacts of climate change. Different levels of adaptation may be global, regional, national, and local. The most critical one is local adaptation, as local people implement it and must be done at the grassroots level. There are two steps in the adaptation process: the first is perception, and the second is taking steps based on the perception to mitigate the potential risks associated with climate change. To take the right step, your perception must be correct. Otherwise, taking the wrong step may result in significant damage. The response is also an essential phenomenon about perception, as there may be specific barriers that restrict farmers from responding, even when they perceive the climatic changes. The barriers include a lack of resources, insufficient capacity to take action, and entrenched beliefs. It shows the importance of people's understanding of climate change, motivating adaptation (Parry et al., 2007).

Climate Change in Mountain Regions

The effect of climate change on the mountainous areas of Pakistan reveals that an increase in temperature due to climate change has a positive impact on the district of Chitral, as well as on nearby regions. At the same time, it negatively affects the agriculture of the Swat district. This is because Chitral is located at a high altitude, while Swat is situated at a lower altitude (Hussain and Mudasser, 2007). Water shortage was reported as the main factor affecting agricultural production by 90% of the respondents. During FGDs, participants reported experiencing food shortages during months of heavy rainfall. Livestock and crop diseases were reported in July and August at most. July was considered the most disastrous month for agricultural productivity and the availability of forest products due to heavy rains and floods. This effect is conveniently validated through meteorological data for July over the past 30-year period, which shows an average rainfall of 320 mm (Shahzad et al., 2019).

Pakistan is among the 20 most climate-affected countries overall, depending on its ranking. Pakistan has experienced significant dry seasons, most notably those of the 1990s and the devastating 2010 floods, which are attributed to environmental change (Akram, 2013). The International Union for Conservation of Nature (IUCN) (2011) undertook a venture to investigate the impact of climate change on Pakistan's mountain areas. They named Bagrote Valley in the Pakistan district of Gilgit-Baltistan. The examination is expected to assess various elements, including temperature, precipitation rate, type of fuelwood used, blooming timing, and water supplies. The purpose of this investigation was to propose effective and proficient methods for moderating and selecting local effects of climate change, taking into account local experiences.

Studies conducted in rural areas of mountainous areas of Pakistan have suggested higher vulnerability of poor and farm households to climate change and other extreme events (Ali and Erenstein, 2017; Ullah et al., 2018), while very little focus is given to mountainous communities faced with multiple hazards through vulnerability capacity assessment in the context of climatic changes. These communities reside in a remote and marginalized area that is geographically disaster-prone, as identified by the UNDP in its Mansehra Disaster Risk Reduction Plan (UNDP, 2007). As an agrarian country heavily dependent on monsoon rains, the effects of climate change have been particularly pronounced in Nepal's mountainous areas, affecting agricultural productivity and growth. Decisions of the farmers whether to implement climate change

adaptation technologies are driven by landholding size, perceived threat of climate change to food security, the interviewee's level of education and gender, perception of the increased incidence of droughts during the rainy season, and income from off-farm sources (Joshi et al., 2017).

The analysis in mountainous areas of Thailand reveals that approximately 45% of family units have experienced the effects of climate change, primarily as increased rainfall, a decline in rainy days over the past two years, and a delay in rains during the most recent rainy season. An investigation into the perceptions of regional individuals and climatic changes reveals that local people accurately identified shifts in rainfall, which significantly influenced their perspectives and understanding of climate-related risks. Over 70% of households experienced the impacts of droughts and floods on their livelihoods; however, didn't completely comprehend their causes. They correctly identified the landslides as a consequence of rising rainfall levels. In any case, they are unaware of the emerging trends in landslides, flood risk, and potential risks associated with these. The discoveries are valuable for determining the requirements in terms of activities and information to advance climate-related risk management at the local level in Thailand. Hazards awareness projects, preparation, and early warning systems are required to crack the low perception of potential risks. Furthermore, a strategy for hazard management that does not wait for a pattern to emerge from climate science reviews is important (Manandhar et al., 2015).

Global Outlook on Climate Change

The effects of climate change on farm income suggest that there may be some benefits from increased temperatures and precipitation in the USA. If crop production losses are properly considered, significant losses in farmland value would result. At the aggregate level, climate change would significantly lower crop yields. There were certain areas where the consequences might be beneficial based on geography. They discovered that higher temperatures result in lower agricultural production, but more rainfall is beneficial for the production of different crops on farms (Mendelsohn et al., 2000). The study highlights uncertainty regarding the economic implications of climate change, as previous studies have estimated the impact of climatic variation using existing technologies, and the future remains unpredictable. There was a lack of understanding of future technologies, economic conditions, long-term climatic changes, and physical crop growth, which hindered the determination of climate change's impact (Kane et al., 1992).

In Ethiopia, a study was conducted to provide information about climate change and its effects on farmers' communities. Deressa et al. (2009) found that approximately 50.6% of Ethiopian farmers reported a rise in temperature over 20 years, while 53% of the farmers also observed a decrease in rainfall over the same period. In this study, a simple model was employed to investigate farmers' awareness of climate change. In this study, questions were framed about factors related to climate change over the last two decades, so that farmers would feel more comfortable recalling the changes they observed during this period.

In developing countries, farmers have observed that over the past two decades, the temperature has risen and rainfall has decreased, which is impacting agricultural production. It was found that climate variability has a more profound influence on human health, food security, and biodiversity loss than other economic factors, such as business and natural disasters (Mubaya, 2017). Akponikpè et al. (2010) noted from their research that farmers' communities in the Sahel region demonstrated that climate change had been occurring for 20-30 years or more. However, according to another farmer community's point of view, climate change started in the last 10 years. In Ghana, a large majority of farmers (>50%) reported that climate change started less than 10 years ago, while in the case of Sahelian Niger, 55% of farmers reported that climate change began 20-30 years ago.

The average temperature increase in China is expected to be between 3 and 4 degrees Celsius by the end of the twenty-first century, depending on the future emission scenarios. The key food crops would face a 37% loss over the next 20 to 80 years without the impacts of carbon dioxide fertilization. There were positive impacts on yield due to increased CO2 levels in the ambient environment, provided that specific breeds, irrigation, and a balanced use of nitrogen fertilizers were employed. Carbon dioxide fertilization increases crop vegetation growth and could increase yield and biomass by 5 to 15% at a 550-ppm level, and possibly more at 450 ppm, with some quality deterioration of grain. They did not add the impacts on land use patterns and water resources (Erda et al., 2005).

Agriculture uses around 87% of the harvested water and accounts for approximately 4% of the worldwide total

national GDP. Worldwide greenhouse gas emissions increased by 17% from 1990 to 2005, which consequently reduced harvest yield per hectare, as indicated by the book's assessments. There are several proposals for mitigating greenhouse gas emissions and enhancing agricultural efficiency. Those include well-prepared consideration of fields, fertilizers, and animals. They also emphasized the need for increased agricultural research and the development of technology and innovation in agriculture (Smith et al., 2007).

The relationship between climate change and US agriculture in the 2030s and 2090s was assessed. Simulations were based on future climate change impacts on grazing and pastureland, livestock, the use of chemicals, demand and supply, and demand for irrigation water, as well as international trade and prices. The impacts of El Niño-Southern Oscillation were captured in climatic conditions, and then the yield of crops was assessed under a changed mean climate. The results showed that the average impacts of climate change on US agriculture were positive. However, there were regional differences, and the Southern US could be affected negatively due to climatic variations. The benefits of crop production were linked with increased temperatures that were larger in 2090 than in 2030 due to increased temperature in the case of the United States of America. But climatic projections were highly uncertain so in climatic studies there remains a high degree of uncertainty (Reilly et al., 2003).

The effect of climate change on mean yield must involve the variability of yields induced by year-to-year fluctuations in weather. Maximum likelihood panel data estimates of climate impacts were constructed using yearly variation in the major crops of the United States of America. It was found that increased rainfall and temperature had a crop-specific impact on yield and variability. Corn crops show opposite effects of high temperature and rainfall on yield and variability. The temperature had a negative impact, while rainfall had a positive impact on corn yields. In the case of Sorghum, an increase in temperature reduces variability and crop yield, while more rainfall increases yield and variability. Future variability decreased for 17 cotton and corn varieties, and increased for soybeans, while mixed effects were observed for wheat and sorghum in the Canadian and Hadley scenarios. Therefore, genetic and breeding programs must incorporate these trends to sustain high yields in the future and maintain the mean crop yield (Chen et al., 2004).

Climate Change in Pakistan

The entire geographic area of Pakistan is 73.61 million hectares, while the total cultivated area is 23.51 million hectares. The most important natural resources in Pakistan are its fertile land and abundant water. Approximately 68% of the area receives 250mm of annual rainfall, while 24% receives between 251 mm and 500mm of annual rainfall. Punjab is endowed with the world’s best irrigation system, thanks to its extensive network of canals and distributaries that extend up to the farmer's fields. Due to its extensive irrigation infrastructure, rich soil, skilled labour force, input availability, and demand for agricultural goods in the context of Agro-based industries, Pakistan has a comparative advantage in the agricultural sector (Ahmad and Afzal, 2022). Pakistan is a country where agriculture provides a means of subsistence for more than 65-70% of the population and contributes 19.2% of the country's GDP. Although Pakistan has a relatively low greenhouse gas emission profile, the country continues to suffer from the dire consequences of climate change, such as floods, droughts, water shortages, and shifts in weather patterns, largely due to the neighbouring developing industrialised countries (Ahmed, 2014). Pakistan has a diversified topography, ecosystems, and climatic zones. Pakistan, blessed with natural resources such as rich agricultural lands, natural gas reserves, and mineral deposits, faces challenges in balancing multiple goals, including economic growth and environmental protection. Most of Pakistan's population of 220.9 million (2020) lives alongside the Indus River, which is vulnerable to severe flooding during July and August. Major earthquakes are also common in the northern and western mountainous areas (Bank, 2020).

Pakistan's rural economy is heavily dependent on agriculture, as the majority of farm families are involved in the sector, and industries also rely on agricultural products. This requirement will take time to ensure the food security and livelihoods of farm families in agricultural industries, due to climate change. Climate change adaptations at the national, provincial, and farm levels can mitigate risk by educating farm families on how to combat climate change, prevent losses, and assist farmers in coping with floods and droughts (IPCC, 2007).

Agriculture is the backbone of Pakistan's economy. However, recent climate changes have had a detrimental effect on agricultural production. Factors such as temperature fluctuations, signs of yearly droughts, and changes in steady rainfall have threatened the agriculture and livelihoods of local farmers. In Pakistan, the devastating floods of 2010 and 2011 highlighted the impact of extreme climate change. These national floods had washed away fertile soils, leading directly to agricultural production losses and an increase in vector-borne diseases in the crops. Nevertheless, these adaptation steps were not considered adequate for increasing farm yields. The study indicated that a greater understanding of the consequences of climate change and the experience of adaptation would not result in an unfortunate adjustment. It will also help secure farmers' lives and health, as well as improve their resilience to climate change (Aldosari et al., 2019).

Potential climate change patterns affecting wheat production in Pakistan were examined using a VAR model procedure and data spanning approximately fifty years. Appraisals have demonstrated that worldwide climate change will significantly impact the production of wheat. It was suggested that wheat production rates should be expanded to meet the residential demand for wheat due to an ever-growing population, which would also increase our revenue from foreign exchange. Fighting climate change requires effective policies and procedures. Heat-resistant varieties, progressively arable land, water preservation methodologies, and a supported water system framework would mitigate the effects of climate change and contribute to a positive trend in wheat production (Janjua et al., 2010).

The impact of environmental change on wheat production in Punjab's mixed cropping zone. Pakistan has examined the standard least squares (OLS) method, which has been used to quantify the effects of climate change, incorporating socioeconomic and environmental factors. Results indicated that climate factors have the primary effect on wheat production, compared to socioeconomic factors, which have a minimal impact. While determining the most sensitive factors, it was discovered that rainfall is a significant variable, indicating that a slight increase in rainfall would positively impact wheat production. An increase in the mean temperature would expand production potential at the sowing stage, while misfortunes have been observed when the mean maximum temperature rises at the mature stages. Initiating new procedures to address hunger needs, even in the face of unfavourable climate changes, would protect people in the future from food insecurity (Abid et al., 2015). The variations in rainfall patterns directly affect the water, agriculture, and disaster management industries. The occurrence, frequency, or severity of extreme climatic conditions has increased in the last couple of decades: over 40% of Pakistanis are highly vulnerable to recurring calamities, including variations in rainfall patterns, storms, flooding, and drought (Hussain, 2010).

Time perspective from 1970 to 2009 revealed that rain has a maximum negative relationship during the Rabi season. The mean least temperature has a maximum negative relationship, and the most extreme Rabi temperature has a solid positive relationship to land costs. Socioeconomic factors, for example, Population intensity and per capita income, have a positive relationship with land pricing. In the Rabi season, a one mm rise in rainfall will diminish the cost of agricultural land by a normal of Pak Rs. 860 for each acre of land, and even a 10c increase in the most extreme temperatures will raise the price of agricultural land by Rs. 25208.66 per acre of land (Hanif et al., 2010).

Agricultural Impacts of Climate Change

Climate change impacts mainly were reported as positive to negative, depending on the area, location, interaction of CO2 effects, and crop type in Indian Agriculture. These studies primarily focused on Rabi crops, such as oilseeds and pulses, which showed high losses due to increased summer temperatures. Some research studies have claimed that Kharif crops have relatively less vulnerability, but they could be more vulnerable due to extreme weather events, such as the onset of the monsoon, the duration and frequency of floods and droughts, viral diseases, and pest attacks. After some adaptations in current production systems, technological advancements, and improved policy implications, the accuracy in weather forecasting and climatic impacts could be minimized (Mall et al., 2006).

Climate change adaptations were crucial for food security in mid-century. Climate risk for crops has been analyzed for 12 food-secure nations using a statistical model and climate projections from 20 General Circulation Models. Results indicated that Asia and Southern Africa were drastically affected by climate changes and their crop production would substantially decrease without

adaptations. Several projections indicated that crop production would be negatively impacted with a 95% or greater chance. However, in the cases of South Asia and Africa, there was high uncertainty, as yield changes varied from positive in some areas to negative in others. This situation was alarming regarding the food security situation in these highly populated regions. There were significant uncertainties that varied widely by crop and region. Asia and South Africa had a significant impact on crops, while also having the highest potential for adaptation benefits (Lobell et al., 2008). A significant linkage has been investigated between climate change and agricultural production yield, based on information from a time series spanning from 1987 to the present. The findings were the moderately consistent impact of temperature on crop production, guaranteeing that temperature has no significant effect on crops, that rainfall is causing an adjustment in Nigerian farming yield with net production gains, and gave a method of reasoning to policymakers to build the measure of water system required for adequate production limits (Olatunji et al., 2012).

Both short-term and long-term vulnerabilities have been found to demonstrate that the temperature rise is likely to disturb the profitability of wheat in the short run, while the long-term impacts are uncertain. Rainfall in both the short and the long term has appeared to have harmful effects. At first, a temperature increase was seen as beneficial for rice production; however, when the temperature exceeds a specific ideal level, it becomes risky for rice production. The impacts of rainfall on rice production have been viewed as negative. At long last, the regular temperature increases harm the long-term production of sugarcane. The effects of climate change on other crops are found to be different (Siddiqui et al., 2012).

The International Union for Conservation of Nature (IUCN) (2008) released a report on climate change with the assistance of the Pakistani Government. This examination primarily focused on the issues and challenges affecting rural production due to climate change. This featured water supply will be diminished, which would decrease crop production per hectare. The study concluded with a few suggestions for adapting techniques that can assist Pakistan in adapting to the circumstances. It was recommended that hi-tech meteorological administrations, for example, early warning systems ought to be introduced against floods, drought, cyclones, and so on, and organic livestock reproduction and seed assortments impervious to heat and drought need to be implemented Farmers' awareness of climate issues needs to be improved and the capacity building techniques clarified. Environmentally friendly technology must be implemented in the farming sector. Huge investments are also required in the fields of forestry services, agriculture, and environmental innovation.

The impact of climate change on the wheat crop was assessed, as it is one of Pakistan's staple food crops. The exploration considered yearly data from 1960 to 2009 and anticipated the climatic trends in wheat production for the 2010-2060 period. No significant increment or decrease in wheat crop production was observed. In any case, the harvest creation circumstance could deteriorate in a matter of seconds, depending on the evolving environment. The exploration has likewise proposed procedures for crop adjustment and moderation to battle future environmental change (Pervez and Henebry, 2015). The environmental effect on major crops in the Punjab region, i.e., wheat, cotton, rice, and sugarcane, was analyzed. An investigation is essential, provided that it identifies the climate impact at four stages of plant growth. For the period 1980-2008, the study used time-set details. A survey of information from the district-wise boards was conducted using a fixed-effect model. The examination's consequences demonstrated that atmospheric factors positively affect wheat crop production, whereas the aftereffects of the investigation are non-positive for rice, cotton, and sugarcane (Siddiqui et al., 2012). The impacts of climate change were assessed on determinants of crop production and biophysical aspects, such as soil and groundwater, and these impacts were also determined in terms of physical agricultural land use and crop production. All the detailed results are fed into the economic model to assess the implications on development pathways, trade, and food security. The results showed that climate change impacts would decrease global food production and would increase the production gap in developed and developing nations (Fischer et al., 2005).

Climate change has significant impacts on subsistence farmers in developing countries, who are smallholders and are the most vulnerable to its effects. The location, socioeconomic situation, and weak policies hinder the adaptive capacity of smallholders in developing countries, especially in Asia and Africa. Small landholdings, poor

infrastructure, limited technological capacity, indigenous knowledge, and low capital availability exacerbate the situation. The climatic vulnerability was farm-specific, making it difficult to estimate the overall vulnerability of all farms due to the interrelationships and complexity of farms. He proposed that efficient utilization of labor for seasons, biodiversity, integrating livestock with farm production, and diversification of income sources could be the adaptations for smallholders regarding climate change (Morton, 2007).

Global cereal production, cultivated land, agricultural output, and food security were assessed under both current and future climate change scenarios. After climate change simulations showed that the crop yields remain -0.6 to -0.9% of the total production of 4.2 Gt without climate change. The decrease in crop production was relatively larger in developing nations, such as Africa, South Asia, and East Asia. Notably, East Asia had the most significant impact, with a crop reduction of 22 to 18% in both mild and harsh GCM scenarios. The adaptation model results showed that global crop production increased substantially due to adaptation and mitigation efforts. In terms of food security, projections showed that already high temperatures lead to 70 to 90 million people facing hunger. Mitigation efforts against climate change were working effectively to sustain global production, minimize socioeconomic costs of production, and ensure food security (Tubiello and Fischer, 2007).

The impact of climatic variations on the United States' Agricultural economy, considering agricultural output and weather changes over the period, was examined. This study utilized the replication of the hedonic model, with the use-value of land and buildings as the dependent variable, instead of land value. The results exhibited a strong positive relationship, predicting a $ 1.2 billion (2%) increase in profit every year (2002 dollars), ranging between -$0.5 billion and $3.1 billion US. They stated that the traditional hedonic model overstates the climate change impacts by neglecting year-to-year variations in favor of the long-term effects. Climate change had a relatively negligible impact on the value of US agricultural land and the economy (Deschênes and Greenstone, 2007).

It has been claimed that climate change poses serious threats to agriculture and global food supply chains. Rising temperatures have affected agricultural production, biodiversity, water resources, and human health severely. The researcher claimed that climate change has multiple consequences for agricultural production worldwide, threatening global food security as the world population continues to rise (Chaturvedi et al., 2014).

Livelihood Impacts in Rural Communities

There is an immense importance of livelihood assets in raising production and reducing the insecurity of livelihoods for poor people. A conceptual framework is developed that relates the functions and attributes of the assets of poor people to their status and strategies for living. The system encourages a more holistic consideration of various assets owned by the poor, thereby enabling policy research, capacity building, and technical initiatives to improve livelihood opportunities for the poor (Dorward et al., 2009).

Different studies measuring vulnerability to climate change reveal insufficiently connected linkages between climate behavior and human actions occurring within the area. Furthermore, research is required to collect stakeholders' perceptions of the risks posed by environmental change, providing dynamic measurements. The findings indicate that natural and financial resources are typically vulnerable to climate change, whereas operational and financial resources are generally protected from its impacts. The findings show that agricultural production's vulnerability to livelihood is due to being 'helpless' against climatic fluctuations and changes during summer, winter, and precipitation (Singh and Nair, 2014).

The International Union for Conservation of Nature (2008) surveys the impacts of climate change and the adaptable methodologies on the Pakistan area of Shigar, specifically the valley of Gilgit-Baltistan. This exploration was a part of the undertaking called "Enlightening Life in Shigar through Unified Social, Natural and Built Environments Planning and Growth." Natural resource-based and naturally agro-pastoral activities mostly characterize Shigar's economy. It is influenced by a range of ecological issues, including inadequate land use, limited access to clean water, inadequate sanitation facilities, and inadequate waste management. Exhaustive analysis of the current situation has demonstrated that climate change has impacted different factors, for example, temperature and rainfall water assets, agriculture (harvests and yield patterns), livestock, biodiversity, and descriptions of day-to-day environments (building configuration, garments, diseases) that are engaged with the valley's present socioeconomic condition. It was recommended to

evaluate the vulnerability condition consistently, bring issues related to climate change to light, and build the community's ability to adapt. The examination concluded by suggesting three areas that require adjustment and improvement, including forestry, education, and agricultural support through innovation and seed distribution.

There is growing evidence that changes in severe droughts, storms, and floods are increasing the vulnerability of currently vulnerable populations. Such stresses are compounded in many African countries by structural instability and volatility in living and employment. The experiences of both rapid and slow life-threatening disruptions lead to persistent deprivation and sluggish rural livelihood regeneration processes across a diverse landscape. The study, however, shows that agricultural programs have helped promote successful livelihood regeneration by reorganizing social structures, enhancing creativity, and providing micro-credit opportunities. While mainstreaming adaptation is challenging at various scales, this work highlights the importance of determining how policies can create conditions for the emergence of a transformation in livelihoods (Osbahr et al., 2008).

The changing environment is expected to worsen the challenges facing people in developing countries, particularly among those groups whose livelihoods rely on natural resources. The adaptive potential of livelihoods primarily determines the degree to which people will cope with possible changes in the environment, whether triggered by climate change or other factors, such as changes in land use and the production of water supplies. The research results indicate that, given the history of people adjusting to the extraordinary seasonal variability in water and related resources, their ability to adapt to unexpected changes in the climate is small, with the poorest being the most vulnerable category. Reasons for the poor resilience include relatively homogeneous systems of livelihoods in villages, unequal governance practices, growing deprivation, and a lack of incentives for diversifying living conditions. It is concluded that while climate change is likely to pose a significant long-term threat to people's livelihoods, climate change adaptation efforts should also consider other environmental changes. The perception of the wider socio-political context and its complexities in rising and decreasing resilience to life is equally important (Nuorteva et al., 2010).

An examination surveying the climate impact of the Rawalpindi division of Punjab on agricultural farm revenues. Wheat was chosen for study because it grows abundantly in the Punjab region. The study's findings indicate that climate change affects crop income. A temperature rise harmed agricultural production, but an increase in rainfall had a positive impact (Shakoor et al., 2011). The conclusion from the investigation suggests a beneficial outcome of climate change on agricultural land in Pakistan. This investigation proposed adjustment and moderation as the essential answer to the severe consequences of climate change. Second, shifting from regular crops like wheat, cotton, and sugarcane to non-conventional crops like rice, maize, and vegetables would be a superior decision for farmers' income and prosperity (Ahmad et al., 2015).

Adaptation and Mitigation Strategies

Small landholders and subsistence farmers were more vulnerable to climate change due to the inadequate resources they had, resulting in low adaptive capacity. The stress factors of climate change would be evident in the markets, particularly regarding input-output prices, availability, and access to markets. Climate change will affect water resources in terms of increased droughts, reduced irrigation, increased floods, and impaired drainage. It would have a detrimental impact on soil fertility, disease and pest attacks, germplasm potential, and weed growth. Improved management practices also improve the carbon sequestration in the soil. In terms of mitigation strategies, carbon sequestration can play a crucial role. There were tradeoffs between carbon sequestration and soil profitability. Migration was also an adaptation to drought, as without water, the survival of life was not possible (Verchot et al., 2007).

Crop diversity, adjusting management practices, modifying land use patterns, changing location, crop rotation, adjusting sowing times, and irrigation according to projected climatic variations could reduce losses. Increased livestock production, conservation tillage, crop diversification, high-efficiency irrigation, migration, the adoption of efficient technology, and improvements in institutional and market mechanisms could be beneficial for climatic adaptation. While climatic impacts were diverse and location-specific, adaptation must also be area-specific. Through proper adaptations and the formulation of effective climate change adaptation and

mitigation policies, long-term food security can be ensured (Nhemachena et al., 2010).

The changing climate has had significant effects on agricultural production. In terms of climate, proposed adaptations include changes to existing climate risk management. The suggested adaptation in management operations at the farm would be effective only in moderating climate change; however, in the event of severe changes, comprehensive work on adaptation measures such as diversification in crops and livelihoods is needed. Climate change studies should be coherent with socioeconomic policy domains and sustainable development goals. Scientific research is necessary to adopt multidisciplinary efforts in finding solutions to the multidimensional global challenges of climate change. Climate change adaptations would be effective if they were applied at the policy level and the top to bottom approach was effective in this case. The benefits of adaptations would be approximately 18% by the suggested adoption rate, but these benefits were calculated under moderate climate change scenarios. They proposed the need for a comprehensive, robust, and transdisciplinary approach to propose adaptations and to practically identify the perfect stakeholder (Howden et al., 2007).

Developed countries have followed a two-way strategy to address climate change, employing both the Bottom-Up approach and the Top-down approach. The essential point of the bottom-up approach is to perceive the consequences of grassroots environmental change more likely. In the top-down approach, risk analysis, cost estimates, and national-level adjustments to the climate change situation are organized. The Top-down methodology tends to the issue at the 'Worldwide' level. The global cost of climate change is established by forecasts at the national level. The research's primary goals are to determine the overall cost of adaptation. It can be completed by identifying the data on small-scale and full-scale levels for the rich and vulnerable nations. Techniques for climate change adaptation and their application cannot be generalized, as each country has its structures and requirements. It should be specific to a location or natural condition (Bank, 2020). This study examines the vulnerability of climate adaptation in various regions of the world, particularly in developing countries. The study focuses on some of the available tools that can be used to assess the danger of climate change and inform research adaptation. The article detailed some of the significant challenges associated with climate change. Enhancing data collection techniques at the national level can aid in improving the understanding of global climate change. It also began with the idea that agricultural adaptation must remain the primary priority. At the grassroots level, efforts must be made to assist the local community, both physically and financially, and to support capacity-building. According to the study, increased financing is the most effective way to support all the efforts described (Stelzer and Quintero, 2014). It is recommended that the effects of climate change on agriculture can be limited by crop diversification, agroforestry, water harvesting, land utilization, and the use of seeds with drought- and heat-tolerant varieties. Furthermore, best practices and data on climate adaptations should be shared among countries to better adapt to changing climatic conditions. It also compiled and summarized the opinions and ideas emerging from the IPCC and the United Nations Framework Convention on Climate Change activities (UNFCCC, 2006).

The conventional coping strategies that have been in use for a century have now reached a stage where they do not help much in mitigating the land shortage problem. For most households, the future may be catastrophic unless adequate steps are taken to provide viable farm sizes or other alternatives that will supplement household income. There are two options: the first is incorporating non-farm activities. In this case, it is appropriate to integrate schemes of alternative means of income generation, such as the cottage industries. Second, given the limited resources, it seems most appropriate to relocate households with smallholdings and landless households to sparsely populated areas. Any strategies to control and/or reduce population pressure must be supported by relevant government policies and a political commitment to achieve a sustainable solution. Furthermore, concerted efforts must be made to promote the adoption of improved agricultural technologies, thereby increasing production and productivity in the agricultural sector. The effects of climate-related issues can be mitigated by introducing better land management and integrated farming (Edenhofer et al., 2010).

A link exists between disaster risk reduction, climate change adaptation, and rural development. It was concluded that disaster risk reduction and climate change adaptation could not significantly affect poverty in the long term. There must be an effort to find less risky enterprises in the long run, to better adapt to the changing

climate and achieve sustainable rural livelihoods (Davies et al., 2009). With a 2°C rise in temperature, the production of all crops would decline in both tropical and temperate regions. However, with adaptations, losses could be reduced by 7 to 15%. Adaptations were more effective for rice and wheat than for maize. The losses would be higher in tropical regions production in temperate regions could also be affected by global warming. There was limited information regarding the inter-annual yield effects of climate change, and most of the time, mean changes were predicted that were not a reliable estimate. As production can be increased in some regions, the impact analysis must be area-, crop-, location-, and season-specific. Previous studies lack a clear definition of uncertainty, a specific time frame, and methods for monetizing and estimating the adaptation benefits of climate change (Challinor et al., 2014).

Climate change presents serious threats to sustainable development in Australia's agricultural production systems. The effectiveness of the adaptation of sowing time and genetic cultivars to increase the yield of the wheat crop was tested. The sowing time and breeds had positive and negative impacts in different locations. It was concluded that wheat farmers at different locations require location-based adaptation packages to better adapt to climatic variations, as well as the timing of sowing and varieties, which have significant impacts on crop yields (Luo et al., 2018).

The primary adaptation strategies involved crop geometry and irrigation water availability options for cotton crops in southern Queensland, Australia. The impact of these adaptations was evaluated on gross margins using different projected scenarios. A bioeconomic model was employed to evaluate the impact of climate change on farm income and production. Without adaptation, the aggregate farm area is substantially reduced due to adverse impacts and decreased water availability. With different row spacing and increased water use efficiency, the losses could be minimized. Results showed that water availability would be reduced by 14% in both 2030 and 2050 compared to the baseline. The crop yield was highly sensitive to decreasing water availability and declined substantially (Williams et al., 2018).

Institutional Roles and Knowledge Dissemination

Growing crop production is closely tied to farmers' awareness of agricultural innovations developed by research institutions to combat climate change. The primary task of agricultural extension is to raise awareness of new technology and encourage the adoption of climate change strategies (Davidson et al., 2001). It refers to the systematic approach and support provided by extension organizations that help farmers cope with climate change, as well as the knowledge development among the rural population in a non-formal manner, which is used throughout the nation to promote the adoption of agricultural innovations (Arshad et al., 2010). Pakistan's increasing population growth requires a considerable rise in production; hence, extension field staff have the responsibility of helping farmers in the country to improve agriculture by providing them with the knowledge that will enable them to make better agricultural decisions (Subedi and Garforth, 1996). Several extension education methods have been used in agriculture extension to educate farmers and disseminate climate change strategies (Bajwa et al., 2010). The importance of natural resources for long-term utilisation, which is essential for sustainable rural development, has been emphasised by extension workers (Ikram-ul-Haq et al., 2009).

Multiple factors affected the adaptation method, but reduced access to credit facilities was considered a common factor in both countries. In South Africa, farmers were influenced by government support, credit facilities, and access to fertile agricultural land to adapt techniques that mitigate the impact of climate change. Similarly, among Ethiopian farmers, the choice of farmers to adapt to climate change is influenced by the availability of income, credit, and extension services (Bryan et al., 2009). Five risks associated with farming lead to production losses. These risks include production, financial, marketing, legal, and environmental risks, as well as human resource risks. All these risks harm agricultural production, leading to massive losses in farm produce. To minimize the impact of these risks on agricultural productivity, farmers must distinguish the risks associated with them and normalize these production risks accordingly to minimize losses (Drollette, 2009).

CONCLUSION

Climate change is not solely an environmental crisis but a profound human development challenge with far-reaching implications for individual and collective well-being. The evidence presented in this chapter demonstrates that the impacts of climate change are

intricately linked to physical health, mental wellness, economic security, and social equity. A dual perspective—one that integrates objective scientific assessments with subjective human experiences—is essential to fully grasp these dynamics. Future policies and climate responses must prioritize inclusive, adaptive, and participatory approaches that consider both empirical data and the lived experiences of affected populations. Only by recognizing the multifaceted nature of well-being can we design sustainable solutions that protect both the planet and the people who inhabit it.

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