german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

GCISC

Ministry of Climate Change
Government of Pakistan

# CLIMATE RISK PROFILE
# PUNJAB

# PROLOGUE

**Romina Khursheed Alam**
Coordinator to the Prime Minister
Ministry of Climate Change & Environmental Coordination
Government of Pakistan

As we stand at the precipice of climate uncertainty, Pakistan faces an urgent call to action. The recent floods, droughts, and other extreme weather events are stark reminders of the far-reaching consequences of climate change. These challenges not only threaten our environment but also pose significant economic and social risks to our nation.

In this critical juncture, it is imperative that we equip ourselves with the necessary tools to confront the impending climate crisis. The Climate Risk Profile of Punjab, presented here, serves as a vital resource in our endeavour to understand and mitigate the impacts of climate change in the local context. Developed through rigorous research and analysis, this profile offers valuable insights into projected climate parameters and their implications for various sectors across Punjab.

I commend the efforts of the German government and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) for their unwavering support in advancing climate resilience in Pakistan. Their commitment to strengthening climate knowledge, fostering organizational development, and facilitating political change processes is commendable. Through collaborative initiatives and cross-sectoral approaches, we strive to harness the potential of mitigation and adaptation measures, paving the way for sustainable development in alignment with the Paris Climate Agreement and Agenda 2030.

The Climate Risk Profile of Punjab, mainly/principally developed by Global Climate-Change Impact Studies Centre (GCISC), serves as a cornerstone in our collective efforts to build a resilient and sustainable future. It provides a comprehensive overview of climate risks and opportunities, empowering decision-makers at all levels to make informed choices. Moreover, it lays the foundation for further research and refinement, facilitating adaptive planning and proactive measures to address evolving climate challenges.

As we embark on this journey towards climate resilience, let us embrace the spirit of collaboration and innovation. Together, we can navigate the complexities of climate change and forge a path towards a brighter, more sustainable tomorrow.

# FOREWORD

**Zahid Pervez**
**Secretary,**
Environmental Protection and Climate Change Department
Government of Punjab,
Pakistan

It is with great pleasure and a sense of responsibility that I introduce the Climate Risk Profile of Punjab. As the custodian of environmental stewardship in the province, it is incumbent upon us to understand and address the multifaceted challenges posed by climate change.

Punjab, as one of the most populous and agriculturally productive regions of Pakistan, is particularly vulnerable to the impacts of climate variability and change. From extreme weather events to shifting precipitation patterns, the manifestations of climate change are increasingly evident in our daily lives.

The Climate Risk Profile of Punjab represents a significant milestone in our ongoing efforts to enhance climate resilience and sustainability. Developed in collaboration with esteemed partners such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German development Cooperation, this profile provides a comprehensive assessment of projected climate parameters and their implications for Punjab's environment, economy, and society.

I extend my sincere appreciation especially to GCISC and to all those involved in the creation of this invaluable resource. Their dedication and expertise have ensured the accuracy and relevance of the information presented herein. By offering a nuanced understanding of climate risks and opportunities, this profile equips policymakers, planners, and stakeholders with the insights needed to formulate effective strategies and interventions.

As we navigate the complex terrain of climate change, it is essential that we adopt a proactive and collaborative approach. The Climate Risk Profile of Punjab serves as a catalyst for informed decision-making and coordinated action, fostering resilience and sustainability across our province.

I encourage all stakeholders to utilize this profile as a guiding tool in our collective efforts to build a climate-resilient Punjab. Together, let us embrace the challenges and opportunities presented by climate change, forging a path towards a greener, more prosperous future for generations to come.

# FOREWORD

**Wolfgang Hesse**
Cluster Coordinator
Energy Climate Change and
Just Transition
GIZ Pakistan

The global climate crisis continues to escalate, making urgent and inclusive action imperative. In Pakistan, the impacts of climate change are acutely felt,, with regions like Punjab facing multifaceted challenges that threaten livelihoods, infrastructure, ecosystems, and particularly the resilience of vulnerable groups, including women, youth, and marginalized communities.

As the Coordinator of the Energy, Climate Change & Just Transition Cluster at GIZ Pakistan, it is my privilege to introduce this Gender Responsive Climate Risk Profile for Punjab. This document represents the culmination of rigorous research, collaboration, and expertise from a wide range of stakeholders, aimed at understanding and addressing the climate risks facing this vital region in a gender-responsive and socially inclusive manner.

Punjab, often referred to as the breadbasket of Pakistan, plays a pivotal role in the Pakistan's agricultural sector. However, the changing climate poses significant risks to agricultural productivity, water availability, and food security. These impacts are not gender-neutral: women farmers, despite substantial contribution to agricultural sector, face systemic barriers, including limited access to land, finance, technology, and decision-making spaces, which increases their vulnerabilities. Additionally, climate impacts ripple across other sectors including water resources management, public health, infrastructure resilience, and ecosystem integrity, where women and marginalized groups often bear disproportionate burdens.

This Climate Risk Profile delves into current climate trends, projected future scenarios, and the differentiated impacts on key sectors and social groups. By examining the interplay between climate variables, socio-economic dynamics, and gender roles, it provides a nuanced understanding of the vulnerabilities in Punjab. It also identifies the pathways for adaptation and mitigation that not only build resilience but also create equitable opportunities for women, men, and marginalized communities to actively shape climate solutions.

At GIZ, we are committed to supporting Pakistan in addressing climate change and building a sustainable, inclusive future.
Through collaborative initiatives, capacity building, and innovative solutions, we strive to empower women and men equally, strengthen community resilience, and ensure that government agencies, private sector actors, and civil society partners advance climate action that leaves no one behind.

# PREFACE

**Muhammad Arif Goheer**
Head – Agriculture &
Coordination Global Climate –
Change Impact Studies
Centre (GCISC)
Islamabad, Pakistan

In a world increasingly defined by the impacts of climate change, understanding the unique risks and vulnerabilities faced by nations is paramount. Pakistan, with its diverse geography, complex socio-economic landscape, and growing population, stands at the forefront of this global challenge. The need for a comprehensive understanding of Pakistan's climate risk profile has never been more urgent.

This study report on the climate risk profile of Punjab represents a culmination of rigorous research, data analysis, and stakeholder engagement aimed at unravelling the intricacies of climate vulnerability within the country. Developed through collaboration between experts from diversified fields of research, this report endeavours to provide a holistic perspective on the multifaceted risks posed by climate change across various sectors and regions of Pakistan.

Through detailed examination and analysis, this report sheds light on the evolving climate patterns, extreme weather events, and their cascading impacts on agriculture, water resources, infrastructure, human health, and ecosystems. Moreover, it delves into the socio-economic implications of climate risks, highlighting disparities, vulnerabilities, and adaptive capacities within different segments of society.

While the findings presented in this report may paint a sobering picture of the challenges ahead, they also serve as a clarion call for action. By identifying key risk factors, hotspots, and priority areas for intervention, this report aims to inform evidence-based policymaking, foster resilience-building efforts, and catalyse transformative actions towards a more climate-resilient future for Punjab, Pakistan.

As we navigate the complexities of climate change, let this report serve as a guiding beacon, illuminating pathways for sustainable development, adaptation, and mitigation. Together, let us embark on a journey of collective action, collaboration, and innovation to safeguard our planet and ensure a prosperous tomorrow for all.

## EXECUTIVE SUMMARY

According to the Global Climate Risk Index, Pakistan is currently the eighth most climate-affected country in the world. Pakistan contributes little to global $CO_2$ emissions (0.75% with just under 3% of the world's population) but is one of the countries most affected by the impacts of climate change. Pakistan is particularly vulnerable to flash floods, heavy monsoon rains, cyclones, droughts, and heatwaves due to extreme weather events. Melting glaciers in the Himalayas threaten flooding in the short to medium term and droughts in the long term. Extreme weather events already cause an average economic loss of almost EUR 3 billion per year. If Pakistan does not take measures to adapt to climate change, more than 21,000,000 people, or 10% of the country's population, could face additional poverty by 2050. At the same time, the technical and financial capacity to adapt to the adverse effects of climate change remains very low. Heatwaves in rapidly and unsustainably growing cities, as well as extreme weather events and natural disasters, particularly affect the poor population dependent on local livelihoods and natural resources.

Punjab, being the second-largest province, has experienced severe droughts, followed by devastating floods. This unpredictable cycle of climatic extremes has severely impacted agriculture production and the supporting irrigation systems. This sub-national profile provides an overview of projected climate change patterns and associated impacts on different sectors in Punjab, Pakistan, by the end of the 21st century under different climate change and socio-economic scenarios (i.e., Representative Concentration Pathways (RCPs) and Shared Socio-economic Pathways (SSPs), based on the latest available IPCC AR6 climate models). In this report, findings are based on RCP-SSP 2.4.5 (a world with moderate emissions, approximately 2.7°C warmer than pre-industrial levels) and RCP-SSP 5.8.5 (a world with very high emissions, approximately 4°C warmer than pre-industrial levels, an unlikely scenario). Pakistan is highly vulnerable to climate change due to its large population, high dependence on agriculture, water resources, and coastal areas, as well as existing socio-economic challenges. Assessing the differences between RCP 2.4.5 and 5.8.5 allows policymakers and planners to identify the level of adaptation and resilience required to cope with various climate change scenarios. This includes strategies for water management, agriculture, infrastructure development, disaster risk reduction, and public health interventions.

Water, agriculture, infrastructure, ecosystems, biodiversity, and health are all highly susceptible to the impacts of climate change in Pakistan. Adaptation in these sectors is emphasized in Pakistan's Climate Change Policy, National Adaptation Plan, and Nationally Determined Contributions (NDCs). These documents prioritize agriculture and energy as key sectors contributing to emissions. This sub-national climate risk profile has been developed using the state-of-the-art CMIP6 climate change scenarios, tailored to Pakistan's unique circumstances. It considers essential climate extremes indicators across spatial and temporal scales. Importantly, this profile complements existing national-level climate risk profiles developed by organizations such as PIK, the World Bank, and the Asian Development Bank, which mainly relied on CMIP5 IPCC scenarios.

The seasonal temperature changes show diverse patterns over different areas in Punjab. Summer temperatures show an increase of 3.5°C in the North with the largest increase of 4°C in the South. During winter, there is more warming expected, with a higher increase above 4°C across the whole Punjab under extreme scenarios. Precipitation trends are uncertain and show distinct seasonal patterns across the province. Summer precipitation is projected to increase significantly (150 mm to 300 mm) in upper Punjab during the late-century period under RCP-SSP 5.8.5. Future dry and wet periods are likely to become more extreme.

This profile incorporates findings from a gender analysis of climate risks in the selected sectors in Punjab that captures the climate risks and impacts, experienced by women, men and other marginalized groups. Conducted under the SAR project, the analysis examined gender-related vulnerabilities through a three-tiered approach: Macro-level (Policy and legal frameworks) Meso- level (institutional analysis), and Micro-level (community-level consultations). The results highlight that women in Punjab, despite their significant contributions to households and livelihoods, experience systemic

barriers in accessing climate-resilient technologies, financial services, and institutional support. These challenges are compounded by restrictive cultural norms and their underrepresentation in decision-making processes.

By aligning climate projections with gender-responsive insights, the profile enhances its value for inclusive planning. It emphasizes on integrating sex-disaggregated data, promoting women's leadership in resilience-building, and designing adaptatio strategies that address the specific needs and capacities of women, men, youth, and marginalized communities. This evidence-based and inclusive approach equips the policymakers, practitioners, and stakeholders with the tools to deliver climate responses that are not only robust and sustainable, but also fair and transformative.

## PROVINCIAL CONTEXT

Punjab is Pakistan's second largest province by area after Baluchistan, covering 205,344 square kilometres. According to the 2023 population census, Punjab's population is 128 million, growing at 2.53% (PGS, 2023). The province's share of the national population has slightly declined from 52.95% to 52.87% due to a lower growth rate than the national average of 2.55% (PGS, 2023). Most of Punjab's population lives in rural areas alongside the Indus River and its tributaries. However, the urban population is gradually increasing at 3%, higher than the country's urban growth rate of 2.67%. Lahore is the largest city with 11.3 million people, followed by Faisalabad with 3.2 million (Economic Survey of Pakistan, 2023). Other major cities include Rawalpindi, Multan, Gujranwala, and Sialkot.

Punjab significantly contributes to the national economy, accounting for 54.2% of the national Gross Domestic Product (GDP). Over the last five years since 2017, the province's annual GDP growth rate has averaged 4.9%. The major economic sectors are Services (62.4%), Agriculture (20%), and Industry (17.6%).

As development continues, employment in agriculture is expected to decline. The share of agriculture in Punjab's economy has already fallen from 45% in 2012-13 to 38.5% in 2017-18. Urbanization and industrial growth are key drivers of this labour shift, while climate change has also contributed by creating uncertainty in agriculture, lowering crop yields, and reducing farmers' profit margins.

Despite its reduced share in the economy, agriculture remains the largest employer in Punjab, engaging 38.5% of the population, especially in rural areas (Government of Pakistan, 2021). It is also a major sector for women's employment, involving 28% of economically active women (PERI, 2021). There are growing concerns about climate change's negative effects on agriculture, including rising temperatures, changing rainfall patterns, and extreme events like floods and droughts.

Punjab's agriculture is mainly irrigated, relying on surface and groundwater from the Indus River system. The average farm size is 7.57 hectares, about three times the national average (Asad et al., 2016). However, over 42% of farmers own less than one hectare, facing significant challenges to sustain their livelihoods under changing climate conditions. Major crops include wheat, cotton, rice, sugarcane, grams, and fodder (PITB, 2021). The sector's adaptive capacity is limited due to poor access to quality inputs, credit, and market services, which often benefits middlemen. This situation increases the risk of food insecurity and poverty for small farmers.

## TOPOGRAPHY AND ENVIRONMENT

The province is predominantly on a plain level, however, there are some mountainous areas in the northwest called the Margalla Hills and extreme South-West named Sulaiman Mountains. There is also a plateau adjacent to the mountains known as the Potohar plateau and a desert belt in the Southeastern part known as Cholistan. Punjab also contains part of the Thal desert. In the South, Punjab's elevation reaches over 2000 metres near the hill station of Fort Munro in Dera Ghazi Khan (Saif Ur-Rehman et al., 2020).

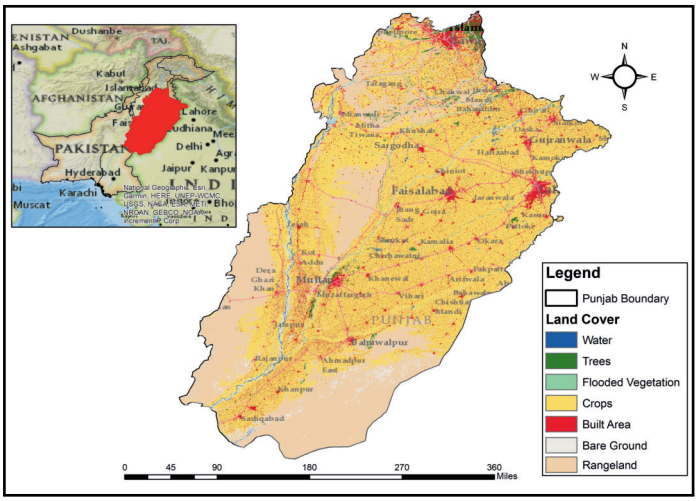


*Figure 1: Location of Punjab Province in Pakistan (Source: Land Cover Atlas of Punjab Province - Sentinel-II)*

Punjab is characterised by a semi-arid climate with increasing aridity from east to west and from north to south. Punjab province can be divided into fourteen Agroecological zones depending on climate and other factors (FAO, 2018).

Each of the agroecological zones is unique in terms of its climatic conditions, land resources and ecological factors allowing the region to follow specific patterns of crop production and pastoral activities.

Punjab has one of the largest irrigation systems supported by a thousand canals to serve the 21.71 million acres of cultivable command area with cropping intensities between 120-150%. The main source of water for Punjab is the Indus River and its tributaries i.e., the Jhelum, Chenab, Ravi and Sutlej rivers. The Indus is fed by melting snow and glacial meltwater from the Himalayas and runs southward, ultimately discharging into the Arabian Sea. However, climate change has impacted the water availability in the Indus and its tributaries through changes in rainfall patterns and has led to increased reliance on groundwater resources which is also evident from the rapid growth of tubewells across the province. Unsustainable agricultural practices, inadequate reforestation techniques as well as poor watershed protection and excessive water abstraction for irrigation have resulted in major environmental issues in the province, including salinity, soil erosion and desertification.

Extreme weather events, including heavy precipitation and droughts, are expected to intensify in the context of climate change, highlighting the need for adaptation measures to protect biodiversity and maintain fragile ecosystems and their services.

# PROJECTED CLIMATE CHANGES

## Temperature

Seasonal temperature projections for Punjab from 1951 to 2100 show a clear, consistent, and significant increase under both emission scenarios, particularly pronounced towards the end of the century. Figure 02 shows largest change in mean temperature is observed during summer (>5°C) in the period 2061-2100 under RCP-SSP585 scenarios. Warmer winters may disrupt traditional agricultural practices and crop cycles, while hotter summers could increase heat stress on crops and livestock, reducing yields and increasing vulnerability to pests and diseases. Rising temperatures may also accelerate glacier melting in the Himalayas, changing river flow patterns and affecting water availability. Additionally, the frequency and intensity of heatwaves may increase, posing health risks. In southwestern Punjab, including Muzaffargarh, Multan, and Lodhran, summer temperatures could rise up to 4.5°C under SSP585, creating substantial challenges for agriculture and livelihoods.

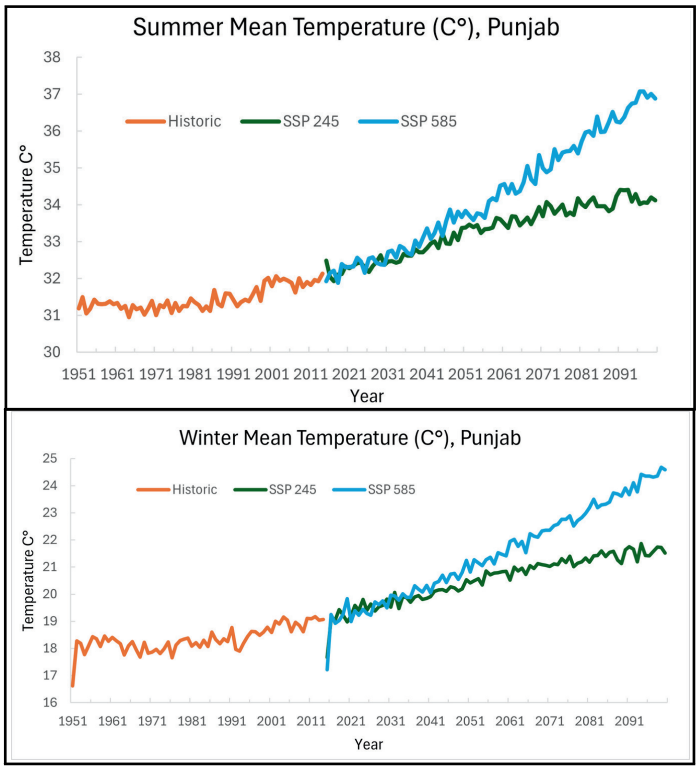


*Figure 02: Future changes in the temporal distribution of Summer and Winter temperatures (T mean °C) of Punjab province during the 150 years from 1950–2100*

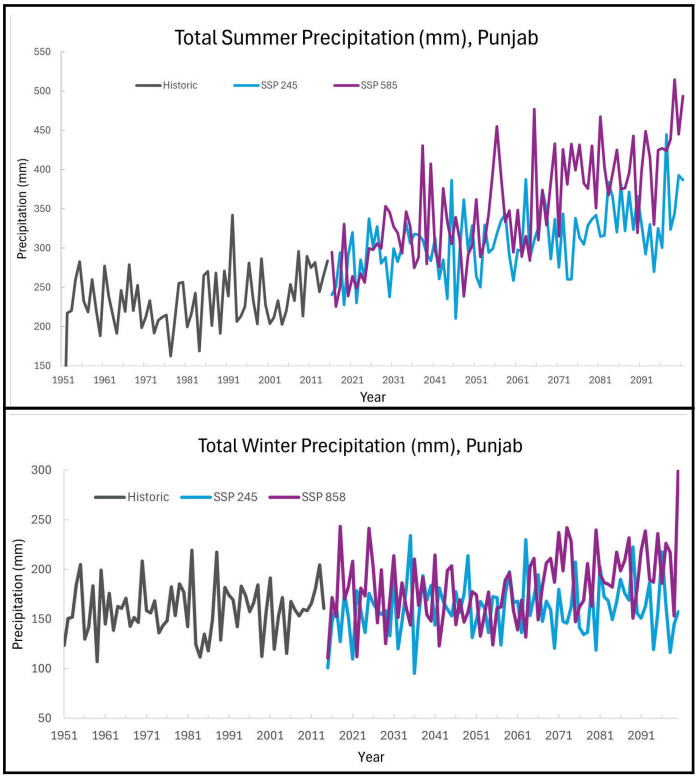


*Figure 03: Future changes in the temporal distribution of Summer and Winter precipitation (mm) of Punjab province during 150 years from 1950–2100*

## Precipitation

Precipitation shows a linear, non-significant increase in summer in Punjab, with no significant change during winter under both emission scenarios. Inter-annual variation is large, with the biggest increase under RCP-SSP585. Figure 03 shows significant trends in seasonal precipitation patterns for future periods F1 (2021-2060) and F2 (2061-2100) under RCP-SSP245 and 585. Spatial maps show distinct precipitation patterns across the province. The summer season highlights higher rainfall levels, particularly in regions influenced by monsoon rains, especially in northeastern Punjab. Elevated precipitation levels range from 10 mm to over 100+ mm, mainly in these areas. The increased intensity and frequency of precipitation align with the monsoon's influence. Towards the end of the century, precipitation levels during the Kharif season are projected to significantly increase under RCP-SSP585, emphasizing the need for adaptive measures and sustainable development strategies.

# PROJECTED CLIMATE CHANGES

## Hot days

As temperatures continue to rise, the frequency of extremely hot days (daily maximum temperature >35°C) is expected to increase significantly across Punjab, especially in the central and southern parts. Hot days are estimated for Punjab using daily maximum temperatures under both RCP-SSP245 and RCP-SSP585 scenarios for future periods F1 (2021-2060) and F2 (2061-2100) shown in Figure 04. The frequency is projected to exceed 8000 days in southern regions during the late century under RCP-SSP585, while northern Punjab may experience fewer hot days due to its cooler micro-climate. Spatial maps highlight these changes in hot day distribution. Southern Punjab, known for fertile lands and major crops like wheat, rice, cotton, sugarcane, and maize, may face severe impacts on crop yields and water availability.

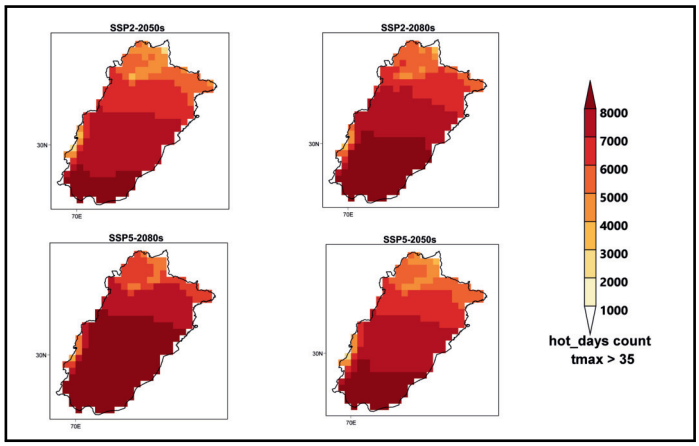


*Figure 04: Future changes in the spatial distribution of hot days of Punjab province during F1 (2021-2060) and F2 (2061-2100) under two emission scenarios i.e., RCP-SSP 245 and RCP-SSP 585*

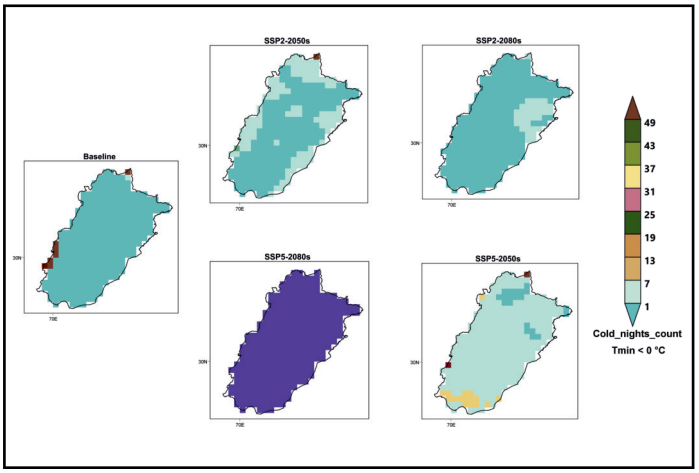


*Figure 05: Future changes in the spatial distribution of cold nights of Punjab province during the control period 1974–2014 and F1 (2021-2060) and F2 (2061-2100) under two emission scenarios i.e., RCP-SSP 245 and RCP-SSP 585*

## Cold Nights

Cold nights are defined as the number of days over a period where the daily minimum temperature is below 0 degrees C of a five-day window centred on each calendar day of a given 40-year climate reference period. Under rising temperatures, cold nights are projected to decrease substantially by the end of the century under both emission scenarios, clearly visible in figure 05. In the mid-century period, there is a greater spatial variability in cold nights while by the end of the century under extreme scenarios warming will increase and cold nights will be diminished.

## Growing Degree Days

The growing degree days (GDD) is considered an important parameter determining the crop growth and development under different temperature regimes (Kalra et al., 2008; Kingra & Kaur, 2012; Meena & Rao, 2013). It assumes a direct and linear relationship between growth and temperature The crops sown on the recommended time have a higher heat requirement than those of later sown crops. This happens because of the lower temperatures during the early vegetative growth stages and comparatively higher temperatures at the time of reproductive stage (Khichar & Niwas, 2007). Growing degree days analysis represents an increase in accumulated growing degree days for both scenarios (RCP 4.5 and RCP 8.5) and time periods (F1 & F2) in all major Wheat producing zones of Punjab including the Potohar region, Central and Southern Punjab.

However, this increase is more intense in RCP 8.5 during the late century period. Figure 06 shows an overall increase of 800-1000 Growing Degree Days (GDD) between the historical and late-century extreme scenarios in the central and southern parts of Punjab. Results indicate that the major irrigated wheat-producing areas of Punjab are poised to face heightened challenges due to escalating temperatures, particularly during critical crop growth stages marked by high temperatures and water stress. This scenario is anticipated to result in diminished productivity.

In the extreme southern parts of Punjab, there's been a notable surge of 800-1000 growing degree days, while the northern regions of Pakistan are anticipated to experience an increase of nearly 600. Consequently, the lower southern areas may become less conducive to crop production due to the intensifying heat in late century period, in the absence of mitigation measures and appropriate adaptation strategies.

In the extreme southern parts of Punjab, there's been a notable surge of 800-1000 growing degree days, while the northern regions of Pakistan are anticipated to experience an increase of nearly 600. Consequently, the lower southern areas may become less conducive to crop production due to the intensifying heat in late century period, in the absence of mitigation measures and appropriate adaptation strategies.

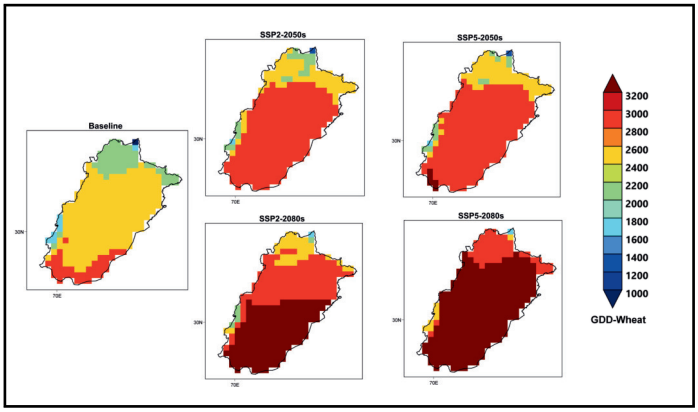


*Figure 06: Spatial distribution of Growing Degree Days (GDD) over Punjab during the baseline period (1974-2014) and F1 (2021-2060) and F2 (2061-2100) under two emission scenarios (RCP-SSP 245 and RCP-SSP 585)*

# SECTOR SPECIFIC CLIMATE RISK ASSESSMENT

## Agriculture

Agriculture is one of the key sectors significantly impacted by climate change due to alterations in optimum temperature required for crop growth. Agriculture contributes largely to Pakistan's economy, with approximately 25% of the population directly linked to this sector. Climate change is affecting Pakistan's cropping patterns and intensity, particularly in Punjab, a major contributor to the country's agriculture sector. Any change in temperature and precipitation over Punjab under climate change can geographically redistribute crop suitability zones.

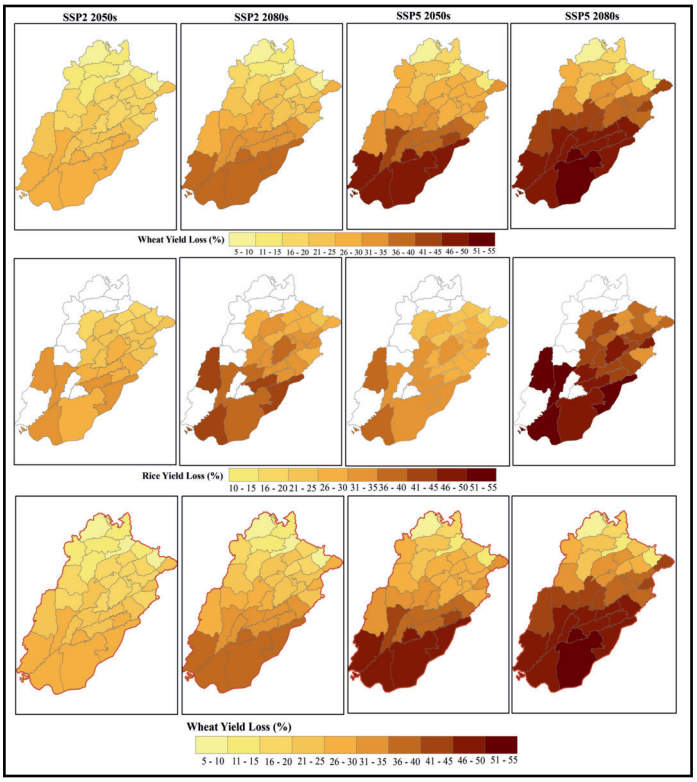


*Figure 07: Potential loss of wheat, rice and cotton crops for climate change scenarios*

The first response of crops to climate change is a decline in yields. Evidence of significant declines in wheat, rice, and cotton yields confirms these adverse effects, disrupting the food supply chain. This decline is mainly triggered by rising temperatures far above the optimum values for crop growth, decreasing the length of phenological stages such as days to anthesis, maturity, and harvesting. A significant decline in wheat yield is expected from north to south Punjab (Figure 07), as also reported by Azmat et al. (2021). Rice yield, a major Kharif crop of central Punjab, is expected to suffer huge losses, like losses reported by Gaydon et al. (2023) in Gujranwala and Narowal. Cotton, a key cash crop in south Punjab, may suffer the most due to climate change, needing more water in regions already facing water shortages

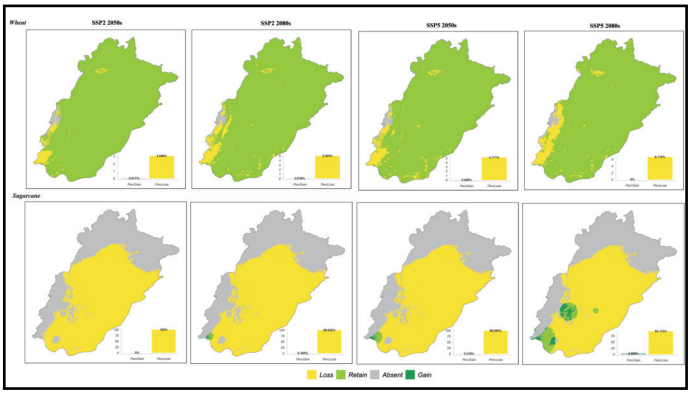


*Figure 08: State of wheat and sugarcane cropping area under climate change scenarios.*

Figure 08 shows potential shifts in the areas of wheat and sugarcane under climate change scenarios. A slight loss in wheat-growing area, covering over 95% of Punjab in the rabi season, can significantly impact wheat production. The maize crop is expected to face substantial area loss, particularly during the 2080s. Cotton is projected to vanish from Punjab under dry and hot conditions. In contrast, the rice area is expected to increase under climate change scenarios.

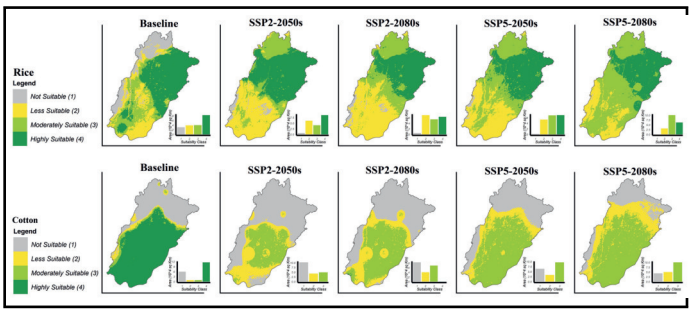


*Figure 09: Suitatbility level of rice and cotton for climate change scenarios.*

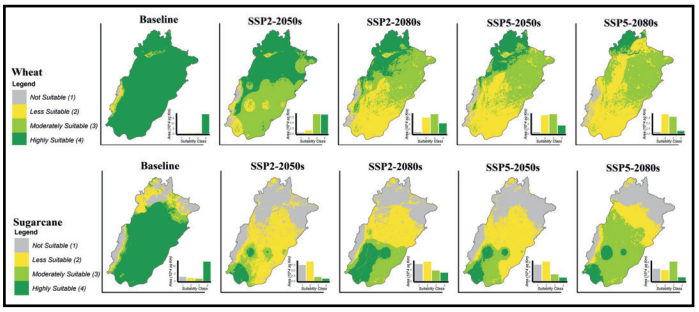


*Figure 10: Suiatbility level of sugarcane and wheat for climate change scenarios.*

Figures 09 and 10 present extended outcomes for the suitability levels of rice, cotton, wheat and sugarcane under climate change. A considerable area currently dedicated to rice is projected to be lost, confining rice cultivation to central Punjab. Cotton suitability will also decline, leaving only moderately suitable areas that may result in lower yields. Wheat's highly suitable regions will shrink towards northern Punjab. Sugarcane will likely be confined to the southern regions with significantly reduced high-suitability areas compared to the baseline.

Figure 11 shows the shifting suitability of Kharif and rabi crops. Climate change is impacting cropping zones, patterns, and intensity in Punjab. In the baseline, cotton, maize, and rice zones dominate. By mid-century, the cotton zone disappears, leaving only rice and maize zones. By the late century, both cotton and maize zones are expected to vanish. For the rabi season, a gradual decrease in wheat and sugarcane areas is observed. Highly suitable cropping zones for sugarcane and wheat will shift towards south and north-central Punjab.

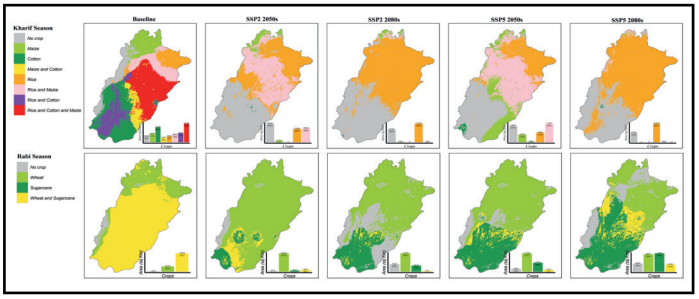


*Figure 11: Potential cropping zones of Kharif and Rabi crops for climate change scenarios.*

Currently, rabi season in Punjab shows a balanced distribution: 75% of the area is suitable for both wheat and sugarcane, 22% is suitable for wheat only, and 2% is unsuitable for any crop.

By the 2050s, combined cultivation areas are expected to drop to 9%, with wheat monoculture areas expanding to 81%. By the 2080s, southern Punjab may become suitable mainly for sugarcane (19%), and the combined suitable area for both crops may decrease to 2%, with 56% of land suitable only for wheat and 23% remaining unsuitable.

Under SSP5 by the 2050s, the combined suitable area for both wheat and sugarcane is projected to fall to 6%. Wheat suitability will be limited to 57% (mainly upper Punjab), and sugarcane to 28% (southern Punjab), while 9% may become unsuitable. By the 2080s, wheat suitability is expected to drop to 34%, sugarcane suitability to rise to 36%, and combined areas to 14%, while unsuitable land increases to 16%.

For the Kharif season, the current landscape is diverse: 25% of the area is suitable for rice, cotton, and maize; 12% is suitable for both cotton and rice; 20% is suitable only for cotton; 11% is suitable for maize; 8% is suitable for rice; 10% is suitable for rice and maize; and only 8% is unsuitable for any crop. By the 2050s, under SSP2 and SSP5, 39% and 31% of the area, respectively, are expected to become unsuitable for cultivation. Rice suitability is projected to rise to 28% (SSP2) and 18% (SSP5), while combined maize and rice areas may increase to 29% (SSP2) and 35% (SSP5). Cotton suitability is expected to decline.

By the 2080s, unsuitable areas are projected to rise to 40% under SSP2 and 33% under SSP5. Rice cultivation is expected to dominate, covering 58% (SSP2) and 65% (SSP5). Maize cultivation is projected to fall to 1% (SSP2) and 0% (SSP5). Combined maize and rice areas will occupy only 1% by the 2080s.

Climate change impacts on Punjab's agriculture show that extreme precipitation and temperature are no longer favourable for current cropping patterns and intensities, forcing the redistribution of cropping zones based on altered climate variables and adaptation measures.

The gender analysis on climate risks from rural Punjab underscores the critical yet often unrecognized role that women play in agriculture.

While the Punjab Agriculture Policy 2020 acknowledges gender inequalities, it does not provide a comprehensive framework to redress them. With the growing pressures of climate change, these gaps are becoming increasingly urgent.

Women in flood-affected communities take on expanded caregiving responsibilities, increased food insecurity, and the additional burden of managing farms and livestock care. Despite their central role, they face persistent challenges, including limited mobility, restricted access to education, healthcare, resources, and agricultural support services. Decision-making in rural households and communities is dominated by men, leaving women with little opportunity to influence adaptation strategies that directly impact their livelihoods.

During interactions with rural women, they articulated practical gender needs and called for localized training in livestock management, crop disease control, and salinity mitigation, that equips them skills, critical for sustaining agricultural production during climate change. Strategies such as changing cropping patterns or adjusting sowing and harvesting cycles must be considered integral to effective climate-responsive agricultural policy.

## Water Resources

Ensuring timely and sufficient water availability is imperative for enhancing agricultural production and ensuring long-term sustainability. In Punjab, surface water resources are limited, posing constraints on potential water supplies. Most of agriculture in Punjab relies on irrigation, contributing over 90% of agricultural output. However, expansion of cultivated land, low water management efficiency, and increased cropping intensity have led to a significant irrigation water deficit of approximately 50%. To meet this growing demand, groundwater is increasingly tapped to supplement surface water.

Snow and glaciers in northern Pakistan are major sources of irrigation water in the Indus, Jhelum, and Chenab Rivers, which are supplied through Tarbela and Mangla dams along with barrages and headworks regulating a unique canal network. Rapid temperature increases have been reported to decline snow formation and accelerate glacier melt, resulting in significant spatial and temporal changes in river inflows (Azmat et al., 2018; Azmat et al., 2020). A slight change in water resources can potentially alter large reservoir operations and agriculture water management.

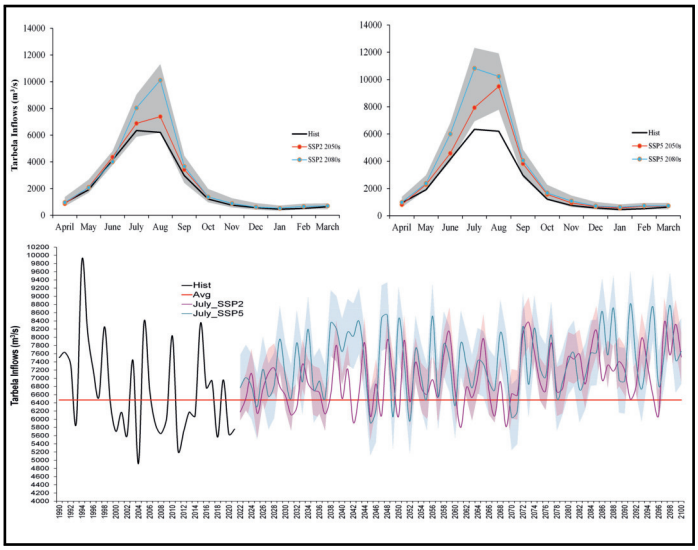


*Figure 11: changes in Tarbela's monthly inflows and during the month of July (peak month) under climate change scenarios*

Tarbela Dam plays a key role in supporting irrigation agriculture in several Punjab districts, including Attock, Rawalpindi, Jhelum, Chakwal, Sargodha, Khushab, and Mianwali, supporting

crops like wheat, rice, sugarcane, cotton, maize, and vegetables. Mangla Dam on the Jhelum River supports irrigation, hydroelectric power, and flood control, benefitting areas in Gujrat, Jhelum, and Mandi Bahauddin. The Head Marala Barrage on the Chenab River regulates the Marala-Ravi Link Canal, supporting agriculture in Sialkot, Narowal, Gujranwala, and Gujrat. Reliable water supply from these structures supports livelihoods and agricultural productivity.

Pakistan's irrigation agriculture system is designed based on water availability, making peak water flows critical for sustainable cropping patterns. Figure 11 exhibits a significant backward shift in Indus River inflow peaks at Tarbela Dam under climate change scenarios. Flows in July show a gradual increase over time, more under SSP5, indicating mass glacier melt. Evapotranspiration (ETp) is increasing in Punjab, particularly in irrigated regions, indicating higher future crop water requirements. Increased ET will significantly raise agricultural water demand,

reduce soil moisture reliability, and present serious challenges for the water-agriculture sector.

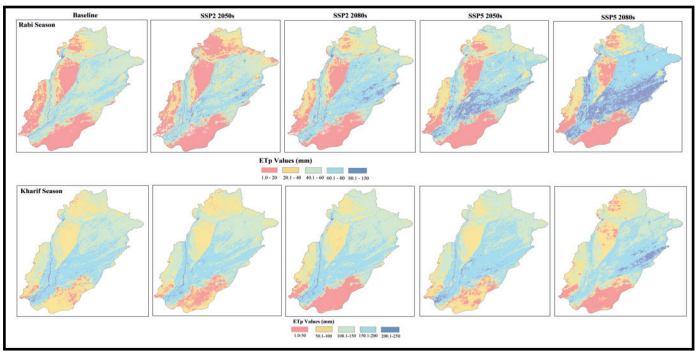


*Figure 12: Change in Potential Evapotranspiration under future scenarios*

Evapotranspiration (ETp), shown in Figure 12, is projected to increase across Punjab, especially in the south. Higher ETp indicates greater crop water requirements, reduced soil moisture reliability, and serious challenges for agricultural water management under future climate change scenarios. Despite the urgency, gender dimensions remain largely absent in water governance frameworks. The Water Policy 2018 makes little provision for integrating gender into planning or implementation.

This gap has significant implications at the community level, where women bear a disproportionate burden of water scarcity. They are primarily responsible for water collection and household water management, and they directly experience the consequences of declining availability and deteriorating quality.women are often excluded from community-based water management programs and disaster preparedness initiatives, leaving their voices unheard in shaping solutions.

Community insights highlight the water conservation as an essential adaptation strategy. Rural women have expressed keen interest in discussions and initiatives related to water use, conservation, and climate resilience. Their involvement is not only a matter of equity but also a practical necessity. Adaptation strategies will be effective when they reflect the realities and knowledge of women and marginalized groups who are directly affected.

Addressing Punjab's water challenges, requires a dual approach by strengthening policy frameworks to embed gender dimensions, and ensuring participation of women in the community-level planning and adaptation strategies.

## Health

Globally, climate change has a negative impact on human health and contributes to the transmission of vector-borne diseases such as dengue (Campbell-Lendrum et al., 2015). Every year, 390 million dengue cases are reported worldwide, and nearly 4 billion people are at risk (Griffin et al., 2016). Several studies reported that temperature is associated with vector survival, ovi-position, hatching development, contact, and transmission. High temperatures accelerate viral replication, shorten the extrinsic incubation period of dengue viruses, and reduce mosquito development time (Huber et al., 2018; Mordecai et al., 2017).

Pakistan is one of the most vulnerable countries to climate change. One of its adverse impacts is the spread of vector-borne diseases, including dengue, where climate change significantly affects the intensity and spread of dengue outbreaks. Dengue Transmission Suitable Days (DTSD) serve as a crucial metric for assessing the spread of dengue across regions. In Punjab province, temperature data from CMIP6 under SSP2 and SSP5 scenarios was used to identify dengue hotspots based on DTSD values. These hotspots were then used to interpolate data for adjoining districts of Punjab. The analysis revealed a potentially higher density of cases in the northern and central parts of Punjab compared to the southern regions. DTSD values are expected to decrease significantly during the mid and late century under future climate change scenarios. The density of DTSD values diminishes from north to south of Punjab, showing an inverse relationship between DTSD and temperature, in conjunction with the elevation of the geographical location.

Malaria is an extremely climate-sensitive tropical disease, making the assessment of changes in risk due to warming trends one of the most important climate change health questions. Meteorological factors like rainfall, temperature, and humidity are associated with malaria incidence from both temporal and spatial perspectives (Abeku et al., 2003; Reid et al., 2012). These meteorological factors can act synergistically to increase larvae development duration, shorten the incubation period of parasites, prolong mosquito survival, provide favourable swampy habitats, increase mosquito populations, and the number of mosquito bites, thus

increasing malaria risk (Adeola et al., 2017; Ikeda et al., 2017)

Malaria is moderately endemic in Pakistan, but its transmission is unstable, with disease burden ranging from very high to low (Khattak et al., 2013; Umer et al., 2018). Malaria Transmission Index (MTI) can attribute erratic malaria transmission patterns to climatic changes. MTI values in Figure 13 (lower panel) show the impact of climate change on malaria spread from the northern to the southern regions of Punjab. There is a clear trend of increasing malaria occurrence from higher elevation areas in the north to lower elevation regions in the south. Significant temporal increase in MTI is observed under climate change scenarios (SSP2 and SSP5) during the 2050s and 2080s. These trends align with studies by Pascual et al. (2006) and Patz and Olson (2006), which highlight the nonlinear and threshold responses of malaria to regional temperature changes. Pascual et al. (2006) found that even a 0.5°C temperature increase can cause a 30–100% surge in mosquito abundance, underscoring the "biological amplification" of temperature effects.

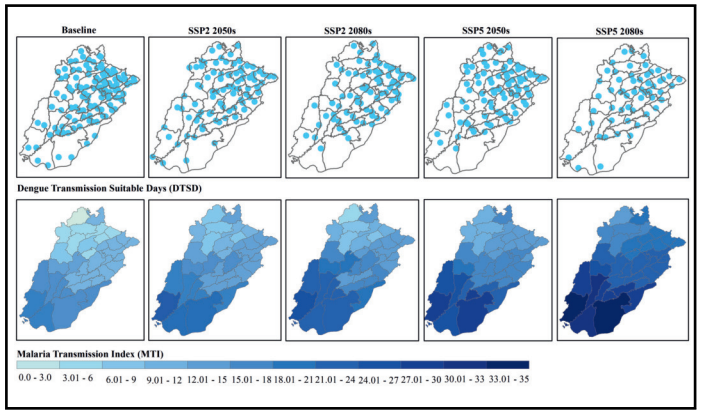


*Figure 13: climate change impact on dengue transmission in Punjab Province under future scenarios.*

Climate change is increasingly undermining human health in Punjab, particularly through the spread of vector-borne diseases such as dengue and malaria. The gender analysis of climate risks on health reveals that women face specific health-related vulnerabilities exacerbated by climate change, however the health and climate policies have not adequately addressed the gender dimensions of these risks. In flood-affected areas, they report worsened health outcomes due to greater exposure to disease vectors, limited access to healthcare, and expanded caregiving responsibilities. Women's restricted access to healthcare and critical support services leaves them less equipped to cope with climate-induced health challenges.

Integrating gender into health and climate adaptation policies is therefore essential. Without targeted measures to improve women's healthcare access and resilience, the response of Punjab to climate-related health risks will remain incomplete and inequitable.

## Ecosystem

Climate change is causing the geographical redistribution of plant and animal species globally. These distributional shifts are leading to new ecosystems and ecological communities,
changes that will affect human societies. Although the geographical range limits of species are dynamic and fluctuate over time, climate change is impelling a universal redistribution of life on Earth. For birds, the first response to warmer and drier conditions is often a shift in location to remain within preferred environmental conditions. Species at the cooler extremes move towards favourable conditions, while the range limits contract at the warmer edges where temperatures, precipitation, and rainfed croplands are no longer favourable.
Different species are responding at different rates and to varying degrees, key interactions among species are often disrupted, and new interactions develop. These changes can result in novel biotic communities and rapid changes in ecosystem functioning, with pervasive and sometimes unexpected consequences that affect both biological and human communities.

Pakistan sits at the intersection of three distinct zoogeographic regions – Oriental, Palaearctic, and Ethiopian – characterized by significant altitudinal shifts and a rich diversity of ecological zones (Anwar et al., 2022). Pakistan's forests are home to numerous endangered and endemic species. However, the delicate equilibrium between these species and their habitats faces disruption due to climate change. Escalating temperatures, changing precipitation patterns, and alterations in rainfed cropland profoundly affect the breeding and wintering species richness across various provinces of Pakistan (Khaliq et al., 2023).

Figure 14 demonstrates the consequential impact of significant drivers such as precipitation, temperature, and rainfed cropland on breeding and wintering species richness in Punjab, Pakistan. These impact values forecast the anticipated alteration in species richness of both breeding and wintering birds under projected environmental conditions. Seasonal migration of bird species, with migratory species predominantly appearing in winter, necessitates comparing wintering (comprising migratory and resident species) and breeding (involving resident species only) bird richness.

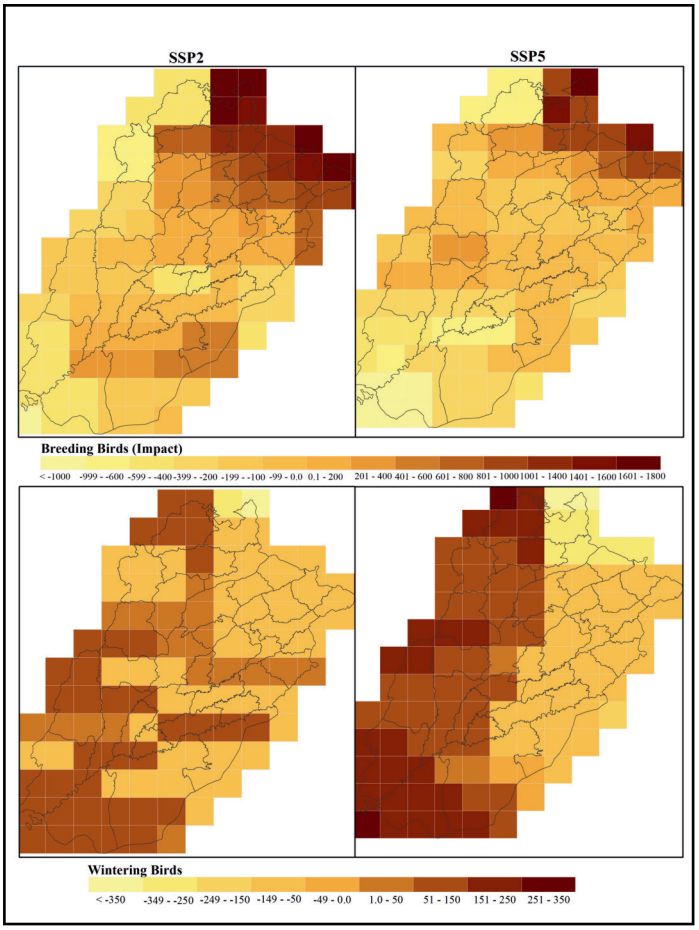


*Figure 14: Combined impact of the projected changes on breeding birds and wintering birds due to significant drivers in Punjab, under SSP2 & SSP5.*

Overarching gender disparities indicate that women and marginalized groups, often rely on
natural resources for livelihoods and household needs, and they are disproportionately affected by ecosystem degradation. Limited access to resources and exclusion from decision-making processes further hinder their ability to adapt to changes in ecosystem services.

## Infrastructure

Floods are a major source of infrastructure loss in Pakistan, mainly due to climate change-induced precipitation or rapid snow and glacier melt combined with high-intensity precipitation over high-altitude regions. Since five rivers meander through the highly populated Punjab province, it is apparently one of the most impacted provinces by extreme events like floods. The 2010 and 2022 floods are living examples of high-intensity precipitation and rapid snow and glacier-induced floods due to climate change. These floods caused severe damages to national infrastructure, including roads, bridges, railway tracks, agriculture fields, and private infrastructure, particularly in urban areas, ultimately damaging urban settlements and the country's economy.

High temperatures can impact infrastructure in a dual way: by expediting the snow and glacier melt process, which can cause riverine flooding, flash flooding, and glacier lake outbursts (GLOFs), and by triggering cracks in roads, bridges, and coastal infrastructures, which can degrade more quickly.

The 2010 flood is an example of high-intensity rainfall that severely damaged the infrastructure of different regions of Punjab. The flood was mainly due to a four-day wet spell of the Monsoon, particularly over the northwest of Pakistan, combined with rapid snow and glacier melt. This generated a massive flash flood in the eastern Hindukush region and the foothills of the Sulaiman Ranges, followed by disastrous fluvial flooding. The 2010 flood reportedly damaged agriculture, road and canal networks, houses, electric supply feeders, and livestock. The total cost of damage was 783,997 USD just in Muzaffargarh district, Punjab.

The 2010 flood, in Pakistan, caused widespread destruction across urban and rural areas, severely affecting local communities and infrastructure networks.

Figure 15 depicts urban damage based on three scenarios by keeping 2030 as a baseline. Based on the 10-year protection plan, scenario A demonstrates that 68.53% and 31.47% of the urban damage are projected to be determined by socioeconomic and climate change, respectively, if no flood protection is employed. the total annual urban damage of the country could reach $2.1 billion by 2030. Scenario B illustrates that 56.67% and 43.33% of the projected

urban damage may be due to socioeconomic and climate change, and the total annual urban damage in the country may reach $3.4 billion by 2030 if no flood protection plan is employed. However, scenario C shows that if Pakistan does not implement flood protection, both socio-economic and climate change may bring a similar increase (50%) in expected urban damage, and the total urban damage in the country may reach $2.6 billion in 2030.

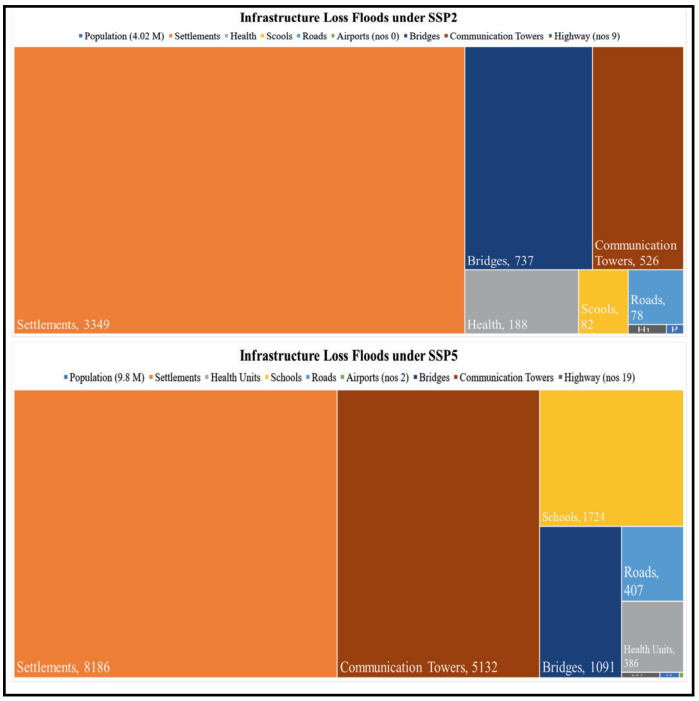


*Figure 15: Infrastructure loss due to floods in Punjab province under SSP2 and SSP5 scenarios.*

Figure 15 depicts urban damage based on three scenarios by keeping 2030 as a baseline. Based on the 10-year protection plan, scenario A demonstrates that 68.53% and 31.47% of the urban damage are projected to be determined by socioeconomic and climate change, respectively, if no flood protection is employed. the total annual urban damage of the country could reach $2.1 billion by 2030. Scenario B illustrates that 56.67% and 43.33% of the projected urban damage may be due to socioeconomic and climate change, and the total annual urban damage in the country may reach $3.4 billion by 2030 if no flood protection plan is employed. However, scenario C shows that if Pakistan does not implement flood protection, both socio-economic and climate change may bring a similar increase (50%) in expected urban damage, and the total urban damage in the country may reach $2.6 billion in 2030.

The dual impact of rising temperatures and high-intensity precipitation will likely continue to threaten the sustainability and resilience of infrastructure systems across Punjab and Pakistan.

Floods, driven by extreme rainfalls are a major source of infrastructure loss in Punjab. The 2010 and 2022 floods caused widespread destruction of roads, bridges, railways, agricultural lands, and private assets. While such damage affects all communities, the impacts are experienced differently by women and marginalized groups.

The analysis shows that women are often excluded from community-based disaster preparedness and infrastructure planning processes. As a result, their specific needs such as safe evacuation routes, safe temporary shelters, and access to post disaster essential services are overlooked. Policies and programs that do not integrate gender perspectives leave critical gaps in disaster response and recovery. The analysis recommended that effective climate resilience strategies must be gender-responsive and inclusive to address the unique vulnerabilities and capacities of women and marginalized groups.

# GENDER ANALYSIS OF CLIMATE RISKS IN THE SELECTED SECTORS: Key Findings & Recommendations

## Macro Level: Policies and legal frameworks

The Punjab Climate Change Policy 2022 and Action Plan 2024 recognize gender vulnerabilities but lack actionable strategies, particularly for marginalized groups. The Punjab Agriculture Policy 2020 identifies gender issues in agriculture without linking them to climate change, while the Punjab Water Policy 2018 broadly acknowledges rural challenges but overlooks gender-specific vulnerabilities. The Climate Change Policy integrates gender mainstreaming and ensures women's participation, while the Action Plan mentions inclusivity without actionable gender-specific goals. The Agriculture Policy highlights the major role of rural women in agriculture as labour but lacks a comprehensive approach. The Water Policy excludes gender considerations, weakening its inclusivity.

The Climate Change Policy addresses intersecting vulnerabilities, such as access and mobility, but the Action Plan and Agriculture Policy only mention participatory barriers without actionable measures. The Water Policy entirely omits intersectionality, neglecting challenges like rural isolation and poverty. Gender-disaggregated data frameworks are absent in the Climate Change Policy, Action Plan, and Agriculture Policy, despite recognizing its importance. The Water Policy fails to address gender-disaggregated data collection altogether, limiting targeted interventions.

While the Climate Change Policy and Action Plan advocate equitable access, they lack actionable measures to address structural barriers. The Agriculture Policy encourages equal access but provides no enabling strategies. The Water Policy fails to address women's access to resources, particularly in rural areas. Although the Climate Change Policy promotes women's participation in governance, the Action Plan includes women from departments like Social Welfare without specific targets. The Agriculture Policy emphasizes participatory processes but overlooks governance roles for women. The Water Policy excludes gender-inclusive governance altogether.

None of the policies incorporate gender-specific Key Performance Indicators (KPIs) or audits. Monitoring frameworks are either absent or gender blind. The Climate Change Policy, Action Plan, and Agriculture Policy lack monitoring systems, while the Water Policy omits accountability mechanisms for gender inclusivity. Disaster Risk Reduction (DRR) planning in the Climate Change Policy and Action Plan lacks a gendered lens. The Agriculture Policy mentions gender strategies but not in relation to DRR. The Water Policy completely overlooks gender in disaster resilience. Gender-responsive budgeting is absent across all reviewed policies. The Climate Change Policy encourages gender budgeting but without tracking mechanisms. The Action Plan, Agriculture Policy, and Water Policy lack any reference to gender-specific expenditures or budget allocations. While Punjab's policies show some recognition of gender vulnerabilities, particularly in the Climate Change and Agriculture Policies; critical gaps persist in implementation mechanisms, intersectionality, access to resources, participation, and monitoring frameworks. The absence of gender-responsive budgeting and gender-disaggregated data further limits policy effectiveness.

## Macro Level Recommendations

Punjab's climate-related policies must be updated to include actionable gender-specific objectives, especially in the Climate Change Action Plan and Agriculture Policy. These should directly address the intersecting vulnerabilities faced by rural women and marginalized groups. Provincial policies must institutionalize gender-responsive budgeting to ensure equitable allocation and tracking of adaptation resources. Sectoral policies in agriculture, water management, and urban planning should be guided by gender-disaggregated data, which must be systematically collected and centrally maintained. Alignment with international frameworks such as the Sendai Framework for DRR is critical to enhance gender-inclusive climate resilience. Dedicated institutional spaces must be created to ensure women's representation in climate policy forums and governance structures.

## Meso Level: Institutions and Organizations

The meso-level analysis for Punjab is informed by 13 Key Informant Interviews (KIIs). Stakeholders acknowledged incremental progress in incorporating gender into policy frameworks, particularly in agriculture and water management. Notable initiatives include women-led cooperatives and gender-sensitive water programs. However, implementation remains inconsistent and fragmented across departments. Socio-cultural resistance and limited institutional capacity hinder the enforcement of gender-responsive frameworks. Despite policies like the Punjab Climate Change Policy recognizing gender roles, there is a lack of actionable mechanisms and interdepartmental coordination to support their practical application.

Gender-inclusive agricultural extension services and community-based disaster preparedness workshops have been implemented, but they require institutional support for scaling up. Representation gaps persist, with women and marginalized groups underrepresented in policy development. The absence of gender-disaggregated data weakens the ability to identify and address unique vulnerabilities. Traditional norms and systemic exclusions continue to limit women's participation in decision-making forums. Programs such as PDMA's evacuation route designs and the inclusion of women in Community-Based Disaster Risk Management (CBDRM) initiatives were recognized as effective but remain isolated and unembedded in broader policy frameworks.

Integration of Climate Risk Assessments (CRAs) is partial. While CRAs have been applied in agriculture and irrigation resulting in hazard mapping and vulnerability assessments their application in health, energy, and urban planning remains limited. CRAs in Punjab often rely on donor-driven frameworks, which are not always aligned with local needs. Weak institutional coordination, lack of updated gender and climate data, and poor engagement with academia and civil society further restrict CRA effectiveness. Although some university-led climate-smart agriculture initiatives show potential, they are not adequately linked to policy formulation or provincial planning frameworks.

## Meso Level Recommendations

Punjab must create multi-stakeholder platforms to promote collaboration among government departments, NGOs, and academic institutions for integrated CRA application. Policymakers and technical staff must be trained in gender-sensitive CRA tools and methodologies. Standardized guidelines should be developed to institutionalize gender inclusion in CRA processes. A province-wide, gender-disaggregated database for women farmers and vulnerable communities must be developed through the Agriculture Extension Department. Gender-responsive pilot projects such as women-led cooperatives and disaster preparedness initiatives should be scaled and embedded in regular institutional workflows to ensure long-term sustainability.

## Micro Level: Individuals, Households and Community

Focus group discussions (FGDs) with 41 women and 17 men from farming communities in Tehsil Khanpur, District Rahim Yar Khan, revealed climate change is having a severe impact on daily life. Women reported increased temperatures, irregular rainfall, hailstorms, and frequent floods, which disrupt routines, damage crops, and strain health systems. Men noted intensified rains and heatwaves, causing damage to crop and livestock. Both groups emphasized how climate disruptions have led to crop failures, livestock illness, salinity, and dependence on distant water sources, deepening financial and livelihood insecurity.

Women reported increased caregiving responsibilities, worsened health outcomes, and food insecurity. Access to resources such as mobile phones, training, and agricultural inputs is limited by cultural norms and geographical isolation. The remoteness of villages restricts education, healthcare, and critical support services. Men mentioned labor migration and the rising cost of agricultural inputs as key stressors. Women highlighted the burden of accessing veterinary care and managing farm responsibilities in male-absent households.

Adaptation strategies include shifting cropping patterns, adjusting sowing and harvesting cycles, conserving water, and reinforcing homes before monsoons. However, decision-making remains male-dominated, with women excluded from leadership roles in adaptation planning. All men claimed decisions were made jointly, yet no woman reported being primary decision-makers. Women requested localized training particularly by women trainers in livestock care, crop disease management, and salinity mitigation. Skill development in tailoring and other alternative livelihoods was also cited as necessary. Men emphasized on better water management, pest control, and training for agricultural resilience. Both groups recognized urgent climate challenges but had different adaptation priorities based on their gender roles.

## Micro Level Recommendations

Rural women in Punjab must be empowered through climate-smart agriculture, livestock care training, and vocational programs. Agricultural extension services should train women through female trainers and be backed by NGOs offering financial and logistical support. Investments in flood-resilient infrastructure, clean water, healthcare, and sanitation must be prioritized by district and provincial governments to improve overall resilience. Community-level planning must be inclusive, involving women, minorities, and other vulnerable groups, with support from political leaders and religious figures to foster participatory decision-making. To reduce economic dependency on climate-sensitive agriculture, livelihood diversification must be supported through skill training and financial assistance for small-scale enterprises

**Table: Assessment of Policies and Action Plans from gender lens: Using Color-coding Indicators for Punjab"**

| Policy Document | Acknowledging Gendered Impact | Gender-Sensitive Policy Objectives | Assessing Gender Intersectionality | Gender-disaggregated Data | Access to Resources | Role in Decisions Making and Governance | Gender Sensitive Monitoring Indicators/ Audit | Inclusion of Gender in DRR | Gender-Sensitive Budgeting |
|---|---|---|---|---|---|---|---|---|---|
| **Punjab CC Policy 2022** | | | | | | | | | |
| **Punjab CC Action Plan 2024** | | | | | | | | | |
| **Punjab Agr. Policy 2020** | | | | | | | | | |
| **Punjab Water Policy) 2018** | | | | | | | | | |

## REFERENCES

1. Abbas, S. (2022). Climate change and major crop production: evidence from Pakistan. Environmental Science and Pollution Research, 29, 5406-5414.

2. Ali, A., Ashraf, M.I., Gulzar, S., Akmal, M.J.E.m., assessment (2020). Estimation of forest carbon stocks in temperate and subtropical mountain systems of Pakistan: implications for REDD+ and climate change mitigation. 192, 1-13.

3. Anwar, M., Rais, M., Baig, M.B., Behnassi, M., (2022). Impacts of climate change on biodiversity in Pakistan: current challenges and policy recommendations, The Food Security, Biodiversity, and Climate Nexus. Springer, pp. 101-123.

4. Azmat, M., Qamar, M.U., Huggel, C., Hussain, E. (2018). Future climate and cryosphere impacts on the hydrology of a scarcely gauged catchment on the Jhelum river basin, Northern Pakistan. Science of the Total Environment, 639, 961-976.

5. Ahmad Q-u-A, Biemans H, Moors E, Shaheen N, Masih I. The Impacts of Climate Variability on Crop Yields and Irrigation Water Demand in South Asia. Water. 2021; 13(1):50.

6. Ahmad, Q. ul A., Moors, E., Biemans, H., Shaheen, N., Masih, I., ur Rahman Hashmi, M.Z., 2023. Climate-induced shifts in irrigation water demand and supply during sensitive crop growth phases in South Asia. Climatic Change (2023) 176:150.

7. Qurat-ul-Ain Ahmad, Eddy Moors, Ilyas Masih, Nuzba Shaheen, Hester Biemans, Muhammad Adnan, The coincidence of Climate extremes with sensitive crop growth phases: Projected impact on sustainable crop water use and crop yield in the IGB river basins, Science of The Total Environment, Volume 916, 2024, 169680, ISSN 0048-9697,https://doi.org/10.1016/j.scitotenv.2023.16968.

8. Azmat, M., Wahab, A., Huggel, C., Qamar, M.U., Hussain, E., Ahmad, S., Waheed, A. (2020). Climatic and hydrological projections to changing climate under CORDEX-South Asia experiments over the Karakoram-Hindukush-Himalayan water towers. Science of the total environment, 703, 135010.

9. Bajracharya, S.R., Maharjan, S.B., Shrestha, F., (2019). Glaciers in the Indus basin, Indus River Basin. Elsevier, pp. 123-144.

10. Biemans, H., Siderius, C., Lutz, A.F., Nepal, S., Ahmad, B., Hassan, T., von Bloh, W., Wijngaard, R.R., Wester, P., Shrestha, A.B., Immerzeel, W.W., 2019. Importance of snow and glacier meltwater for agriculture on the Indo-Gangetic Plain. Nat. Sustain. 2,594–601.
https://doi.org/10.1038/s41893-019-0305-3

11. Campbell-Lendrum, D., Manga, L., Bagayoko, M., Sommerfeld, J. (2015). Climate change and vector-borne diseases: what are the implications for public health research and policy? Philosophical Transactions of the Royal Society B: Biological Sciences, 370, 20130552.

12. Gul, A., Chandio, A.A., Siyal, S.A., Rehman, A., Xiumin, W. (2022). How climate change is impacting the major yield crops of Pakistan? an exploration from long-and short-run estimation.
Environmental Science and Pollution Research, 29, 26660-26674.

13. Hong, C.-C., Huang, A.-Y., Hsu, H.-H., Tseng, W.-L., Lu, M.-M., Chang, C.-C.J.n.C., Science, A. (2023). Causes of 2022 Pakistan flooding and its linkage with China and Europe heatwaves. 6, 163.

14. Huber, J.H., Childs, M.L., Caldwell, J.M., Mordecai, E.A. (2018). Seasonal temperature variation influences climate suitability for dengue, chikungunya, and Zika transmission. PLoS neglected tropical diseases, 12, e0006451.

15. Jamal, K., Li, X., Chen, Y., Rizwan, M., Khan, M.A., Syed, Z., Mahmood, P. (2023). Bias correction and projection of temperature over the altitudes of the Upper Indus Basin under CMIP6 climate scenarios from 1985 to 2100.
Journal of Water and Climate Change, 14, 2490-2514.

16. Jan, I., Ashfaq, M., Chandio, A.A. (2021). Impacts of climate change on yield of cereal crops in northern climatic region of Pakistan. Environmental Science and Pollution Research, 28, 60235-602451

17. Khan, I.A., Khan, W.R., Ali, A., Nazre, M.J.F. (2021). Assessment of above-ground biomass in pakistan forest ecosystem's carbon pool: A review. 12, 586.

18. Lutz, A., Immerzeel, W., Shrestha, A., Bierkens, M. (2014). Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. Nature Climate Change, 4, 587-592.

19. Mordecai, E.A., Cohen, J.M., Evans, M.V., Gudapati, P., Johnson, L.R., Lippi, C.A., Miazgowicz, K., Murdock, C.C., Rohr, J.R., Ryan, S.J. (2017). Detecting the impact of temperature on transmission of Zika, dengue, and chikungunya using mechanistic models. PLoS neglected tropical diseases, 11, e0005568.

20. Nanditha, J., Kushwaha, A.P., Singh, R., Malik, I., Solanki, H., Chuphal, D.S., Dangar, S., Mahto, S.S., Vegad, U., Mishra, V. (2023). The Pakistan flood of August 2022: causes and implications. Earth's Future, 11, e2022EF003230.

21. Pascual, M., Ahumada, J.A., Chaves, L.F., Rodo, X., Bouma, M. (2006). Malaria resurgence in the East African highlands: temperature trends revisited. Proceedings of the National Academy of Sciences, 103, 5829-5834.

22. Patz, J.A., Olson, S.H. (2006). Malaria risk and temperature: influences from global climate change and local land use practices. Proceedings of the National Academy of Sciences, 103, 5635-5636.

23. Qamer, F.M., Abbas, S., Ahmad, B., Hussain, A., Salman, A., Muhammad, S., Nawaz, M., Shrestha, S., Iqbal, B., Thapa, S. (2023). A framework for multi-sensor satellite data to evaluate crop production losses: the case study of 2022 Pakistan floods. Scientific Reports, 13, 4240.

24. Syed, A., Raza, T., Bhatti, T.T., Eash, N.S. (2022). Climate Impacts on the agricultural sector of Pakistan: Risks and solutions. Environmental Challenges, 6, 100433.

25. S. & Gornott, C. (2022). Climate Risk Profile for Pakistan, Potsdam : A joint publication by the Potsdam Institute for Climate Impact Research (PIK), the German Federal Ministry for Economic Cooperation and Development (BMZ), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the Ministry of Planning, Development and Special Initiatives of Pakistan.

26. United Nations. (n.d.). Achieve Gender Equality, Sustainable Development Goal 5. Retrieved from https://www.globalgoals.org/goals/5-gender-equality/ Office of the Special Advisor on Gender Issues and Advancement of Women. (2001). Gender Mainstreaming: Strategy for Promoting Gender Equality.

27. UN Women. (2022). Gender-responsive Implementation of the Sendai Framework for Disaster Risk Reduction. Retrieved from https://wrd.unwomen.org/sites/default/files/2023-04/GRISFDRR_GN1.pdf

28. Asian Development Bank. (2024). Gender Equality and Climate Change Sectors Guide. Retrieved from https://www.adb.org/sites/default/files/institutional-document/1009446/gender-equality-climate-change-sectors-guide.pdf

29. United Nations Framework Convention on Climate Change (UNFCCC). (2023). Advancing Gender-Responsive Climate Action: Policy Brief Reveals Progress and Challenges. Retrieved from https://unfccc.int/news/advancing-gender-responsive-climate-action-policy-brief-reveals-progress-and-challenges

30. Government of Rwanda. (2018). National Environment and Climate Change Policy. Retrieved from https://bch -rwanda.rema.gov.rw/fileadmin/user_upload/policies/National_Environment_and_Climate.pdf

31. IURC. (2023). Gender Equality Perspective in Urban Planning: Sweden Case. Retrieved from https://www.iurc.eu/wp-content/uploads/2023/09/Guidelines-Umea_Urban-planning-and-gender-inclusion.pdf

32. Government of Nepal. (2015). Agriculture Development Strategy (ADS) 2015-2035. Retrieved from https://moald.gov.np/wp-content/uploads/2023/02/ADS-Final-English-Part-1-2-combined.pdf

33. Khandker, S.R., Khalily, M.A.B., Khan, Z. (n.d.). Rural credit programs and women's empowerment in Bangladesh. ScienceDirect.

34. Udas, P. (2006). Quota System and Women's Participation: Lessons from Water Policy in Nepal. Retrieved from https://www.academia.edu/3789501/Quota_system_and_womens_participation_Lessons_from_water_policy_in_Nepal

35. UNDP. (2022). Mainstreaming Gender into the National Adaptation Plan (NAP) process. Retrieved from https://www.undp.org/vietnam/publications/mainstreaming-gender-national-adaptation-plan-nap-process

36. Government of Bangladesh. (2009). Bangladesh Climate Change Strategy and Action Plan 2009. Retrieved from https://www.usaid.gov/sites/default/files/2022-05

37. UN Women. (2024). Bangladesh Climate Change and Gender Action Plan 2024. Retrieved from https://asia pacific.unwomen.org/sites/default/files/2024-07/bd-ccgap-final-2024.pdf

38. Hassan, G., Hassan, F.R. (2017). Sustainable use of groundwater for irrigated agriculture: A case study of Punjab, Pakistan. European Water, 57, 475-480.

## List of Abbreviations

| | |
|---|---|
| **BMZ** | German Federal Ministry for Economic Cooperation and Development |
| **KP** | Khyber Pakhtunkhwa |
| **CRP** | Climate Risk Profile |
| **CMIP** | Coupled Model Intercomparison Project |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **FAO** | Food and Agriculture Organization |
| **GCMs** | Global Climate Models |
| **GDD** | Growing Degree Day |
| **GDP** | Gross Domestic Product |
| **INDCs** | Intended Nationally Determined Contributions |
| **GHGs** | Greenhouse Gases |
| **GIZ** | Gesellschaft für Internationale Zusammenarbeit |
| **GLOFs** | Glacial Lake Outburst Floods |
| **MoCC & EC** | Ministry of Climate Change and Environmental Coordination |
| **RCPs** | Representative Concentration Pathways |
| **SSPs** | Shared Socioeconomic Pathways |
| **LULUCF** | Land use, Land-Use Change and Forestry |
| **Mm** | Millimeters |
| **PET** | Potential Evapotranspiration |
| **PRECIP** | Precipitation |
| **TAVG** | Average Temperature |
| **TMAX** | Maximum Temperature |
| **TMEAN** | Mean Temperature |
| **TMIN** | Minimum Temperature |
| **TX10P** | 10th percentile of TX (Cold Days) |
| **TX99P** | 99th percentile of TX (Warm Days) |

This Publication has been developed and produced with the support of the German Federal Ministry for Economic Cooperation (BMZ) through the Support to Strengthening Climate Adaptation and Resilience (SAR) project implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The views expressed in this publication do not necessarily represent those of GIZ Pakistan.

This profile is part of the German Development Cooperation's endeavour to bolster the Pakistani governments' access to precise information regarding climate change's far-reaching impacts across diverse economic sectors. We extend heartfelt appreciation to all authors and reviewers, with special recognition to Mr. Muhammad Arif Goheer, whose unwavering commitment significantly shaped this pivotal resource.

**Scientific content developed by:**
GCISC is Global Change Impact Studies Centre, Pakistan

**Scientific coordination**:
Dr. Muhammad Azmat (NUST)
**Main authors**:
Dr. Muhammad Azmat (NUST),
Ms. Qurat-ul-Ain Ahmad (GCISC),
Ms. Nuzba Shaheen (GCISC),
Dr. Muhammad Abid (GIZ),
Mr. Sanaullah Khan Hassanzai (GIZ),
Ms. Ghazala Naeem (GHQ)

**Contributors:**
Ms. Swera Javed (GIZ),
Ms. Aruba Irfan (GIZ),
Mr. Zaheer Abbass (GIZ),
Ms. Munawar Sultana (GIZ)

**Published and implemented by:**
Global Change Impact Studies Centre
On behalf of
Ministry of Climate Change and Environmental Coordination