Pakistan's **Third National Communication** on Climate Change (TNC)

To the United Nations Framework Convention on Climate Change (UNFCCC)

TRACK EMISSIONS / DRIVE MITIGATION / ADAPT FOR RESILIENCE / EMPOWER INSTITUTIONS / INNOVATE FOR CLIMATE

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Foreword

I am honored to present Pakistan's Third National Communication on Climate Change, submitted under the United Nations Framework Convention on Climate Change (UNFCCC). This report, which fulfils our country's obligations under the Convention, is based on years of extensive collaboration across government, academia and industry stakeholders.

Pakistan is among the world's most climate-vulnerable nations. Our geography is diverse, ranging from glacial highlands to fertile plains, vast deserts and extensive coastal areas. This varied landscape exposes us to a variety of climate risks, such as accelerating glacier melt in the north, prolonged droughts in the southwest, rising sea levels along the coastal belt and erratic monsoon rains across the country. We are already witnessing more frequent and intense heatwaves, floods and droughts, and these impacts are projected to intensify over the coming decades.

The 2022 monsoon floods brought these risks into sharp focus. Between June and September 2022, unprecedented rains inundated about one-third of Pakistan's land area. Over 33 million people were affected, and approximately 8 million were displaced. These events underscore the urgent need to strengthen climate resilience nationwide.

In response, the Government of Pakistan has significantly advanced its policy and planning frameworks. The Pakistan Climate Change Act of 2017 laid the foundation for a robust institutional structure. This includes a Climate Change Authority, a Climate Change Council and a dedicated Climate Change Fund to coordinate national action.

We have also updated our Nationally Determined Contributions and launched a long-term National Adaptation Plan. Most notably, following the 2022 floods, we initiated a Resilient Recovery, Rehabilitation and Reconstruction Framework. This is a USD 16.6 billion programme to rebuild flood-affected regions through climate-resilient approaches.

On the mitigation front, our latest greenhouse gas inventory presents a clear picture. Emissions rose from 489.87 MtCO2e in 2018 to 521.46 MtCO2e in 2021. The agriculture, forestry and other land use sector accounts for 46.75% of total emissions, while the energy sector contributes 40.90%. These figures, compiled in line with IPCC guidelines, highlight the challenge of reconciling economic growth with climate commitments.

For Pakistan, the Third National Communication is not simply an exercise in fulfilling reporting obligations. Rather, the findings of this report will guide our transition towards a low-carbon development. Pakistan's climate institutions are prepared to act on these insights. The Ministry of Climate Change and Environmental Coordination serves as the national coordinating body for climate adaptation and mitigation. It ensures the implementation of climate policies across federal and provincial levels. With this strong institutional foundation and broad-based engagement, we have prepared the Third National Communication as a basis for climate action.

The Third National Communication provides a clear and evidence-based assessment of Pakistan's climate challenges and progress. I reaffirm our national commitment to using these findings to accelerate both adaptation and mitigation measures.

I extend my sincere appreciation to all contributors, from national experts to international development partners, for their support in this important effort. Together, we will build a more climate-resilient, sustainable and prosperous future for Pakistan.

Aisha Humera Ch.
Secretary
Ministry of Climate Change and Environmental Coordination
Government of Pakistan

Executive summary

Pakistan is among the most climate-vulnerable countries in the world, ranked first in the Germanwatch 2025 Climate Risk Index, rising from 8th position in the previous assessment. Yet the country contributes less than 1% to global emissions, underscoring the deeply unequal nature of climate impacts.

Despite ambitious mitigation targets under the Updated Nationally Determined Contributions, which commit to a 50% cut in emissions by 2030 (15% unconditional, 35% conditional), mitigation alone is not sufficient for Pakistan. The urgent concern is that climate change is already disrupting lives, livelihoods and key economic sectors, making adaptation the foremost priority.

In 2022, Pakistan experienced catastrophic floods that displaced 8 million people and caused loss and damage exceeding USD 30 billion, including USD 14.9 billion in infrastructure damage and USD 15.2 billion in lost GDP.

These impacts are still being felt today, and the economy has not fully recovered. As agriculture and energy, two of the most climate-sensitive sectors, form the backbone of Pakistan's economy, extreme weather events triggered by climate change are magnifying economic vulnerability and undermining national development.

Climate projections detailed in Pakistan's Third National Communication on Climate Change show that these impacts are not anomalies but evidence of a worsening trend. Rising temperatures, erratic rainfall, water stress, glacial melt and the increased frequency of extreme events will continue to intensify over the next decades, threatening food security, urban resilience, energy security, water availability and biodiversity.

Given the scale and urgency of these challenges, Pakistan requires immediate and sustained international support across the following priority areas:

- Finance: Substantial and predictable financial support is essential to enable large-scale implementation of adaptation and resilience initiatives. Current international support is far below the estimated USD 7-14 billion annually required for adaptation alone.

- Technology: Deployment of locally appropriate and climate-resilient technologies in agriculture, water management, energy, transport, waste and industry is critical to protect livelihoods and infrastructure.

- Capacity building: Enhancing technical and institutional capacities for emissions inventories, vulnerability assessments, MRV systems, climate finance tracking and implementation of climate actions is imperative, especially at the provincial and local levels.

- Long-term engagement: Support must be ongoing, long-term and scaled up significantly, with a focus on equity, local ownership and integration with national development goals.

If timely and robust action is not taken, the consequences for Pakistan will be devastating, not just for its people and ecosystems but also for regional peace and global climate security. Investing in Pakistan's climate resilience today is an investment in sustainable development and global stability.

Acronyms and abbreviations

ADB	Asian Development Bank
ADP	Annual Development Programme
AEDB	Alternative Energy Development Board
AFOLU	agriculture, forestry and other land use
AJK	Azad Jammu and Kashmir
APSCO	Asia-Pacific Space Cooperation Organisation
ARE	Alternative and Renewable Energy
ASAD	Applied System Analysis Division
AWS	automated weather stations
BAU	business as usual
BRT	bus rapid transit
BTR	Biennial Transparency Report
BUR1	Pakistan's First Biennial Update Report
CARE	Climate Adaptation and Resilience for South Asia
CH4	methane
CIMMYT	International Maize and Wheat Improvement Center
CITEPA	Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique
CMIP	Coupled Model Intercomparison Project
CO2	carbon dioxide
COP	Conference of the Parties
CPEC	China-Pakistan Economic Corridor
DDMA	district disaster management authority
DERA	Drought Emergency Relief Assistance
EDB	Engineering Development Board
EDGAR	Emissions Database for Global Atmospheric Research
EPA	environmental protection agency
ESG	environmental, social and governance
ESM	Earth System Model
EST	environmentally sound technology
ETCO2	end-tidal carbon dioxide
ETF	Enhanced Transparency Framework
EV	electric vehicle
EWS	early warning system
FAO	Food and Agriculture Organisation
FFC	Federal Flood Commission
FFD	Flood Forecasting Division

FREL	Forest Reference Emission Level
GB	Gilgit Baltistan
GCF	Green Climate Fund
GCI	Global CCS Institute
GCISC	Global Climate-Change Impact Studies Centre
GCM	general circulation model
GEF	Global Environment Facility
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLOF	glacial lake outburst flood
GMRC	Glacier Monitoring Research Centre
GoKP	Government of Khyber Pakhtunkhwa
GoP	Government of Pakistan
GoPb	Government of Punjab
GoS	Government of Sindh
GWP	Global Warming Potential
HDIP	Hydrocarbon Development Institute of Pakistan
HKH	Hindukush-Karakoram-Himalaya
ICIMOD	International Centre for Integrated Mountain Development
ICT	Islamabad Capital Territory
IFAD	International Fund for Agricultural Development
IFRC	International Federation of Red Cross and Red Crescent Societies
INGO	international non-governmental organisation
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use
ITA	International Trade Administration
IUCN	International Union for Conservation of Nature
KP	Khyber Pakhtunkhwa
LUCF	land use change and forestry
MoC	Ministry of Communications
MoCC	Ministry of Climate Change
MoE	Ministry of Energy
MoF	Ministry of Finance
MoNFSR	Ministry of National Food Security and Research
MoPDSI	Ministry of Planning, Development and Special Initiatives
MoWR	Ministry of Water Resources

MPGs	modalities, procedures and guidelines
MRV	measurement, reporting and verification
MSW	municipal solid waste
MtCO2e	million tons of carbon dioxide equivalent
N2O	nitrous oxide
NAP	National Adaptation Plan
NC	National Communication
NCAR	National Center for Atmospheric Research
NCFS	National Climate Finance Strategy
NDCs	Nationally Determined Contributions
NDMA	National Disaster Management Authority
NDMC	National Disaster Management Commission
NDRMF	National Disaster Risk Management Fund
NEECA	National Energy Efficiency and Conservation Authority
NEOC	National Emergency Operations Centre
NEPRA	National Electric Power Regulatory Authority
NESPAK	National Engineering Services Pakistan
NGO	non-governmental organisation
NIO	National Institute of Oceanography
NTDC	National Transmission and Despatch Company
NTFP	non-timber forest product
PAEC	Pakistan Atomic Energy Commission
Pak-EPA	Pakistan Environmental Protection Agency
PARC	Pakistan Agricultural Research Council
PBS	Pakistan Bureau of Statistics
PCCA	Pakistan Climate Change Authority
PCCC	Pakistan Climate Change Council
PCIP	Pakistan Climate Investment Platform
PCRWR	Pakistan Council of Research in Water Resources
PDMA	provincial disaster management authority
PFI	Pakistan Forest Institute
PMD	Pakistan Meteorological Department
PRB	Population Reference Bureau
QPM	quantitative precipitation measuring
R&D	research and development
REDD+	Reducing Emissions from Deforestation and Forest Degradation

SCA	snow cover area
SDG	Sustainable Development Goal
SNC	Second National Communication
SNGPL	Sui Northern Gas Pipelines Ltd
SRSP	Sindh Rural Support Programme
SSP	shared socioeconomic pathway
SUPARCO	Space and Upper Atmosphere Research Commission
SWDS	solid waste disposal site
SWE	snow water equivalent
TCWC	Tropical Cyclone Early Warning Centre
TNC	Third National Communication
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USD	US dollar
USPCAS-W	US-Pakistan Center for Advanced Studies in Water
WAPDA	Water and Power Development Authority
WB	World Bank
WIT	Water Informatics and Technology
WMO	World Meteorological Organisation
WWA	World Weather Attribution
WWF	World Wide Fund for Nature

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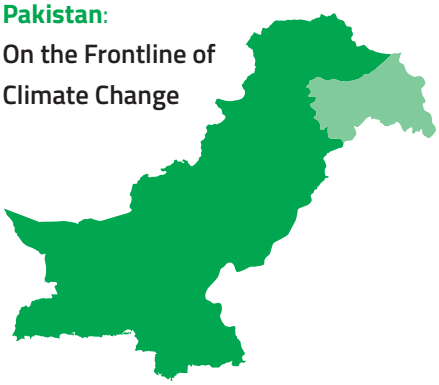
Pakistan's Third National Communication on Climate Change fulfills the country's reporting obligations pursuant to the Paris Agreement under the United Nations Framework Convention on Climate Change.

Pakistan:
On the Frontline of Climate Change



Climate vulnerability

1st **in Global Climate Risk Index 2025 (up from 8th)**

- **Vulnerable to multiple climate impacts due to diverse geography (mountains, glaciers, floodplains, deserts, coastline)**
- **Rising temperatures, erratic rainfall**
- **Frequent floods, droughts and heatwaves**

National circumstances and institutional arrangements

Chapter 1 provides an overview of the country's geography, climate and demographics, and of natural resources and economic sectors most affected by climate change. It discusses the vulnerabilities that arise from these factors, the loss and damage incurred, and institutional arrangements in place for climate action.

Geography

Pakistan is among the most climate-vulnerable nations in the world. Its diverse geography, with glacial highlands, fertile plains, vast deserts and coastal areas, exposes the country to a range of climate-related risks, which include accelerated glacial melt in the north, prolonged drought in the southwest, erratic monsoons across the Indus Basin and rising sea levels along the coast.

Climate

The climate is highly variable, with fluctuations in rainfall leading to recurring droughts and floods. This variability is increasingly influenced by the effects of climate change. Average temperatures have increased at an alarming rate, while rainfall patterns have become erratic. Flooding is a persistent threat, droughts are becoming more frequent, and the country is also experiencing heatwaves more regularly, with record-breaking temperatures.

Demographics

Pakistan has an estimated 241.47 million people and an average annual growth rate of 2.55%. It is projected to become the fifth most populous country globally by 2050. As of 2023,

- **Population: 241.47 million (2023)**
- **Growth rate: 2.55% annually**
- **Rural population: 61.18%**
- **Poverty: 37.2% live below USD 3.65/day**
- **Projected to be the 5th most populous country by 2050**

- **Water scarcity: By 2040, per capita availability will be < half the global standard**
- **Forest cover: Only 5.1% of land area**
- **Biodiversity loss and coastal degradation due to sea level rise and reduced river flows**

approximately 37.2% of the population is estimated to live below the poverty line, defined as earning less than USD 3.65 per day. With 61.18% of the population living in rural areas and climate change affecting precarious rural livelihoods, rural poverty will increase. This in turn will increase migration to the cities, which are already struggling to cope with the effects of extreme weather events. Increased urbanisation will also increase emissions due to higher energy consumption, waste production and transportation needs.

Natural resources

Pakistan's natural resources are under intense pressure from population growth and unsustainable use. These resources are further threatened by the impacts of climate change.

Water. Pakistan is rapidly approaching water scarcity. By 2040, per capita availability is projected to fall to less than half of the global standard for adequate water supply. Climate change is destabilising seasonal flows, while the rate of groundwater extraction is unsustainable. Reservoir capacity has dropped and new water storage infrastructure will take decades to complete. Climate change will increase Pakistan's vulnerability to extreme water scarcity.

Forests and biodiversity. Pakistan's total forest area is relatively low, covering an estimated 5.1% of the total land area. These forests play a critical role in ecological stability and climate resilience, and support the livelihoods of millions. Climate change is affecting forest ecosystems and degrading habitats, leading to biodiversity loss. The loss of biodiversity affects ecosystem services, such as carbon sequestration, water purification and soil fertility, as well as livelihoods.

Coastal areas. Pakistan's coastal areas were once rich in biodiversity but today many species are in decline or have disappeared altogether. The vulnerability of coastal ecosystems is exacerbated by climate change. Reduced water flows and sea level rise are damaging mangroves and coastal ecosystems.

Economy

- **Economic growth affected by: high inflation, debt, trade deficit, extreme weather**

Agriculture

- **24% of GDP, employs ~40% of labour force**
- **Crop yield losses:**
  - **Wheat ↓ 14.7%**
  - **Rice ↓ 20.5%**
- **Affected crops: sugarcane, cotton**

Energy

- **Fossil fuels: 80% of energy mix**
- **Renewables: 8%**
- **Rising temperatures**
- **Increased energy demand**

Loss and damage

- **2022 floods:**
  - **8 million displaced**
  - **USD 30+ billion total losses**
- **Damage: USD 14.9 billion**
- **GDP loss: USD 15.2 billion**
- **Sector-specific losses:**
  - **Housing: USD 5.6 billion**
  - **Agriculture, food, livestock: USD 3.7 billion**
  - **Transport, communication: USD 3.3 billion**
- **Reconstruction cost: USD 16.3 billion**

Disaster preparedness

- **Lead agency: National Disaster Management Authority**
- **Tools:**
  - **Nationwide weather alerts (Meteorological Department)**

Economy

Pakistan faces economic challenges on multiple fronts, including high inflation, escalating debt and a persistent trade deficit. The economy relies heavily on climate-sensitive sectors, making it highly vulnerable to the impacts of climate change. Economic growth is also affected in the wake of extreme weather events, which cause substantial losses.

Agriculture. The sector contributes 24% to GDP and employs close to 40% of the labour force. Heatwaves and water scarcity have dramatically reduced crop yields. Staples like wheat and rice have seen a decline in yields of 14.7% and 20.5% respectively. Cash crops like sugarcane and cotton are also affected. This decline in agricultural production poses a serious threat to food security.

Energy. The country's energy mix is heavily dependent on fossil fuels (oil, gas, coal), which account for 80% of total energy consumption, with renewables (hydro, solar, wind, bagasse) comprising 8%. The sector is impacted by climate change in two main ways. On the supply side, water scarcity and temperature fluctuations affect generation capacity. On the demand side, rising temperatures increase consumption for cooling, and drive greater energy use for water pumping and irrigation.

Loss and damage

The 2022 floods displaced 8 million people, with estimated losses exceeding USD 30 billion (USD 14.9 billion in damage and around USD 15.2 billion in loss to GDP.) Sectors that were worst affected were housing (USD 5.6 billion); agriculture, food, livestock and fisheries (USD 3.7 billion); and transport and communications (USD 3.3 billion). The cost of reconstruction and rehabilitation is estimated at USD 16.3 billion.

Disaster preparedness

The **National Disaster Management Authority** is the primary agency responsible for disaster preparedness and management. It coordinates with provincial and district disaster management authorities, carries out risk assessments and develops disaster response plans. The **Pakistan Meteorological Department** monitors weather conditions, providing alerts for floods, cyclones

- Flood control and water storage infrastructure
- Updated building codes

Climate governance

- Coordinated by: Ministry of Climate Change and Environmental Coordination
- Data centre: Global Climate-Change Impact Studies Centre

Platforms

- RiSQ Transparency Platform
- Pakistan Climate Investment Platform
- Planned: National Carbon Registry, Domestic Emissions Trading System

Key policies and frameworks

- National Climate Change Policy
- Pakistan Climate Change Act
- Updated Nationally Determined Contributions
- National Adaptation Plan
- Framework for Carbon Market Development

and other weather-related hazards. Pakistan has also invested in **structural interventions** to mitigate the impacts of disasters. This includes flood control infrastructure, water storage facilities and updated building codes.

International commitments

Pakistan is engaged in the international climate dialogue through its participation in the UNFCCC process and annual COP meetings. The country advocates for equitable climate policies that address the needs of developing nations, emphasising the principle of common but differentiated responsibilities. The country is also involved in regional initiatives that strengthen South-South cooperation.

Institutional arrangements for climate reporting

The **Ministry of Climate Change and Environmental Coordination** is the national coordinating body for climate-related initiatives. It is responsible for ensuring the implementation of climate change policies. Its research arm, the **Global Climate-Change Impact Studies Centre**, is the national repository for climate-related data.

Measurement, reporting and verification. Pakistan has developed a number of platforms and tools to strengthen transparency and accountability in climate governance. These include the **RiSQ Transparency Platform** to strengthen national reporting capabilities and the **Pakistan Climate Investment Platform** to monitor climate finance mobilisation. Plans are underway to establish a **National Carbon Registry** and **Domestic Emissions Trading System**.

Climate change and government priorities

The Government of Pakistan recognises climate change as a national priority. It has developed several policies, strategies and plans aimed at mitigation, adaptation and resilience:

- National Climate Change Policy: Aims to strengthen climate resilience, mainstream climate adaptation and mitigation measures
- Pakistan Climate Change Act: Establishes an institutional framework for climate governance
- Updated Nationally Determined Contributions: Formalises the country's emissions reduction commitments

- National Adaptation Plan: Sets out long-term adaptation strategies for sectors vulnerable to climate change
- Framework for Carbon Market Development: Provides for carbon markets, improved emissions tracking and developing regulatory frameworks for carbon credit trading.

Total GHG emissions (2021)

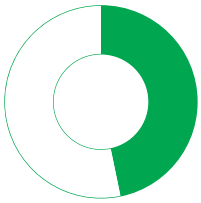
521.46 MtCO2e

Previous emissions (2018)

489.87 MtCO2e

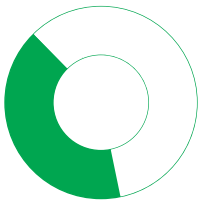
Increase since last period

6.45%



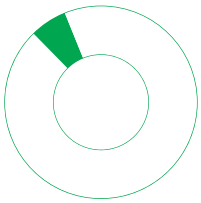
AFOLU

46.75%



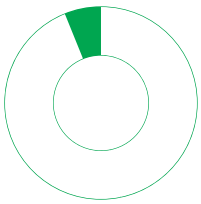
Energy

40.90%



Waste

06.22%



IPPU

06.13%

Forests and grasslands sequestered

14.2 MtCO2e

National greenhouse gas inventory (2020-21)

Chapter 2 presents Pakistan's latest greenhouse gas (GHG) inventory, developed in accordance with the Intergovernmental Panel on Climate Change 2006 Guidelines. It provides emissions estimates for carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) from anthropogenic sources, employing a tier-1 methodological approach with default emission factors.

Pakistan's GHG emissions have increased by around 6.45% since the last reporting period, from 489.87 million tons of carbon dioxide equivalent (MtCO2e) in 2018 to 521.46 MtCO2e in 2021. This upward trend is driven by sectors that are key to economic development: agriculture, energy, waste management and industry. This highlights the challenge for countries like Pakistan of cutting emissions without adversely affecting economic growth.

- The **agriculture, forestry and land use** (AFOLU) sector is the largest contributor, at 46.75%. Within this category, the dominant source is enteric fermentation from livestock, followed by emissions from manure management, rice cultivation, and agricultural soils.
- The **energy** sector is the second largest contributor, at 40.90%, with power generation and transport responsible for the bulk of emissions.
- The **waste** sector contributes 6.22%, mainly from solid waste disposal and domestic wastewater.
- The **industrial processes and product use** (IPPU) sector is responsible for 6.13% of total emissions, mostly from cement production and the use of chemicals and metals in manufacturing.

On the removals side, **forests and grasslands** sequestered approximately 14.2 MtCO2e, partially offsetting national emissions.

Emission reduction targets (compared to 2021 baseline)

Energy
15% reduction by 2035

AFOLU
15% reduction by 2040

IPPU
50% reduction by 2045

Waste
50% reduction by 2045

Ongoing mitigation activities

- **Energy: ~70 renewable energy projects (planning/implementation stage)**
- **Transport: Electric Vehicle Policy + EV promotion incentives**
- **Agriculture: Projects improving energy/irrigation efficiency and carbon sinks**
- **Forestry:**
  - **Large-scale reforestation programmes**
  - **Protected area expansion**
  - **Blue carbon commitments**
- **Industry:**
  - **Clean energy transition incentives**
  - **Textile industry pilot projects**
- **Waste:**
  - **Hazardous waste policies**
  - **Clean tech innovation projects in waste management**

Mitigation scenarios and proposed measures

Chapter 3 analyses Pakistan's emission trends using GHG inventory data beginning in 1994. It develops climate projections under various emission reduction scenarios to assess future impacts. Based on this analysis, it suggests emission reduction targets by sector to support evidence-based decision making. Suggested emissions reductions to maintain 2021 benchmark emission levels are as follows:

- **Energy**: 15% reduction by 2035
- **AFOLU**: 15% reduction by 2040
- **IPPU**: 50% reduction by 2045
- **Waste**: 50% reduction by 2045.

The chapter then presents an overview of mitigation activities and initiatives currently underway, which include:

- **Energy**: Policies and incentives for alternative and renewable energy, with close to 70 renewable energy projects in the planning or implementation stage
- **Transport**: Electric vehicle policy in place and incentives to promote use of electric vehicles
- **Agriculture:** Multiple projects across the country to improve energy and irrigation efficiency, and enhance sinks
- **Forestry**: Multiple large-scale reforestation programmes across the country to enhance sinks, expansion of protected areas, blue carbon commitments
- **Industry**: Policies and incentives in place for clean energy transition, pilot projects in the textiles industry
- **Waste**: Policies in place for hazardous waste, projects to test clean technology innovations for waste management.

Key recommended actions:

- **Energy**: Develop clean energy plan, promote green building and infrastructure, ensure energy efficiency, provide financial incentives
- **Transport**: Focus on mass transit, non-motorised transport, electric vehicles and public awareness
- **Agriculture**: Promote adoption climate-smart agriculture practices, support agroforestry and the use of green manure, invest in adaptation

- **Forestry and other land use**: Focus on alternative fuels and sustainable forest management, expand protected areas system and afforestation efforts, explore carbon sequestration potential
- **Industrial processes**: Focus on energy efficiency
- **Waste**: Promote waste-to-energy plants and biofuel production, formalise waste collection, establish recycling facilities.

+0.6°C increase in average annual temperature over the last century

Rate accelerated from
0.17°C/decade (1951–1970)
0.23°C/decade (1971–1990)
0.31°C/decade (1991–2020)

Rainfall decline
-5 mm/decade (1971–1990)
-4.68 mm/decade (1991–2020)

Agriculture impacts

- **Wheat yields fall by 3-4% for every 1°C rise**
- **73% of agricultural land is irrigated with groundwater**
- **Sea-level rise and saltwater intrusion impacting cultivation in the Indus delta**

Water resources

- **60-80% of Indus River flows depend on glaciers**
- **Pakistan's major reservoirs (Mangla, Tarbela, Chashma) can store water for only 30 days (vs. 120-day international minimum)**
- **Groundwater depth >80 ft in Punjab increased 12x (2010-2020)**

Vulnerability and adaptation

Chapter 4 analyses observed climate change trends using historical data for temperature and rainfall, and develops climate change projections for the next 10 to 60 years. Based on this analysis, the main observed trends are as follows:

Temperature. Recent extreme heatwaves Pakistan has experienced are part of a clear trend. Over the last century the average annual temperature has increased by around 0.6°C. The rate of warming is also accelerating. Between 1951 and 2020, the overall temperature increased by 0.17°C/decade (1951-1970), 0.23°C/decade (1971-1990) and 0.31°C/decade (1991-2020). Climate change projection models show that this trend will continue under all scenarios, with the percentage of temperature extremes gradually increasing from the 2030s to the 2090s.

Rainfall. Precipitation patterns are becoming erratic and rainfall is declining. From 1971 to 1990, rainfall declined by 5 mm/decade, and from 1991 to 2020 it fell by 4.68 mm/decade. Under future scenarios rainfall patterns show increasing unpredictability, with rising temperatures leading to increased snow and ice melting, which could increase the intensity and frequency of extreme precipitation events.

The chapter uses these projections to assess the vulnerability of key sectors.

Agriculture. The impacts of observed climate change trends on agriculture include the following:

- **Crop yields**: Every 1°C rise in temperature reduces wheat yields by 3-4%, with a more pronounced impact on crops like rice and cotton.

- **Water availability**: Supply for irrigation, especially from the Indus, is increasingly erratic due to glacial melt and altered monsoon patterns.
- **Sea-level rise** and **saltwater intrusion** are making parts of the Indus delta unsuitable for cultivation.

Livestock. Major challenges to livestock productivity are as follows:

- **Temperature rise**. Heat stress impacts livestock production, reducing feed intake, growth rates and milk production, while increasing vulnerability to diseases.
- **Atmospheric CO2**. High CO2 concentrations degrade fodder quality, reducing vital nutrients in animal feed.
- **Water scarcity** affects feed production. During extended dry periods, livestock suffer from dehydration, weight loss and increased mortality.

Fisheries. Major vulnerabilities of the marine and inland fisheries sector include the following:

- **Rising sea temperatures** and ocean warming cause shifts in fish distribution, and affect fish health, reproduction and growth.
- **Ocean acidification**, caused by increased CO2 absorption, harms shellfish populations, and threatens marine biodiversity and aquaculture.

Forests and ecosystems. Climate change has increased the vulnerability of forest ecosystems:

- **Forest degradation** and shifts in species composition can be observed as a result of temperature rise, erratic rainfall and the frequency of extreme weather events.
- **Water availability** has decreased, affecting forest health. Prolonged dry spells and higher temperatures also increase the risk of forest fires.
- **Biodiversity loss** is being accelerated by climate change. Temperature changes and erratic precipitation patterns disrupt habitats and decrease the availability of food sources for wildlife.

Water resources. Key climate-related challenges include the following:

- **Glacial dynamics**. The country's dependence on the Karakoram glaciers for 60-80% of Indus flows makes it highly vulnerable to unpredictable glacial dynamics.
- **Variability in river flows**. Monsoon and winter rainfall patterns are becoming increasingly erratic, and difficult to predict and manage.
- **Reservoir capacity depletion**. The storage capacity of Pakistan's three major reservoirs (Mangla, Tarbela, Chashma) has been reduced due to sedimentation. These reservoirs can only store water for up to 30 days, compared to the international minimum of 120 days. Most advanced countries have water storage capacity of 1 to 2 years.
- **Groundwater depletion**. The water table is falling rapidly. In Punjab alone, the area with groundwater levels exceeding 80 ft in depth has expanded more than twelvefold between 2010 and 2020. Replenishment is slow because of altered rainfall patterns. With around 73% of agricultural land in Pakistan irrigated with groundwater, the impact on agriculture is potentially devastating.

Coastal areas. Key threats to fragile coastal ecosystems include:

- **Sea level rise** leads to flooding in coastal habitats like mangroves, damaging fish breeding grounds.
- **Saltwater intrusion** into freshwater systems alters sali
- **Reduced freshwater availability**, changes in river flows from glaciers and changing rainfall patterns impact the Indus River and its delta, crucial for inland fisheries, and create water scarcity issues for aquaculture.

Energy. Climate change poses significant risks to Pakistan's energy sector and particularly to the country's clean energy transition.

- Pakistan's reliance on **hydropower** makes the energy sector particularly susceptible to climatic variations. Increasing the share of hydel in the power mix will become difficult with climate change affecting water supply and river flows, as noted above.
- **Extreme weather events** like droughts and floods will damage or destroy generation and supply infrastructure.
- **Demand is likely to grow**, not only as a result of industrial development and population growth but also in the face of climate change, with rising temperatures increasing electricity demand.

The chapter presents an overview of the legal and policy framework in place for adaptation measures, which includes:

- **National Climate Change Policy**: Emphasises adaptation and resilience, recognising the need to address climate impacts like water scarcity, extreme weather events and sea level rise.
- **Framework for Implementation of Climate Change Policy**: A strategic plan that translates climate policy into actionable measures, setting priorities, assigning responsibilities, allocating resources, and ensuring monitoring and evaluation.
- **Pakistan Climate Change Act**: Establishes mechanisms to coordinate and oversee planning and implementation of adaptation initiatives.
- **National Adaptation Plan**: Outlines the country's adaptation priorities with a focus on six areas: the agriculture-water nexus; natural capital (land, water and air); urban resilience; human capital; disaster risk management; and gender, youth, and social inclusion.
- **Resilient Recovery, Rehabilitation, and Reconstruction Framework** (4RF): Developed in response to the 2022 floods with the goal of building long-term resilience in Pakistan's flood-affected regions.
- **National Flood Protection Plan-IV**: Addresses flood protection challenges in Pakistan through innovative and integrated measures, with structural and non-structural strategies to reduce flood impacts, enhance resilience and protect critical infrastructure.
- **National Food Security Policy**: Prioritises climate-smart agriculture, sustainable water use, and improvements in crop yield and quality.
- **National Water Policy**: Outlines a strategy for integrated management, conservation and sustainable use, covering governance, efficiency, infrastructure development, water quality, disaster risk reduction and the protection of ecosystems.

The chapter concludes by presenting an overview of programmes and projects across the country that aim to strengthen adaptation capacity and build resilience. Key initiatives include:

- **Recharge Pakistan**: Building resilience to climate change-induced flooding and drought, focusing on ecosystem-based adaptation and green infrastructure.
- **Living Indus**: Contains 25 high-impact interventions for policy makers, practitioners and civil society to support ecological restoration of the Indus Basin.
- **Scaling-up of glacial lake outburst flood risk reduction in Northern Pakistan**: Enhancing climate resilience of communities at risk from GLOF events using a multi-layered approach to strengthen institutional capacity, scale up early warning systems, and provide training.
- **Climate Adaptation and Resilience for South Asia**: Focuses on climate planning tools, regional cooperation and innovative technologies.
- The **Water Resource Accountability in Pakistan**: Aims to improve water resource management at the federal, provincial and district levels by establishing reliable water accounts and supporting water policy implementation.
- **Federal Drought Emergency Relief Assistance**: Focuses on resource management, water conservation and infrastructure development to support agricultural growth in drought-affected areas.
- **Multiple initiatives** to build more resilient agriculture systems.

Financial constraints

- **No dedicated national climate fund**
- **Lack of Innovative financial instruments (green bonds, carbon markets)**
- **Fragmented financial tracking systems**
- **Private sector hesitant due to perceived risks and lack of incentives**
- **Cumbersome international funding procedures**
-

Climate finance received

- **Green Climate Fund (GCF):**
  - **USD 950.3 million directly**
  - **USD 1.95 billion via regional programmes**
- **Global Environment Facility (GEF): USD 17.43 million**
- **Other donors and development partners: USD 1.54 billion**

Constraints, gaps and financial, technical and capacity needs

Chapter 5 identifies Pakistan's finance and capacity needs for the planning, implementation and monitoring of climate action. The analysis is based on desk research, and interviews with experts and stakeholders.

Financial constraints

Pakistan lacks the resources to implement mitigation and adaptation measures at the scale that is required. Challenges to accessing finance are as follows:

- **Domestic financial mechanisms**: Limited private sector involvement due to perceived risks and lack of incentives, absence of a dedicated National Climate Fund to pool resources, fragmented financial tracking and reporting, lack of innovative financial instruments (e.g., green bonds, carbon markets), and poor coordination between government agencies.

- **Total received: ~USD 2.5-4.5 billion**

Funding gap

- **Adaptation needs alone: USD 7-14 billion annually**
- **Total estimated need (2023-2030): USD 350 billion**
  - **USD 153 billion for adaptation and resilience**
  - **USD 197 billion for sectoral decarbonisation**
  - **~10% of cumulative GDP**

Capacity constraints

- **Insufficient technical expertise for GHG inventory preparation**
- **Data gaps in agriculture, water, disaster risk sectors**
- **Weak monitoring and evaluation systems**
- **Poor proposal development capacity**

Stakeholder engagement

- **Minimal private sector and community involvement**
- **Lack of ownership of climate policies by non-government actors**

- **International climate finance**: Lengthy and complex application procedures, conditionalities tied to bilateral aid that reduce flexibility to tailor projects to local needs, and fragmented financial tracking systems that undermine effective resource allocation and utilisation.

Financial support received

Pakistan has to date accessed international climate finance mainly through mechanisms like the Green Climate Fund (GCF) and Global Environment Facility (GEF).

- Between 2015 and 2024, GCF contributed USD 950.3 million directly to Pakistan, in addition to 1.95 billion for regional programmes in which Pakistan is a participant.
- GEF support for projects in Pakistan currently stands at USD 17.43 million.
- Pakistan has also received support for climate initiatives from other international donors and development partners to the tune of USD 1.54 billion.

This is significantly lower than the estimated requirement of USD 7-14 billion annually for adaptation alone, according to some studies. More recent studies estimate Pakistan's total investment needs between 2023 and 2030 for a comprehensive climate response to be USD 350 billion, or nearly 10% of cumulative GDP for the same period. This consists of an estimated USD 153 billion for adaptation and resilience, and USD 197 billion for the decarbonisation of key sectors.

Capacity building and human resource development

Capacity remains a significant challenge, including at the provincial and local levels where most climate adaptation and mitigation activities are implemented. Issues include:

- **GHG inventory preparation**: Lack of technical expertise and institutional arrangements to compile accurate GHG inventories.
- **Data collection and analysis**: Substantial gaps in climate-related data, management and analysis, particularly in key sectors such as agriculture, water management and disaster risk reduction.
- **Tracking implementation**: Absence of monitoring and evaluation systems to track progress on climate projects, making it difficult to measure effectiveness.
- **Proposal development**: Lack of expertise for preparation of competitive climate finance proposals, limiting the ability to access international funding.

Stakeholder engagement

The involvement of the private sector, civil society and local communities in climate policy formulation and implementation remains minimal. The lack of broad-based civil society and community participation has led to a gap in ownership over climate policies among non-government actors. Poor private sector engagement has meant that the opportunity is lost to leverage private sector expertise, resources and innovation in key areas such as renewable energy, sustainable agriculture, urban planning, disaster risk reduction and climate finance.

Key recommendations to address these gaps and constraints include:

- Strengthen coordination mechanisms and establish institutional arrangements for planning, implementation and monitoring.
- Mobilise climate finance with policy measures, backed by legislation, to provide incentives and to facilitate access to international funding.
- Build robust measurement, reporting and verification systems to increase transparency, build trust, ensure accountability and allow progress to be measured.
- Enhance stakeholder participation through nationwide consultations with local governments, civil society organisations and the private sector to create ownership of climate policies.

Key priorities

- **Energy**
  - **Financial self-sustainability**
  - **Energy efficient building codes**
  - **Promotion of small and micro hydro power**
- **Transport**
  - **Transition to EVs (public transport, private vehicles)**
  - **Policies and incentives for EV industry**
- **AFOLU**
  - **Climate-smart agriculture**
  - **Energy-efficient irrigation**
  - **Ambitious reforestation programmes**
- **Water**
  - **Conservation and efficiency (tech and non-tech solutions)**
  - **Enhancing storage capacity**
  - **Groundwater recharge projects**

Development and transfer of environmentally sound technologies

Chapter 6 assesses Pakistan's technology needs in key sectors, identified on the basis of their contribution to national GHG emissions and/or their vulnerability to climate change. It assesses barriers to the adoption of technological solutions and provides recommendations.

Needs assessment

Energy. The government is making efforts to accelerate Pakistan's clean energy transition. Priorities for the energy sector include financial self-sustainability, compliance with international commitments to reduce emissions, the introduction of energy efficiency building codes, and promoting small and micro hydro power projects though incentives and partnerships. Environmentally sound technologies (ESTs) to address these needs include:

- **Waste**
  - **Improved collection and disposal systems**
  - **Enforcement of hazardous waste regulations**
- **IPPU**
  - **Energy efficiency (tech solutions)**
  - **Emissions monitoring**
  - **Carbon tax and green reforms**

Common barriers

- **Technical:**
  - **Lack of skilled human resources**
  - **Missing local GHG data and modeling**
  - **No quality control for local tech**
- **Financial:**
  - **Low R&D funding**
  - **High capital costs**
  - **Expensive feasibility studies**
- **Social:**
  - **Security (theft, vandalism)**
  - **Low awareness**
  - **Lack of local ownership**

General recommendations

- **GHG inventory mechanism development**
- **Financial support for green projects**
- **Policy realignment with climate goals**
- **Capacity development and training**

- Widespread adoption of solar technology, especially for public buildings
- Energy management technologies such as smart meters and load management software
- Solar powered water pumps and lighting systems, particularly in disaster prone areas
- Smart energy storage and backup devices, such as pumped storage hydel (PSH), to support grid stability on account of alternate and renewable energy deployment
- Quality control mechanisms for micro hydel plants and allied equipment
- Regulatory framework for off grid renewable energy systems in remote areas.

Transport. The government has taken a number of steps to cut emissions and reduce the sector's dependence on conventional fuel. Priorities for the sector include promoting the adoption of electric vehicles (EVs) with policy measures and incentives, the adoption of Euro-II emission standards for vehicles, and financial incentives for hybrid and hydrogen fuel cell vehicles. ESTs to address these needs include:

- Clean energy vehicles and clean energy bikes
- Smart charging stations for EVs
- Vehicle emission standards and capacity for proper inspections
- Fuel efficient public transport system.

Agriculture, forestry and other land use. Many initiatives are underway to boost agricultural production, increase forest cover and promote sustainable land management practices. Priorities for the AFOLU sector include the introduction of climate-smart agricultural practices, the use of precision agriculture technologies for greater efficiency, developing climate-tolerant crop varieties, and promoting commercial biogas plants for waste reduction and production of green manure. EST needs for the sector include:

- Climate resilient, drought-, pest- and salt- tolerant crop varieties
- Smart agriculture practices (e.g., drip irrigation, hydroponics, laser land levelling, carbon sequestration, tunnel farming, direct seeding, advance mechanisation for sowing and harvesting)
- Advanced GIS and GPS models
- Cloud seeding for drought-prone areas
- Technologies, tools, training and data for risk assessment and vulnerability mapping.

Water. Pakistan's priorities for the water sector include integrated flood management and nature-based solutions to enhance flood resilience, climate-smart irrigation practices, and the installation of reverse osmosis and desalination plants. EST needs for the sector are as follows:

- Glacier monitoring for temporal changes through GIS monitoring
- Water efficient techniques (e.g., furrow, drip and sprinkle irrigation)
- Promotion of solar water desalination for irrigation and drinking
- Rain and flood water harvesting, and spate irrigation systems
- Green infrastructure (e.g., permeable pavements, green roofs) to manage storm water runoff
- Water storage and groundwater recharge technologies (e.g., delay action dams, check dams, percolation ponds, recharge wells, shafts and trenches).

Waste. Many waste management initiatives are being implemented across the country. Priorities for the sector include integrated waste management from collection until disposal, recycling of municipal and industrial wastewater after proper treatment, and mandatory requirement for wastewater treatment plants in all new urban schemes. The following ESTs have been identified for the waste sector:

- Mechanical and biological wastewater treatment (e.g. anaerobic digestion)
- Waste-to-energy technology (e.g., incineration, gasification, pyrolysis, bio gasification)
- Cost effective wastewater treatment solutions (e.g., constructed wetlands, anaerobic bioreactors)
- Small scale sewage treatment systems using improved technologies (e.g., trickling filters, membrane processes).

Industrial processes and product use. In the industrial sector, the focus has been on energy efficiency and clean energy. Plans for the IPPU sector include the introduction of a carbon tax to support mitigation measures, emission monitoring in the industrial sector, green fiscal reforms and energy audits in the industrial sector. The following ESTs are required for the IPPU sector:

- Automated system for regulation of oxygen levels at burner to guarantee optimal performance and safety
- Reuse of treated waste water for industrial processes like cooling systems, manufacturing, food processing and other high-rate processing units
- Water-efficient wet processing and alternatives that require less or no water such as dry dyeing
- Waste heat recovery systems to improve energy efficiency in industrial operations.

Barriers and recommendations

The chapter provides a comprehensive assessment of barriers to the transfer and adoption of ESTs, based on the type of barrier (technical, financial, social) in each key sector. Key barriers common to all sectors include:

- **Technical**: Lack of skilled manpower; lack of country-specific literature, data and information about

climate change modelling; absence of GHG inventories at the provincial level; absence of quality control mechanism for indigenous technologies

- **Financial**: Lack of research and development &D funds in the public sector, high capital costs for imported raw material, expense of feasibility studies
- **Social**: Security issues for installed technologies (e.g., theft, vandalism), lack of ownership of technological solutions, loss of trained manpower due to termination of staff after completion of project, lack of public awareness.

The chapter concludes by providing detailed recommendations to address barriers in each sector. General recommendations include:

- Develop and institutionalise a GHG inventory preparation mechanism
- Provide financial assistance to green projects and facilitate local production of ESTs
- Realign all existing and new policies with climate change considerations
- Provide scholarships for climate change related studies and sector-specific training.

Overview

Focus: Climate change research and systematic observation
Goal: Integration with global research and improved national monitoring

Key institutions involved

- **Global Climate-Change Impact Studies Centre (modeling, GHG inventories)**
- **Pakistan Meteorological Department (data collection, early warnings)**
- **National Disaster Management Authority (disaster preparedness)**
- **SUPARCO (satellite-based environmental monitoring)**
- **PCRWR (water quality, hydrological research)**
- **National Institute of Oceanography (sea level, marine biodiversity)**

Research and systematic observation

Chapter 7 provides an overview of current research and systematic observation activities related to climate change in Pakistan.

Policy on research and systematic observation. Pakistan has several policies and frameworks that call for research and systematic observation on climate change. These policies focus on improving data collection, climate modeling and monitoring of environmental changes, while ensuring integration with global research efforts.

Institutions conducting climate research and systematic observation. Several national institutions carry out climate research and systematic observation. These include the Global Climate-Change Impact Studies Centre (climate modeling, impact assessments, GHG inventory preparation), Pakistan Meteorological Department (data collection, early warning systems, hydrological modeling), National Disaster Management Authority (risk assessments, disaster preparedness planning), Pakistan Space and Upper Atmosphere Research Commission (satellite imaging for environmental monitoring), Pakistan Council of Research in Water Resources (hydrological studies, water quality monitoring), and National Institute of Oceanography

Funding sources

- **Government allocations**
- **International climate funds**
- **Bilateral and multilateral grants**
- **Public-private partnerships**
- **Collaborations with international platforms**

Research focus areas

- **Climate modeling and risk profiles**
- **Glacier monitoring and GLOF risk reduction**
- **Sea level rise and coastal erosion**
- **Climate-smart agriculture**
- **Agro-ecological zoning**
- **Precision agriculture (via satellite imagery)**

Systematic observation capabilities

- **Meteorological and hydrological networks**
- **Weather forecasting, early warnings, climate and hydrological monitoring**

Climate challenges addressed

- **Agricultural vulnerability**
- **Glacial melt and water supply issues**
- **Floods and extreme weather**
- **Drought and water scarcity**
- **Sea-level rise and coastal erosion**
- **Ecosystem and biodiversity shifts**
- **Heatwaves and rising temperatures**

(monitoring sea level rise, marine biodiversity, coastal dynamics).

Funding for research and systematic observation. Activities are funded through government allocations, international climate funds, bilateral and multilateral grants, and public-private partnerships. Pakistan also collaborates with international research platforms and organisations on a number of activities.

Research priorities, focus areas and ongoing initiatives

Pakistan's climate strategy prioritises research to develop evidence-based solutions for mitigation and adaptation. Key areas of research and systematic observation include:

- Climate modeling and scenario development: High-resolution regional climate models, climate risk profiles, river basin water-climate assessments
- Vulnerability assessments: national multi-hazard vulnerability assessment, coastal risk assessment
- Glacial and mountain areas research: glacier monitoring and risk assessment, GLOF risk reduction, glacier ice core studies
- Coastal studies and sea level rise: sea water intrusion and coastal erosion monitoring, mangrove restoration and protection
- Climate-resilient agriculture: climate-smart agriculture research, precision agriculture through satellite monitoring, agro-ecological zoning for food security.

Systematic observation

Pakistan has an extensive meteorological and hydrological data collection network, managed by multiple national organisations. Their activities include weather forecasting, early warning systems, climate monitoring and hydrological assessments. Collectively, these organisations and their partners form a robust network for systematic observation and research.

Addressing climate challenges through research and systematic observation

Pakistan's research efforts aim to address the country's key climate challenges:

- Agricultural vulnerability to climate change
- Glacial melt and water availability

- Flooding and extreme weather events
- Drought and water scarcity
- Coastal erosion and sea level rise
- Biodiversity and ecosystem changes
- Heatwaves and rising temperatures.

Climate awareness and information sources

- **99% believe climate change is caused by human activity**
- **6.3% think it is due to natural processes**
- **Climate change impacts noticed:**
  - **17.3% note rise in temperatures**
  - **16.0% note change in rainfall**
- **Primary information sources:**
  - **27% digital (internet/social media)**
  - **12% TV and academic literature**
  - **10% newspapers and seminars**

Education and capacity building

- **81% of organisations offer climate education**
- **81% report current capacity-building activities as inadequate**
- **Main challenges:**
  - **25% insufficient funding**
  - **16% lack of skilled staff**
  - **16% limited tech/resources**

Knowledge sharing and networks

60%+ of organisations are in climate networks

- **74% focus on knowledge exchange**
- **70% coordinate climate action**
- **61% collaborate on mitigation/adaptation**
- **53% focus on capacity building**

Other relevant information

Chapter 8 discusses cross-cutting themes that are relevant for effective climate action. These include public awareness, education and training; networks for knowledge sharing; and the role of women in climate action. Findings in this chapter are based on a series of surveys conducted to obtain stakeholder feedback on each theme, supplemented by desk research.

Public awareness of climate change

The overwhelming majority (99%) of respondents believe that climate change is taking place and is the result of human activities. Only 6.3% attribute climate change to natural processes. Respondents have observed climate-related changes over the last five years: 17.3% note a rise in temperatures and 16.0% report a change in rainfall.

Digital platforms (internet, social media) are the primary source of information on climate change for 27% of respondents, followed by television (12%), academic literature (12%), newspapers (10%) and seminars/workshops (10%).

Education, training and public awareness initiatives

Of the organisations surveyed, 81% offer climate change learning activities targeting youth (30%), followed by business/industry (23%). The majority of organisations develop climate-related publications, including guides and manuals, and offer e-learning courses. Most address multiple climate-related themes.

Capacity building

The majority of organisations surveyed provide some climate-related capacity building for their workforce and well as externally.

Gender and climate impact

- **77.8% say women are disproportionately affected**
- **71.7% report income/livelihood impacts**
- **74.3% lack alternative livelihoods or emergency savings**
- **47.3% have access to clean water/sanitation**
- **81.2% say climate change disrupts access to basic services**

Health and safety

- **76.4% report climate-related health issues**
- **17.5% report mental health effects**
- **32% lack access to maternal health services**
- **18.8% report increased post-disaster violence**

Women in leadership

- **54% say women are included in climate-related decisions**
- **84.6% are willing to take leadership roles**
- **46.6% say no community disaster preparedness plans exist**
- **21.8% received disaster preparedness support (solar pumps, emergency kits, training)**

The frequency and effectiveness of these activities limited, with 81% of organisations reporting that capacity-building activities inadequate. Key challenges in capacity development include insufficient funding (25%), lack of skilled human resources (16%), and limited access to technology and physical resources (16%).

Knowledge, information sharing and networking

More than 60% of organisations are members of national and/or international climate change networks. A significant percentage of these networks focus on knowledge exchange (74%) and coordinating climate action initiatives (70%), along with collaboration on adaptation and mitigation strategies (61%), and capacity building (53%).

Gender and climate change

A survey was conducted in 300 households belonging to climate-vulnerable communities. A representative sample of 30 to 45 women per village/district was developed. Key findings on gender equality and women's empowerment in the context of climate challenges are as follows:

- **Awareness of climate change**: A substantial percentage of respondents are aware of climate change, with first-hand experience witnessing climate change impacts within their communities.
- **Impacts of climate change on women and marginalised groups**: The majority of respondents (77.8%) perceive a disproportionate impact on women, citing increased household responsibilities and challenges in accessing water and sanitation. Reported impacts of climate change include water scarcity, excessive rain and flooding, temperature fluctuations, and increased frequency of extreme weather events.
- **Impact of climate change on women's livelihoods**: The majority of respondents (71.7%) report that household income and livelihoods are affected by climate change. Impacts include restricted access to food and water, and limited earning opportunities due to climate-induced events. Livelihoods are precarious, with 74.3% reporting a lack of alternate livelihood opportunities, insufficient savings and/or no funds to cope with emergencies.

- **Women's access to basic services**: Just 47.3% of respondents have access to basic services like clean water and sanitation. The vast majority (81.2%) report that climate change affects access to basic services. Significant disruptions include access to firewood and other energy sources (74.1%) and access to education as a result of school closures or displacement (27.1%).
- **Women's access to healthcare**: Of the women surveyed, 32% lack access to maternal health facilities as a result of climate-induced disasters, 25.8% face challenges in accessing child health services and 10.4% lack access to neo-natal health services.
- **Impact of climate change on women's health**: The majority (76.4%) of respondents report health issues due to climate change, and 17.5% report mental health issues such as emotional trauma and post-traumatic stress in the wake of extreme weather events.
- **Gender-specific challenges related to climate change**: The majority (65.3%) of respondents face gender-specific challenges related to climate change, such as increased caregiving responsibilities, and difficulty accessing resources and services.
- **Women's safety concerns**: As many as 18.8% of women report increased violence post-disaster, while 13% report experiencing harassment in non-permanent settlements.
- **Disaster preparedness**: Around 46.6% of respondents report that there are no strategies in place to cope with climate change effects in their communities.
- **Support for mitigation or adaptation activities**. The vast majority (78.2%) of respondents report no support, while just 21.8% have received some type of assistance. Types of support received include solar-powered water pumps, emergency kits, first-aid training and cash payments for post-disaster rehabilitation.
- **Women's role in decision making and leadership for climate action**: According to the survey, 54% of respondents report that women are included in climate-related decision making. The vast majority (84.6%) confirm their willingness to take leadership roles for climate action within their communities.

1

National circumstances and institutional arrangements

1.
National circumstances and institutional arrangements

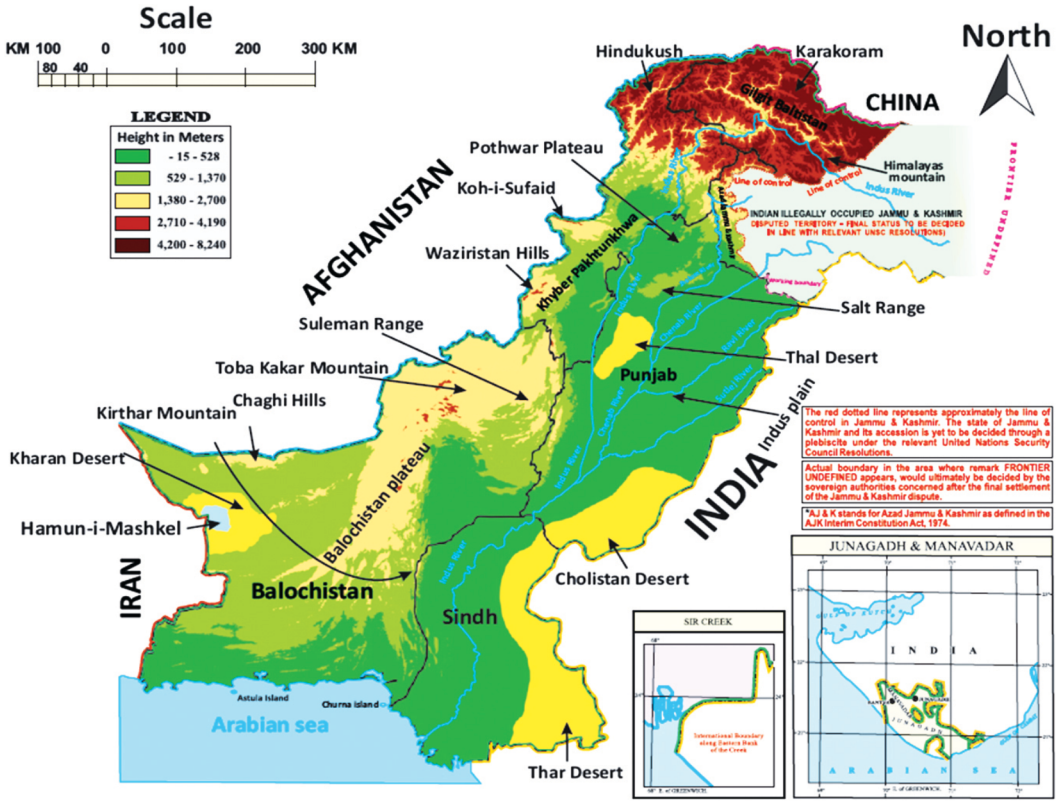
This chapter examines Pakistan's national circumstances and institutional arrangements in the context of climate change. It provides an overview of the country's geography, climate and demographics, and of natural resources and economic sectors most affected by climate change. It discusses the vulnerabilities that arise from these factors, the loss and damage incurred, and institutional arrangements in place for disaster management.

The chapter then looks at Pakistan's international commitments on climate issues, and at the national institutional framework in place to act on these commitments. This includes key government policies, ministries and statutory bodies, as well as systems for monitoring and reporting.

1.1 Geography

Pakistan is spread over an area of 796,095 sq km, between the coordinates of 23° and 37° North and 61° and 77° East (PBS, 2022). The country lies at the intersection of the Indian subcontinent, the Middle East and Central Asia (Figure 1.1), making Pakistan potentially a key player in regional climate action, particularly transnational cooperation on climate resilience.

Figure 1.1: Map of Pakistan



The country is home to diverse landscapes and ecological zones, consisting of plains, deserts, forests, mountains, plateaus, wetlands and coastal areas (Mohsin, 2020). This makes the climate challenges Pakistan faces particularly complex.

In the north and north-west stand formidable mountain systems, including the Himalaya, Hindukush and Karakoram ranges, interspersed with valleys and glaciers that serve as reservoirs for Pakistan's freshwater resources. These areas face significant climate-related challenges, particularly glacial melt, which threatens water availability and increases the risk of glacial lake outburst floods (GLOFs). Shifts in precipitation patterns and rising temperatures also affect crop yields, while deforestation and habitat destruction threaten biodiversity in these regions.

The central and eastern parts of the country are dominated by the Indus River Plain, which is the backbone of Pakistan's agricultural economy. This region, nourished by the Indus River and its tributaries (Beas, Chenab, Jhelum, Ravi and Sutlej), supports the cultivation of important crops such as wheat, cotton and rice, watered by one of the world's largest irrigation systems, the Indus Basin irrigation network. The Indus River Plain is highly vulnerable to shifting rainfall patterns, reduced river flows and the impacts of glacial melt from the Himalayas and Hindukush.

In the west, the Balochistan Plateau is an arid expanse where rising temperatures, climate-induced shifts in monsoon patterns, decreased rainfall and prolonged drought are exacerbating water scarcity and affecting agriculture, which is already limited by the region's arid conditions.

In the southeast, the Thar Desert extends into Sindh province and beyond into India, while the Cholistan Desert lies in southern Punjab. These arid regions face significant risks as a result of climate change. Rising temperatures, erratic rainfall patterns and prolonged drought have led to severe water scarcity, threatening agriculture. The region's fragile ecosystems are also becoming increasingly water-stressed, leading to biodiversity loss and speeding up the pace of desertification.

Pakistan's coastline stretches approximately 1,050 km along the Arabian Sea, from the western border with Iran at Jiwani to the eastern border with India at Sir Creek, traversing the provinces of Balochistan and Sindh. Coastal areas are vulnerable to rising sea levels and frequent cyclone activity, which destroy livelihoods and displace entire communities (Weeks et al., 2023; Noman et al., 2022).

1.2 Climate

Pakistan falls predominantly within the subtropical zone, partially extending into temperate regions (Farooqi et al., 2005). The country experiences four seasons, the onset and duration of which vary according to the location. Winter is generally dry, with temperatures in the plains between 4°C and 20°C, while mountain regions can drop to as low as -50°C. The area weighted precipitation during the winter is around 30% of the total annual rainfall. Spring is pleasant with mild temperatures up to 25°C, with area weighted rainfall at around 12% of total annual rainfall

Summer in the plains and coastal areas is characterised by temperatures from 30°C to extremes as high as 50°C. In mountainous regions summer temperatures remain comparatively mild. The weather is usually dry, except during the monsoon from mid-June to September. Monsoon

rainfall accounts for nearly 55% of annual precipitation. In the autumn or post-monsoon season, temperatures range between 10°C to -4°C in hilly areas. Rainfall during autumn is around 4% of total area weighted annual precipitation.

Pakistan's climate is highly variable, with significant fluctuations in rainfall patterns leading to recurring droughts and floods. This variability is influenced by phenomena such as El Niño, which impacts both temperature and flood frequency, but also increasingly by the effects of climate change.

In fact the climate has undergone significant changes over the last several decades. Observed climate trends indicate that Pakistan has experienced a steady rise in average annual temperatures, increasing by 0.16°C per decade from 2001 to 2023, with the highest warming trends observed in the north of the country. The seasonal temperature increase varies, with winter warming at 0.20°C per decade and summer at 0.14°C per decade. The province of Khyber Pakhtunkhwa (KP) and the territories of Azad Jammu and Kashmir (AJK) and Gilgit Baltistan (GB) have shown the highest temperature increases.

Rainfall patterns have become erratic as well. While an increasing trend was observed from 1951 to 1970 (+0.80 mm/decade), precipitation has since been decreasing by 5 mm/decade (1971-1990) and 4.68 mm/decade (1991-2020). Areas like KP, AJK and GB have recorded significant declines in precipitation.

Extreme weather events in recent decades have caused widespread displacement and loss of life, along with severe damage to homes, land and infrastructure. Flooding is a persistent threat, with heavy rainfall leading to river overflows and landslides. Droughts are becoming more frequent, leading to prolonged dry spells particularly in Balochistan and Sindh. The country is also experiencing heatwaves more frequently, with record-breaking temperatures in Balochistan and Sindh.

1.3 Population

Pakistan is the sixth most populous country in the world, with an estimated 241.47 million people as of 2023 (PBS, 2023). With an average annual growth rate of 2.55% (Table 1.1), the country is projected to become the fifth most populous country globally by 2050.

Table 1.1: Population and annual growth rate

Administrative unit	Population (million)			Annual growth rate (%)		
	1998	2017	2023	1998	2017	2023
Pakistan	**132.36**	**207.68**	**241.47**	**2.69**	**2.40**	**2.55**
Balochistan	6.57	12.34	14.89	2.47	3.37	3.20
KP	20.92	35.50	40.85	2.72	2.82	2.38
Punjab	73.62	109.98	127.68	2.64	2.13	2.53
Sindh	30.44	47.85	55.69	2.80	2.41	2.57
Islamabad	0.81	2.01	2.36	5.19	4.91	2.81

Source: GoP, 2023 .

The total fertility rate is 3.7 children per woman (PBS, 2020), placing Pakistan among the countries with the highest fertility rates in the Asia-Pacific region (PRB, n.d.). Population density stands at approximately 303 individuals per sq km, with 38.82% of the population living in urban areas (GoP, 2023).

Climate change will exacerbate poverty across the world and Pakistan is no exception. As of 2023, approximately 37.2% of the population is estimated to live below the poverty line, defined as earning less than USD 3.65 per day (WB, 2023). But with 61.18% of the population living in rural areas and climate change affecting already precarious rural livelihoods, rural poverty will increase.

This in turn will increase migration to the cities, where the urban poor live in informal settlements. Increased urbanisation will put additional strain on urban infrastructure, which struggles to cope with the effects of extreme weather events. Increased urbanisation will also increase GHG emissions due to higher energy consumption, waste production and transportation needs.

1.4 Natural resources

Pakistan's natural resources are already under intense pressure from population growth and unsustainable use. These resources are further threatened by the impacts of climate change.

1.4.1 Water

Climate change will increase Pakistan's vulnerability to extreme water scarcity. The country's water resources are under severe stress, with per capita surface water availability dropping from 5,260 m^3 in 1951 to 1,000 m^3 in 2016 and projected to fall further to 860 m^3 by 2040 (PCRWR and USPCAS-W, 2016). The capacity of the country's three main reservoirs, Chashma, Mangla and Tarbela, designed to hold a total of 15.75 MAF, is down to 13.1 MAF largely due to sedimentation. These reservoirs can store water for only 30 days, compared to the 120-day global standard. Upcoming dams like Dasu, Diamer Bhasha and Mohmand could add 12 MAF of capacity but will take many years to complete. The Indus River, which carries 200 million tons of sediment per year at Tarbela and 330 million tons at Kotri, is experiencing accelerated siltation (Mahessar et al., 2020). This build-up reduces reservoir storage capacity, impacting water supply and hydroelectric power generation.

Groundwater depletion is another major concern. Some 73% of agricultural land depends on groundwater, making Pakistan the third-largest user globally of groundwater for irrigation. Punjab alone accounts for 90% of groundwater extraction, with 1.2 million tube wells in operation (Qureshi, 2020). NASA data from 2003-2013 identified the Indus Basin aquifer as the second most overstressed globally, being depleted at an unsustainable rate. Groundwater levels in Punjab have fallen drastically, with areas exceeding 80 ft in depth increasing from 52.65 sq km in 2010 to 1,868.64 sq km in 2020.

The Indus Delta, home to the world's seventh-largest mangrove forest, is shrinking due to reduced freshwater inflows and rising sea levels. A 2018 study found that the delta has shrunk by 92%, with 60% of the floodplain barren and 32% submerged (Siyal, 2018). Mangrove cover declined from 16% in 1990 to 10% in 2017, despite conservation efforts. Saltwater intrusion has made farmland unproductive, forcing 1.2 million residents to migrate to Karachi.

The Hindukush-Karakoram-Himalaya (HKH) region, which accounts for 60-80% of the Indus River's flow, is undergoing rapid glacial melt due to rising temperatures. GLOFs are becoming increasingly frequent, threatening downstream communities. The 2022 Shisper Glacier flooding event in the Upper Indus Basin caused widespread destruction (Hussain, 2022). The Hassanabad Bridge in Hunza was destroyed, severing critical transport and disrupting access to food, water and electricity (Chatta, 2022). While most glaciers worldwide are retreating (IPCC, 2023), Karakoram glaciers represent an anomaly. Here, some glaciers are stable or advancing slightly (Scherler et al., 2011; Hewitt, 2014). But stability does not diminish GLOF risks.

Pakistan experiences high inter-annual and intra-annual variability in precipitation, leading to alternating floods and droughts. The country's water infrastructure (dams, barrages, link canals) is strained by these fluctuations. Monsoon and winter rains, essential to maintain the hydrological cycle, have become increasingly unpredictable. Rising temperatures accelerate glacier and snow melt, disrupting historical water supply patterns.

Pakistan's agricultural lands suffer from salinity and waterlogging, reducing crop productivity. Over 6.3 million ha are salinity-affected, while 1 million ha face waterlogging (ENVPK, 2021). Poor water management and inefficient drainage exacerbate these issues, particularly in Punjab and Sindh.

Transboundary water conflict is another major challenge. Pakistan's water resources are shared with India and Afghanistan, leading to disputes over river flows. India's upstream water management projects, including dam construction, impact water availability in Pakistan under the Indus Waters Treaty. Similarly, issues with Afghanistan over water control in the Kabul River Basin add to Pakistan's water security concerns.

1.4.2 Forests

Forests play a critical role in ecological stability, biodiversity conservation and climate resilience. Deforestation, unsustainable land use practices and climate change have severely depleted forest cover.

Pakistan's total forest area is estimated to be 4.8 million ha, or 5.1% of the total land area (FAO, 2020a). The country has various forest types, including alpine, temperate, sub-tropical, dry and mangrove, which contribute to climate resilience and support the livelihoods of millions. Despite their ecological significance, Pakistan has one of the highest deforestation rates in Asia, losing approximately 27,000 ha of forest annually (FAO, 2015).

Climate change is accelerating forest degradation through increased temperatures, erratic rainfall, prolonged droughts and extreme weather events. The northern mountainous regions, home to coniferous forests, are highly vulnerable to glacial retreat and shifting precipitation patterns, which impact tree growth. Mangrove forests along the Indus Delta, which constitute 97% of Pakistan's total mangrove cover, are under threat due to reduced freshwater inflows, rising sea levels and coastal erosion. Studies indicate that Pakistan's mangrove area has declined by nearly 50% over the past century due to deforestation, pollution and land encroachment (IUCN, 2020).

The forestry sector supports millions of people by providing timber, fuelwood, non-timber forest products (NTFPs) and ecosystem services. Overexploitation of these resources has

accelerated deforestation. The demand for fuelwood accounts for 68% of total wood consumption, contributing significantly to forest depletion (MoCC, 2021b). Illegal logging and encroachment for agriculture further reduce forest cover, particularly in KP, AJK and GB. Forest fires, triggered by prolonged dry spells and rising temperatures, have become more frequent in the forests of Balochistan and KP, causing significant environmental and economic losses.

1.4.3 Biodiversity

Pakistan's rich biodiversity is essential for maintaining ecological balance, supporting a wide variety of flora and fauna across diverse ecosystems, including mountains, forests, wetlands, coastal areas and deserts. Habitat destruction and human activities have already depleted the country's biodiversity, which is now under additional pressure from climate change impacts.

Pakistan is home to 195 mammal species, 668 birds, 177 reptiles and 174 freshwater fish, with several species categorised as endangered or critically endangered (IUCN, 2020). Climate change is exacerbating biodiversity loss by altering temperature and precipitation patterns, reducing food availability and increasing the frequency of extreme weather events. The Himalaya and Karakoram regions, which serve as biodiversity hotspots, are particularly vulnerable to glacial retreat and increased flooding, impacting both plants and animals (WWF, 2021). The loss of biodiversity affects ecosystem services, including carbon sequestration, water purification and soil fertility, as well as livelihoods (MoCC, 2021a).

1.4.4 Coastal areas

Pakistan's coastline spans approximately 1,050 km along the provinces of Balochistan and Sindh (Weeks et al., 2023; Noman et al., 2022). These coastal areas were once rich in biodiversity, including commercially valuable marine species, but today many species have disappeared or are in decline.

The Indus Delta mangroves, covering approximately 600,000 ha, are among the largest arid climate mangrove forests globally (GoS, 2025a). Historically, Pakistan had eight mangrove species but today only four species remain, with *Avicennia marina* being the most dominant. Mangrove cover in the Indus Delta has declined by nearly 50% over the past century, affecting critical breeding and nursery grounds for commercially valuable fish and shellfish species (IUCN, 2020).

Mangrove forests along the Indus Delta have suffered severe degradation due to deforestation, overgrazing and reduced freshwater flows from the Indus River. The reduction in freshwater influx, caused by the construction of dykes and barrages upstream, has limited sediment deposition, increasing soil erosion and salinity levels. The Kotri Barrage allows only flood-season water to reach the Keti Bunder region, severely affecting the mangrove ecosystem.

Mangroves serve as a buffer against storm surges and are vital for carbon sequestration. They are also the breeding ground for over 80 commercially valuable fish and shellfish species, supporting Pakistan's fishing industry, which earned approximately USD 531.217 million in exports in 2023-24 (GoP, 2023). The destruction of

mangrove forests threatens coastal fisheries and marine biodiversity, significantly impacting both the ecosystem and the livelihoods of coastal communities.

Pakistan's coastal waters also support coral populations, particularly around Astola Island, Charna Island, Gwadar, Jiwani and Mubarak Village, with at least 35 species of hard corals identified. Corals are highly sensitive to temperature fluctuations and pollution, and upcoming infrastructure development projects such as the Gwadar Port could further disrupt coral habitats.

Coastal beaches also serve as nesting sites for marine turtles, including the endangered green turtle (*Chelonia mydas*) and the olive ridley turtle (*Lepidochelys olivacea*) which is classified as vulnerable (IUCN, 2025). Although wildlife protection laws and conservation projects aim to protect nesting sites along Astola Island, Gwadar, Hawkes Bay, Jiwani, Paradise Point, Sandspit and Sonmiani, these areas are under pressure from egg poaching, habitat destruction and coastal urban development.

The vulnerability of coastal ecosystems is exacerbated by climate change. Mangrove forests and coral reefs are threatened by sea level rise and extreme weather events (Walters et al., 2008). Increased soil erosion, salinity and the reduction of freshwater flow from the Indus River have intensified land degradation.

Rising sea surface temperatures and declining annual precipitation trends, as observed in climate data, indicate continued climate instability in coastal areas. The reduction of freshwater discharge from the Indus River, crucial for agriculture and fisheries, has negatively impacted the local economy. Limited income opportunities and poor infrastructure reduce the adaptive capacity of communities residing in these areas, increasing their vulnerability to climate risks. In many cases this has forced coastal communities to migrate, seeking shelter and employment away from disaster-prone areas.

1.5 Economy

Despite achieving modest GDP growth of 2.38% in 2023, economic recovery, particularly from climate-induced disasters, has been sluggish. The agriculture sector, which grew by 6.25%, remains acutely vulnerable to climate risks (GoP, 2023). The escalating demand for financial resources to implement both mitigation and adaptation measures has stretched Pakistan's fiscal capacity to its limits.

Pakistan faces economic challenges on multiple fronts, including high inflation, escalating debt and a persistent trade deficit. The economy is also highly vulnerable to the impacts of climate change, with extreme weather events causing substantial losses. These economic challenges in turn affect Pakistan's ability to respond to climate change. High levels of public debt, a widening fiscal deficit and limited financial resources make it difficult to invest in climate adaptation and mitigation. The cost of building resilience through infrastructure development, disaster preparedness and clean energy is substantial, requiring significant national and international financing. Pakistan's economic dependence on agriculture, which is highly vulnerable to climate change, exacerbates the situation.

Declining agricultural productivity due to erratic weather patterns directly affects GDP, making it all the more difficult to finance adaptation and mitigation efforts. The high costs associated with building resilience, such as strengthening healthcare, improving disaster relief and supporting vulnerable populations, require significant investment. Given these constraints, Pakistan relies heavily on international climate finance and foreign assistance to bridge the funding gap and implement climate policies.

To address these challenges, Pakistan needs a climate-resilient economic strategy that integrates development with climate adaptation and mitigation. Policies focused on green energy, climate-smart agriculture and improved water management can help mitigate economic risks. Additionally, access to international climate finance, such as the Loss and Damage Fund and Green Climate Fund, is crucial for strengthening Pakistan's ability to cope with the increasing economic burdens of climate change. Without urgent action, climate change will continue to exacerbate economic instability, pushing more people into poverty and slowing down development.

1.5.1 Agriculture

Pakistan's agricultural sector plays a critical role in the country's economy, contributing 24% to GDP and employing 37.4% of the labour force (GoP, 2023). The heavy dependence of this sector on rainfall and the Indus River makes it highly vulnerable to climate change. Within this sector, livestock is a dominant sub-sector, comprising 60.84% of agricultural income and 14.63% of GDP, and supporting more than 8 million rural families (GoP, 2023).

Climate change poses a serious risk to food security and rural employment. The effects of climate change on Pakistan's major crops are already apparent. Wheat and rice, the country's staple crops, have seen a decline of 14.7% and 20.5% in production, respectively (Haq et al., 2021). Unpredictable precipitation and rising temperatures are disrupting key growth stages, especially for cotton (Davidson, 2018). In Sindh and southern Punjab, cotton yields are declining due to early heatwaves, while sugarcane production is suffering from alternating drought and waterlogging conditions. A recent study using crop simulation models predicts wheat and rice yield reductions of 14.1% and 15.2%, respectively, under continued warming (Rahman et al., 2022).

Each region faces distinct climate challenges that impact agricultural productivity. Punjab, the country's agricultural hub, is experiencing water scarcity due to erratic rainfall and glacier melt, which affects wheat and cotton. Rising temperatures are altering traditional growing seasons, while flash floods from monsoon rains damage crops and displace communities. Soil degradation caused by excessive fertiliser use and inefficient irrigation practices is depleting soil fertility.

Similarly, Sindh, a key producer of rice, sugarcane and cotton, is struggling with waterlogging and salinity due to poor irrigation and declining river flows. The province is frequently affected by droughts, particularly in the southern regions, which significantly reduce water availability for high-demand crops. The increasing frequency of heatwaves also affects labour productivity, while sea intrusion in coastal areas is making farmland unsuitable for cultivation.

KP is witnessing glacial melt and unpredictable water flows, leading to both floods and water shortages. The region is also highly prone to flash floods, which destroy infrastructure and farmlands. The growing seasons are becoming shorter and soil erosion, worsened by deforestation and unpredictable rainfall, is further decreasing agricultural productivity.

Balochistan, with its arid climate, is among the most vulnerable provinces. Severe droughts and water shortages have devastated both agriculture and livestock production. Rapid desertification due to declining rainfall and poor land management is forcing farmers to abandon agricultural land, leading to a decline in productivity. The region also faces extreme temperatures and soil erosion, making farming increasingly difficult.

In GB, where 36% of the population depends on agriculture, the reliance on glacial water is a major challenge. GLOFs and shifting rainfall patterns pose significant threats to farmland and infrastructure. Increasing rainfall variability is triggering landslides, disrupting farming cycles and access to markets.

Similarly, AJK, though rich in natural resources, is experiencing heavy monsoon rains and flash floods, which damage soil and crops while increasing soil erosion. Deforestation and irregular rainfall patterns are further compounding these difficulties, leading to the risk of crop failure and food shortages.

1.5.2 Energy

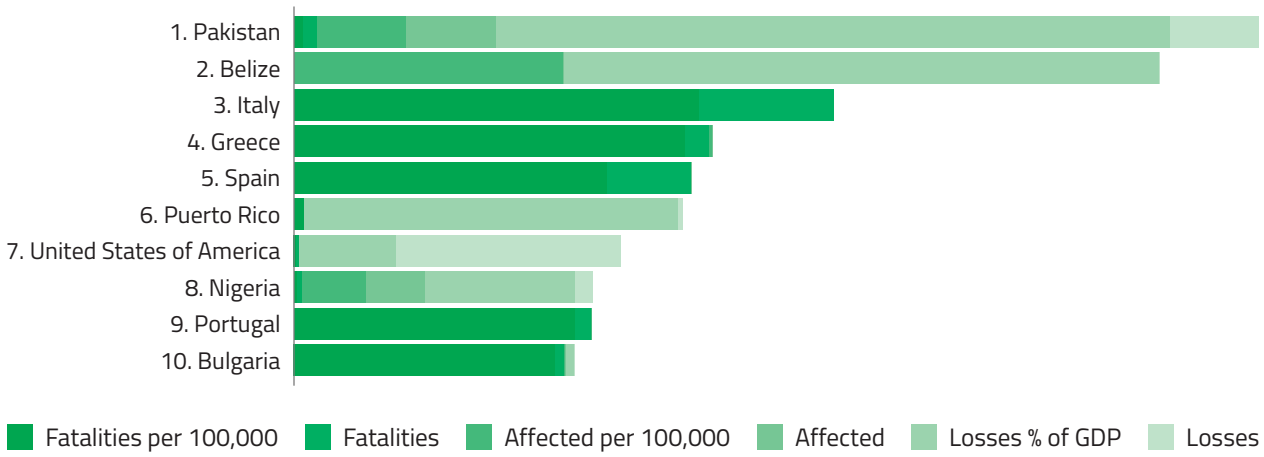
Energy is key to Pakistan's economic growth. The sector faces substantial challenges due to economic, environmental and geopolitical factors, which are exacerbated by climate change. The country's energy mix remains heavily dependent on fossil fuels, primarily natural gas and oil, contributing significantly to GHG emissions and exposing the system to price volatility, supply disruptions and geopolitical tensions. Fossil fuels (oil, gas, coal) account for 80% of total energy consumption, with renewables (hydro, solar, wind, bagasse) comprising 8% (GoP, 2022d).

The energy sector is directly impacted by climate change in two main ways. On the supply side, water scarcity affects hydropower generation, temperature fluctuations reduce power generation efficiency and extreme weather events disrupt energy infrastructure. On the demand side, rising temperatures increase electricity consumption for cooling, alter seasonal demand patterns, and drive greater energy use for water pumping and irrigation. Emissions considerations play a critical role in Pakistan's transition toward a low-carbon energy system, including expanding renewable energy, improving energy efficiency and implementing mitigation strategies.

1.6 Loss and damage

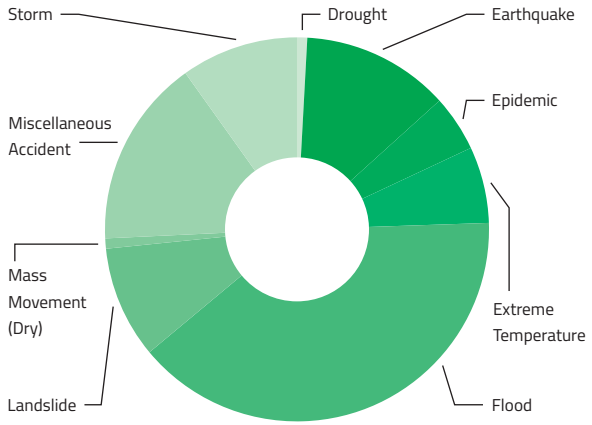
Until recently, Pakistan was the 8th most vulnerable nation globally to the impacts of climate change (Germanwatch, 2023). The Climate Risk Index was revised in 2025 and Pakistan is now ranked 1st in the list of countries most affected by climate change (Germanwatch, 2025). As the index notes, Pakistan ranks highest mainly because of the exceptionally high economic losses it has suffered and the number of people affected (Figure 1.2). Over the last four decades, the most frequent disasters Pakistan has faced have been related to extreme weather events (Figure 1.3).

Figure 1.2: Climate Risk Index 2025 rankings



Source: Germanwatch, 2025

Figure 1.3: Average annual natural hazard occurrence (1980-2020)



Source: Climate Change Knowledge Portal

1.6.1 Floods

Between June and September 2022, Pakistan was hit by unusually heavy monsoon rains. The resulting floods, the worst in the country's history, affected more than 33 million people (nearly 15% of the population) and displaced around 8 million (IFRC, 2023). A national state of emergency was declared in August of that year, when around one-third of the country was inundated.

More than 1,700 people were killed and 12,800 were injured. Around 1 million homes were destroyed and 2.1 million sustained significant damage (GoP, 2023). The floods inundated 4.5 million acres of agricultural land and killed 1.1 million livestock (IFRC 2023). More than 5,000 km of roads and 250 bridges were destroyed (Khan, 2022).

Total economic losses from the 2022 floods exceed USD 30 billion, with an estimated USD 14.9 billion in damage and around USD 15.2 billion in loss to GDP. Sectors that were worst affected were housing (USD 5.6 billion); agriculture, food, livestock and fisheries (USD 3.7 billion); and transport and communications (USD 3.3 billion).

The cost of reconstruction and rehabilitation is estimated at USD 16.3 billion (GoP, 2023). Sectors with the greatest reconstruction and recovery costs are transport and communications (USD 5.0 billion); agriculture, food, livestock and fisheries (USD 4.0 billion); and housing (USD 2.8 billion). The provinces of Balochistan and Sindh were the worst hit, accounting for approximately 15% and 50%, respectively, of reconstruction costs (GoP, 2023).

Pakistan is no stranger to devastating floods. In 2010 the country witnessed severe floods that affected around 20 million people, with close to 2,000 killed, 1.6 million houses damaged or destroyed, and millions of hectares of agricultural land inundated. The 2010 floods caused an estimated USD 10 billion in financial losses (NDMA, 2011). Other major floods occurred in 2011 and 2012, affecting 55-60 million people and causing more than 3,500 deaths (Qamer et al., 2023).

1.6.2 Heatwaves and droughts

Pakistan has witnessed several record-breaking heatwaves in recent years, with catastrophic consequences. The 2015 Karachi heatwave caused more than 1,200 fatalities, making it one of the deadliest in the country's history. In May 2019, another heatwave struck, causing at least 65 deaths, with Jacobabad recording a high of 49°C.

During the most recent heatwave, in April-May 2022, temperatures soared to 50°C in Jacobabad and 49.5°C in Nawabshah. A real-time extreme event attribution study shows that climate change made the heatwave 30 times more likely (WWA, 2022).

The combination of climate change, El Niño effects and reduced monsoon rainfall has led to prolonged dry spells, particularly affecting Balochistan and Sindh, which have historically experienced two to three droughts per decade. The country has witnessed prolonged periods of drought in recent decades (1998-2002, 2014-17, 2020-22). In 2022, the UN listed Pakistan as one of 23 drought-hit countries (UNCCD, 2022).

1.6.3 Coastal areas

Six record-breaking cyclones during the last two decades have devastated coastal communities (GoS, 2012). Most recently, Biparjoy was a powerful tropical cyclone that formed over the east-central Arabian Sea in June 2023. An estimated 1.2 million people were affected by winds of 90-120 km/h (55-75 mph) and 81,000 people were evacuated. Heavy gusts and torrential rain damaged 2,460 houses and destroyed 190.

Sea level rise in coastal areas has led to a high rate of soil erosion of about 20 m per year. As a result of saltwater intrusion into the Indus Delta, approximately 1.2 million residents have relocated to Karachi, seeking refuge from the delta's deteriorating conditions (Ebrahim, 2020).

1.7 Disaster preparedness

The National Disaster Management Authority (NDMA) is the primary agency responsible for disaster preparedness and management. The NDMA coordinates with provincial and district disaster management authorities (PDMAs and DDMAs), carries out risk assessments and implements disaster response initiatives. A key task for the NDMA is the development and periodic revision of national disaster management policies and plans, ensuring coordination between government bodies, NGOs and international agencies. It provides specialised training for disaster management personnel at all levels and conducts public awareness campaigns on disaster preparedness and risk reduction to bolster community resilience.

Effective early warning systems are integral to disaster preparedness. Pakistan has made substantial investments in meteorological and hydrological monitoring infrastructure to provide timely alerts for floods, cyclones and other weather-related hazards. The Pakistan Meteorological Department (PMD) plays a central role in forecasting and disseminating warnings, with its Flood Forecasting Division (FFD) using satellite imagery, radar technology and river monitoring systems to predict flood risks and communicate them to the public.

To build resilience and mitigate the impacts of disasters, Pakistan has prioritised various structural interventions. Key initiatives include the construction of flood control infrastructure, such as embankments, levees and retention basins, aimed at managing and redirecting floodwaters. In urban centres like Islamabad and Karachi, efforts are underway to develop seismic-resilient infrastructure, updating building codes and retrofitting existing structures to withstand earthquakes. Comprehensive water management strategies are also being developed, focusing on dams and reservoirs to regulate water resources and mitigate the effects of both floods and droughts.

1.8 Climate change and international commitments

Pakistan is engaged in the international climate dialogue through its participation in the UNFCCC process and annual COP meetings. The country advocates for equitable climate policies that address the needs of developing nations, emphasising the principle of common but differentiated responsibilities and respective capabilities. Through these engagements, Pakistan urges developed countries to take the lead in emissions reduction while supporting developing nations with financial and technological resources.

Pakistan's role in international climate negotiations is evident from its contribution to global climate policies, where it collaborates with other nations to push for climate justice and fair implementation of climate agreements. The country is also involved in regional initiatives that strengthen South-South cooperation and promote joint climate resilience efforts among vulnerable nations.

1.9 Institutional arrangements for climate change reporting

Pakistan's institutional landscape provides a framework for integrating climate concerns into national development policies and programmes. Besides working to build resilience across sectors, and facilitating adaptation and mitigation efforts, these institutions are also responsible for climate change monitoring and reporting.

1.9.1 Ministry of Climate Change and Environmental Coordination

The Ministry of Climate Change and Environmental Coordination (MoCC) is the national coordinating body for climate-related initiatives. It is responsible for ensuring the implementation of climate change policies, working with the relevant government agencies to ensure that climate considerations are mainstreamed into national development plans and programmes, and sectoral policies. The MoCC steers the country's climate response by facilitating collaboration between federal and provincial governments, research

institutions, universities and the private sector. Through the Global Climate-Change Impact Studies Centre (GCISC), the ministry coordinates climate research and data collection.

At the international level, the MoCC serves as the focal point for multilateral environmental agreements to which Pakistan is a Party, including the United Nations Framework Convention on Climate Change (UNFCCC) and reporting obligations under the Convention. It is responsible for preparing and submitting Pakistan's Nationally Determined Contributions (NDCs), National Communications (NCs) and Biennial Transparency Reports (BTRs) to the UNFCCC. This process requires coordination with sectoral ministries, technical experts and relevant stakeholders to compile data, analyse emission trends and report on progress.

1.9.2 Global Climate-Change Impact Studies Centre

The GCISC serves as the research arm of the MoCC. Its mission is to improve understanding of global environmental changes and their implications for Pakistan. It studies climate change and its impact on key sectors of the economy, providing policy makers with insights and recommendations to address climate threats and build resilience. The GCISC acts as the national repository for climate-related data. It serves as the Secretariat for the NDCs and the National GHG Inventory, and is responsible for data collection, analysis, compilation and reporting for these national documents. A key initiative led by the GCISC is the establishment of an NDC platform and a GHG inventory system.

1.9.3 Ministry of Planning, Development and Special Initiatives

The Ministry of Planning, Development and Special Initiatives (MoPDSI) plays a key role in the implementation of the Sustainable Development Goals (SDGs) in Pakistan. In collaboration with provincial planning bodies and the United Nations Development Programme (UNDP), MoPDSI has launched the National Initiative for Sustainable Development Goals to systematically integrate the 2030 Agenda into national and subnational planning processes. This initiative establishes a structured mechanism for aligning policy formulation, financing strategies and data collection to support evidence-based decision making. Since 2018, baseline data and performance targets have been institutionalised to enable monitoring, evaluation and reporting, ensuring that Pakistan's SDG commitments are tracked through a coordinated framework.

1.9.4 National Disaster Management Authority

The National Disaster Management Authority (NDMA) is the lead agency at the federal level responsible for managing disaster management activities in Pakistan. It serves as the executive arm of the National Disaster Management Commission (NDMC), the apex policy making body for disaster management, which operates under the chairmanship of the Prime Minister. In the event of a disaster, all relevant stakeholders including government ministries, departments and agencies, the armed forces, international NGOs (INGOs) and local NGOs work under NDMA's leadership to ensure a coordinated response.

The NDMA works in with the MoCC on climate resilience efforts, including the development and implementation of disaster risk management strategies to cope with climate-related hazards such as floods, droughts, heatwaves and cyclones. It is also responsible for the development and implementation of early warning systems, emergency response mechanisms and long-term risk reduction planning.

A key aspect of NDMA's role is data sharing and coordination with the MoCC on climate-induced disaster trends. It prepares risk maps, carries out vulnerability assessments and develops contingency plans to support PDMAs and DDMAs in disaster preparedness and response.

The NDMA works with the MoCC to build resilience at the community level through capacity-building, public awareness and training. This includes promoting climate-smart infrastructure, nature-based solutions and sustainable land use planning to minimise disaster risks.

At the international level, NDMA collaborates with the MoCC to engage with global climate finance mechanisms such as the Green Climate Fund (GCF) and the Adaptation Fund, securing resources to implement climate-resilient disaster management projects. Along with the MoCC, the NDMA represents Pakistan in climate negotiations and disaster risk reduction forums, advocating for technology transfer, financial support and capacity building to combat climate-induced disasters.

1.10 Measurement, reporting and verification

Pakistan has developed a number of measurement, reporting and verification (MRV) platforms and tools to strengthen transparency and accountability in climate governance:

- The RISQ Transparency Platform strengthens national MRV capabilities under the Enhanced Transparency Framework (ETF).
- The Pakistan Climate Investment Platform (PCIP) provides a structured mechanism for monitoring NDC implementation and climate finance mobilisation.
- The National Forest Monitoring System for REDD+ aims to improve reporting mechanisms.
- Plans are underway to establish a National Carbon Registry and Domestic Emissions Trading System to introduce market-based carbon pricing and promote emissions trading, focusing on the energy and industry sectors.
- Under the UNDP Climate Promise initiative, efforts are underway to develop provincial MRV guidelines.
- The GHG Inventory MRV Framework, developed by GCISC, aims to improve the quality and accuracy of Pakistan's emissions reporting.
- Sector-specific MRV systems track emissions from agriculture and other climate-sensitive sectors, providing data for targeted mitigation actions.

These initiatives support Pakistan's efforts to comply with international reporting standards, make data-driven policy decisions and strengthen climate governance.

Despite periodic reporting to the UNFCCC, Pakistan lacks a comprehensive national MRV system. Data for GHG monitoring is not available in a single database or repository, complicating the tasks of accurate GHG inventory development, and emissions monitoring and reporting. To address this gap, the GCISC is taking the lead in establishing a national MRV framework, in collaboration with international partners including

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Centre Interprofessionnel Technique d'Études de la Pollution Atmosphérique (CITEPA) France.

The new MRV system will provide comprehensive data covering the legal, institutional and procedural aspects of climate reporting. It is designed to:

- Integrate GHG emissions data across sectors such as energy, agriculture, industry, waste management and forestry
- Track progress on climate adaptation and mitigation actions, including policies, projects and sectoral initiatives
- Ensure compliance with international reporting requirements, including Biennial Transparency Reports (BTRs), National Communications (NCs) and NDC progress reports
- Improve coordination between federal ministries, provincial governments, research institutions, private sector entities and civil society to streamline data collection, verification and submission.

To ensure that the MRV system is inclusive, effective and widely accepted, comprehensive stakeholder consultations have been conducted across the country. These consultations have engaged relevant ministries, provincial governments, academic institutions, research organisations and industry representatives to gather insights on data availability, reporting challenges and sectoral needs.

The MRV system will be launched in the near future, marking a significant milestone in Pakistan's climate governance and reporting structure. The GCISC will serve as the lead organisation and will be responsible for:

- Collecting and analysing emissions data from different sectors
- Tracking adaptation and mitigation projects implemented across the country
- Ensuring transparent reporting and submission of climate data to international bodies under the Paris Agreement
- Capacity building and technical support to provincial and sectoral agencies to improve climate data collection and reporting mechanisms.

Other statutory bodies and government departments contribute to data collection and MRV:

- The Pakistan Bureau of Statistics (PBS) and the Economic Survey of Pakistan collect and make available census and socioeconomic data.
- Provincial agricultural departments, particularly in Punjab and Sindh, monitor crop yields and other productivity metrics.
- The Pakistan Agricultural Research Council (PARC), in collaboration with provincial agriculture departments, conducts surveys to evaluate the effectiveness of climate-smart interventions and practices.
- Provincial water management authorities track water use, supply and the adoption of water-efficient irrigation systems.
- Regular provincial-level reports are integrated into the national reporting framework overseen by the MoCC, creating a continuous feedback loop for improving adaptation strategies.

1.11 Climate change and government priorities

The Government of Pakistan recognises climate change as a national priority. It has developed several policies, strategies and plans aimed at mitigation, adaptation and resilience. Key government policy documents and their objectives are summarised in Table 1.2.

Table 1.2: Major climate-related policies and priorities

Legal or policy initiative	Date	Key objectives
National Climate Change Policy	2012, updated 2021	Strengthening climate resilience, promoting sustainable development, enhancing water resource management and mainstreaming climate adaptation and mitigation measures
Pakistan Climate Change Act	2017	Establish institutional frameworks for climate governance, create the Climate Change Authority and integrate climate policy into national planning
Updated Nationally Determined Contributions	2021	Reducing GHG emissions by 20% by 2030, expanding renewable energy, enhancing afforestation and promoting energy efficiency
National Adaptation Plan	2023	Developing long-term adaptation strategies for sectors vulnerable to climate change, including agriculture, water and health
Framework for Carbon Market Development in Pakistan	2023	Establishing carbon markets, improving emissions tracking and developing regulatory frameworks for carbon credit trading

2

National greenhouse gas inventory (2020-21)

2.
National greenhouse gas inventory (2020-21)

Pakistan's greenhouse gas (GHG) inventory for 2020-21 has been prepared using the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for national GHG inventories (IPCC, 2006). It provides emissions information for carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) from anthropogenic sources. The inventory was compiled using IPCC Inventory Software (Version 2.69) in line with IPCC Guidelines and the Katowice Decision (2018) which requires all parties to use the IPCC 2006 Guidelines.

2.1 Pakistan's GHG inventory preparation process

Pakistan's first GHG inventory, submitted to the UNFCCC as part of the country's Initial National Communication on Climate Change (GoP, 2003), was compiled by M/s Hagler Bailly between 1999 and 2003. The project was supported by the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). The inventory covered the fiscal year 1993-94 (referred to as 1994) and was compiled in accordance with the IPCC 1996 Guidelines. Total estimated GHG emissions in the 1994 inventory amounted to 181.7 million tons of carbon dioxide equivalent (MtCO2e) (GoP, 2010). Sector-specific emissions in the 1994 inventory were as follows: energy 47.2%, agriculture 39.4%, industrial processes and product use (IPPU) 7.3%, land use change and forestry (LUCF) 3.6%, and waste 2.5% (GoP, 2010).

The second GHG inventory, for the year 2007-08 (referred to as 2008), was compiled in 2009 by the Applied System Analysis Division (ASAD) of the Pakistan Atomic Energy Commission (PAEC) (Ahmad et al., 2009). This inventory also used the 2006 IPCC Guidelines. The draft report was not formally submitted to the UNFCCC but is available. The 2008 inventory estimates GHG emissions at 309.4 MtCO2e, with sectoral contributions as follows: energy 50.7%, agriculture 38.8%, IPPU 5.8%, LUCF 2.9%, and waste 1.8% (Ahmad et al., 2009).

ASAD subsequently revised the 2008 inventory, using the Revised 1996 IPCC Guidelines. In the revised 2008 inventory, prepared in 2016, estimated GHG emissions total 329.5 MtCO2e, with sectoral contributions as follows: energy 51.1%, agriculture 38.2%, IPPU 5.6%, LUCF 2.8%, and waste 2.2% (Ahmad et al., 2016; GoP, 2022e).

In the absence of an established institutional mechanism for GHG inventory preparation, the Global Climate-Change Impact Studies Centre (GCISC) took the lead in 2014, using indigenous capabilities. GCISC's first inventory, for the year 2011-12 (referred to as 2012), was prepared in 2014-15 based on the Revised 1996 IPCC Guidelines. It was published as a research report in 2016 (GCISC, 2016). Total estimated GHG emissions in the 2012 inventory amount to 374.1 MtCO2e, with contributions by sector as follows: energy 45.8%, agriculture 43.5%, IPPU 5.2%, LUCF 2.6% and waste 2.8% (Mir and Ijaz, 2016).

In 2016, GCISC compiled the GHG inventory for the year 2014-15 (referred to as 2015) using the UNFCCC Non-Annex I National GHG Inventory Software (Version 1.3.2). This inventory was developed in accordance with the Revised 1996 IPCC Guidelines, employing a tier-1 approach that relies on default emission factors depending on national circumstances and data availability.

According to the 2015 inventory, Pakistan's total estimated GHG emissions for the year 2014-15 amounted to 408.1 MtCO2e, with the following sectoral contributions: energy 45.5%, agriculture 42.7%, IPPU 5.4%, LUCF 2.5% and waste 3.8%.

It is worth noting that initial calculations for this inventory reported total emissions at 405 MtCO2e, and this figure was used in Pakistan's First Nationally Determined Contributions (NDCs) document, submitted to the UNFCCC in November 2016. After stakeholder consultations and revisions to emissions data based on their feedback, an updated figure of 408.1 MtCO2e was calculated, and this was the figure reported in Pakistan's Second National Communication to the UNFCCC (GoP, 2018).

The next GHG inventory, for the year 2017-18 (referred to as 2018), was compiled by GCISC in 2020 using IPCC Inventory Software (Version 2.69), in line with IPCC 2006 Guidelines. According to the 2018 inventory, total estimated GHG emissions for the year 2018 stood at 489.87 MtCO2e, with sectoral contributions as follows: energy 44.7%, agriculture 40.4%, IPPU 5.3%, LUCF 5.2% and waste 4.4%. This inventory formed the basis for Pakistan's First Biennial Update Report (BUR1), submitted to UNFCCC in April 2022 (GoP, 2022e). Pakistan's GHG inventory development process and findings are summarised in Table 2.1.

2.2 Activity data, emission factors and methodological tier

Following the Katowice and Sharm El-Sheikh decisions, GCISC has prepared Pakistan's latest national GHG inventory using the most current datasets, based on the IPCC 2006 Guidelines and IPCC AR5 Global Warming Potential (GWP). This report presents Pakistan's 2020-21 inventory (referred to as 2021), marking GCISC's fourth inventory compilation.

Table 2.1: GHG inventory development and findings

Year	Developed by	Total	GHG emissions by sector (%)				
		MtCO2e	Energy	Agriculture	Industrial processes	LUCF	Waste
1994	M/s Hagler Bailly (based on 1996 IPCC Guidelines)	181.7	47.2	39.4	7.3	3.6	2.5
2008	ASAD/PAEC (Revised 1996 IPCC Guidelines)	329.5	51.1	38.2	5.6	2.8	2.2
2008	ASAD/PAEC (2006 IPCC Guidelines)	309.4	50.7	38.8	5.8	2.9	1.8
2012	GCISC (Revised 1996 IPCC Guidelines)	374.1	45.8	43.5	5.2	2.6	2.8
2015	GCISC (Revised 1996 IPCC Guidelines)	408.1	45.5	42.7	5.4	2.5	3.8
2018	GCISC (Revised IPCC 2006 Guidelines)	489.87	44.7	40.4	5.3	5.2	4.4

The 2021 GHG inventory has been prepared using the 2006 IPCC Guidelines, employing a tier-1 methodological approach with default emission factors (IPCC, 2002). The inventory covers four key sectors:

- Energy (including transport)
- Industrial processes and product use (IPPU)
- Agriculture, forestry and other land use (AFOLU)
- Waste.

2.2.1 Data collection procedures and arrangements

A systematic approach was employed for data collection, engaging relevant stakeholders at both the federal and provincial levels. Capacity building sessions were conducted with stakeholders to enhance their understanding of data requirements, reporting standards and management practices. Engagement was conducted through field visits, formal correspondence and online meetings.

2.2.2 Data sources

Data on activities contributing to GHG emissions and removals by sinks was primarily sourced from national studies, reports and online databases published by government ministries, departments and agencies. Sector-specific data was also collected through desk review of published documents, and expert opinions were obtained through stakeholder consultations. Data sources used to compile the 2021 GHG inventory are shown in Table 2.2.

Activity data for various sectors focused on the following processes and/or activities:

- Energy: fuel combustion, fugitive emissions
- IPPU: emissions from industries such as minerals, chemicals, metals and electronics
- AFOLU: livestock, manure management, forestland, cropland, grasslands, wetlands and rice cultivation (data sources were supplemented by expert judgments)
- Waste: solid and liquid waste generation, collection and management (compiled through stakeholder engagement and report analysis).

2.2.3 Stakeholder consultations for data gaps

Available data sources in Pakistan do not fully meet the requirements of the GHG inventory. Where data was unavailable or incomplete, consultations were held with federal and provincial ministries, departments and agencies, as well as universities and research institutions. In some cases consultations were held with the parent organisations responsible for various publications to address data gaps and obtain expert judgments on missing information.

Pakistan is in the process of establishing a GHG inventory management system. Once the necessary institutional arrangements are in place, it is expected that many of these data gaps will be covered in upcoming GHG inventory compilations.

2.2.4 Methods for GHG emissions and removals estimation

GHG emissions and removals were estimated using the 2006 IPCC Guidelines, following a tier-1 methodological approach. Collected data, expert inputs, and judgments were systematically processed to meet inventory requirements. To address data gaps, IPCC-recommended data splicing techniques were applied. The estimates provide a comprehensive account of emissions and removals across all sectors. Sector-specific methodological notes are included within the relevant sections below.

Table 2.2: Data sources used for GHG inventory preparation

Sector	Documents	Stakeholder consultations
Energy	• Pakistan Energy Yearbook 2018 (HDIP, 2021) • Pakistan Energy Yearbook 2021-22 (GoP, 2021a) • Economic Survey of Pakistan (MoF, 2021) • State of Industries Report (NEPRA, 2021)	• Federal ministries and provincial departments (e.g., MoE, MoC, MoPDSI, provincial energy departments) • Pakistan Bureau of Statistics (PBS) • Hydrocarbon Development Institute of Pakistan (HDIP) • AJK Power Development Organisation (AJK-PDO)
IPPU	• Economic Survey of Pakistan (MoF, 2021)	• Federal Ministries (e.g., MoC, MoI&P, MoPDSI, MoDP) • Provincial Departments (e.g., Industries, Commerce, Investment and Skills Department (ICID), Punjab, Directorate of Industries and Commerce (DoIC), Khyber Pakhtunkhwa, Industries and Commerce Department (I&CD), Sindh) • Pakistan Industrial Technical Assistance Centre (PITAC) • AJK Public Procurement Regulatory Authority (AJKPPRA) • Small Industries Corporation (SICAJK), AJK
AFOLU	• Agriculture Statistics of Pakistan 2020-21 (MoNFSR, 2021) • Economic Survey of Pakistan (MoF, 2021) • FAO Statistics (FAO, 2021) • National Forest and Rangeland Resource Assessment Study (PFI, 2004) • FRELs/Forest Reference Level, the National Forest Monitoring System, the Measurement, Reporting and Verification System for REDD+ (GoP, 2019a) • Forestrypedia of Pakistan (Forestrypedia, 2021)	• National Fertiliser Development Centre (NFDC) • Pakistan Agriculture Research Council (PARC) • Livestock and Dairy Development Board (LDDB) • Urban Resource Centre (URC), Sindh • Federal Ministries (e.g., MoNFS&R, MoF, MoIPC) • Provincial Agriculture and Forestry Departments • The Urban Unit, Lahore • Rice Research Institute, Kala Shah Kaku
Waste	• Economic Survey of Pakistan (MoF, 2021) • Pakistan's First Biennial Update Report (GoP, 2022e) • Solid Waste Management Sector in Pakistan (ADB, 2022) • Compendium on Environment Statistics of Pakistan (2020)	• Environmental Departments of various universities (e.g., ENV-AIOU, ENV-NUST) • Federal and Provincial Environmental Departments (e.g., Pak-EPA, EPDs, EPAs) • Provincial Waste Management Companies

2.3 Summary of 2021 GHG inventory results

Total estimated GHG emissions for 2021 demonstrate a notable increase compared to inventories for 1994, 2008, 2012, 2015 and 2018. In 2021, total emissions stood at 521.46 MtCO2e, up 31.6 MtCO2e from the last reporting period (2018).

This upward trend is predominantly driven by sectors that are key to economic development: energy, agriculture, industry and waste management. This highlights the challenge for countries like Pakistan of cutting emissions without adversely affecting economic activities.

In the 2021 inventory, the AFOLU sector emerged as the largest emitter, accounting for 46.75% of total emissions, followed by energy at 40.90%. The waste sector was responsible for 6.22% of emissions, while the IPPU sector accounted for 6.13% (see Tables 2.3 and 2.4).

Table 2.3: Summary of GHG emissions 2021

Sector	Sub-sector	Emissions (MtCO2e)		Percentage of total emissions
		Sub-sector	Sector total	
Energy	Energy industries	48.87	213.28	40.90%
	Manufacturing industries and construction	72.23		
	Transport	51.01		
	Other (commercial, residential, agricultural)	36.80		
	Fugitive fuel emissions	4.37		
Industrial processes and product use	Mineral industry	27.39	31.98	6.13%
	Chemical industry	3.02		
	Non-energy fuel and solvent use	0.22		
	Other (paper and pulp, food and beverages)	1.35		
Agriculture, forestry and other land use	Livestock	130.14	243.76	46.75%
	Land	34.82		
	Managed soils	66.80		
	Rice cultivation	12.00		
Waste	Solid waste disposal	17.52	32.44	6.22%
	Waste incineration and open burning	0.31		
	Wastewater treatment and discharge	14.61		
Total emissions			**521.46**	**100%**

Table 2.4: Details of GHG emissions 2021 (MtCO2e)

Categories	Million tons			
	Net CO2 emissions/ removals	Emissions		
		CH4	N2O	Total
Pakistan total	**273.24**	**173.90**	**74.32**	**521.46**
1 - Energy	**206.68**	**5.34**	**1.26**	**213.28**
1.A - Fuel combustion activities	**206.66**	**0.98**	**1.27**	**208.91**
1.A.1 - Energy industries	48.68	0.04	0.14	48.87
1.A.2 - Manufacturing industries and construction	71.84	0.16	0.23	72.23
1.A.3 - Transport	49.50	0.66	0.85	51.01
1.A.4 - Other sectors	36.64	0.12	0.05	36.80
1.A.5 - Non-specified	0	0	0	0
1.B - Fugitive emissions from fuels	**0.01**	**4.36**	**0.00001**	**4.37**
1.B.1 - Solid fuels	0.001	0.73		0.73
1.B.2 - Oil and natural gas	0.009	3.63	0.00001	3.64
1.B.3 - Other emissions from energy production				0

Categories	Million tons			
	Net CO2 emissions/ removals	Emissions		
		CH4	N2O	Total
1.C - Carbon dioxide transport and storage	**0**			**0**
1.C.1 - Transport of CO2	0			0
1.C.2 - Injection and storage	0			0
1.C.3 - Other	0			0
2 - Industrial processes and product use	**30.68**	**1.30**		**31.98**
2.A - Mineral industry	**27.39**	**0**	**0**	**27.39**
2.A.1 - Cement production	25.76			25.76
2.A.2 - Lime production	1.33			1.33
2.A.3 - Glass production	0.03			0.03
2.A.4 - Other process uses of carbonates	0.27	0		0.27
2.B - Chemical industry	**3.02**	**0**		**3.02**
2.B.1 - Ammonia production	3.02			3.02
2.C - Metal industry	**0**	**0**		**0**
2.D - Non-energy products from fuels and solvent use	**0.22**	**0**		**0.22**
2.D.1 - Lubricant use	0.22			0.22
2.E - Electronics industry	**0**	**0**		**0**
2.F - Product uses as substitutes for ozone depleting substances	**0**	**0**		**0**
2.G - Other product manufacture and use	**0**	**0**		**0**
2.H - Other	**0.05**	**1.30**	**0.00**	**1.35**
2.H.1 - Pulp and paper industry	0.0001	0.02		0.02
2.H.2 - Food and beverages industry	0.05	1.28		1.33
3 - Agriculture, forestry and other land use	**35.77**	**137.23**	**70.76**	**243.76**
3.A - Livestock	**0**	**122.54**	**7.60**	**130.14**
3.A.1 - Enteric fermentation	0	112.83	0	112.83
3.A.2 - Manure management	0	9.71	7.60	17.31
3.B - Land	**31.35**	**2.69**	**0.78**	**34.82**
3.B.1 - Forest land	28.44	0.13	0.07	28.64
3.B.2 - Cropland	2.50	2.54	0.62	5.67
3.B.3 - Grassland	0	0.02	0.01	0.03
3.B.4 - Wetlands	0.41	0	0.08	0.48
3.C - Managed soils	**4.43**		**62.37**	**66.80**
3.C.2 - Urea application	4.43			4.43
3.C.3 - Direct N2O emissions from managed soils			40.50	40.50
3.C.4 - Indirect N2O emissions from managed soils			17.55	17.55
3.C.5 - Indirect N2O emissions from manure management			4.32	4.32
3.D - Rice Cultivation		**12.00**		**12.00**
4 - Waste	**0.11**	**30.03**	**2.30**	**32.44**
4.A - Solid waste disposal	**0**	**17.52**	**0**	**17.52**
4.A.1 - Managed waste disposal sites				

Categories	Million tons			
	Net CO2 emissions/ removals	Emissions		
		CH4	N2O	Total
4.A.2 - Unmanaged waste disposal sites				
4.A.3 - Uncategorised waste disposal sites				
4.B - Biological treatment of solid waste				
4.C - Incineration and open burning of waste	**0.11**	**0.15**	**0.04**	**0.31**
4.C.1 - Waste incineration	0.08	0.01	0.02	0.11
4.C.2 - Open burning of waste	0.03	0.14	0.02	0.20
4.D - Wastewater treatment and discharge		**12.36**	**2.25**	**14.61**
4.D.1 - Domestic wastewater treatment and discharge		10.14	2.25	12.39
4.D.2 - Industrial wastewater treatment and discharge		2.22	0	2.22
Memo items				**0**
International bunkers	**0.15**	**0.0001**	**0.001**	**0.15**
1A3a1 - International aviation	0.11	0.00002	0.0008	0.11
1A3d1 - International marine (bunkers)	0.0393	0.0001	0.0003	0.040
Multilateral operations	**0**	**0**	**0**	**0**
CO2 emissions from biomass	**0.175**			**0.175**

2.4 Energy

Rising energy demand, driven by industrial expansion, urbanisation and population growth, remains a major concern. A mix of energy sources including fossil fuels (natural gas, coal, oil) and hydroelectric power dominate electricity generation. Pakistan has made significant progress in expanding renewable energy capacity, focusing on wind, solar and biomass. To support renewable energy, the government has introduced policies and provided incentives, such as net metering for solar installations. The China-Pakistan Economic Corridor (CPEC) initiative remains instrumental in improving infrastructure and addressing energy shortages. The country also continues to import electricity from Iran and Tajikistan.

Despite these efforts, energy shortages and load shedding continue. Infrastructure challenges also persist, such as distribution losses, circular debt and outdated transmission systems.

To address these issues, energy conservation and efficiency initiatives have gained attention, alongside commitments to reduce reliance on fossil fuels and increase the share of clean energy. The government continues to encourage private sector participation in energy projects through incentives and public-private partnerships. Reforms aimed at improving efficiency and transparency are also underway, with international collaboration supporting the effort.

2.4.1 Overview of energy sector emissions

The energy sector is the second-largest contributor to GHG emissions, with fossil fuel combustion accounting for 97.95% of CO2e emissions from the sector. Emissions from fuel combustion are categorised as stationary or mobile sources. Stationary combustion includes activities in energy industries (extraction, production, electricity generation), manufacturing industries (iron and steel production, chemical manufacturing) and residential, commercial and

institutional sectors. Mobile combustion covers road transport (cars, trucks, buses), rail transport, domestic aviation, national navigation and gas pipeline transport. Emissions from international transport using bunker fuels are reported separately as per IPCC guidelines and excluded from national totals.

In 2021, the main sources of thermal power generation in Pakistan were furnace oil, natural gas, high-speed diesel and coal (GoP, 2021a). A summary of GHG emissions from various categories within the energy sector is provided in Table 2.5.

The energy sector contributed 213.28 MtCO2e, accounting for 40.90% of Pakistan's total GHG emissions. The bulk of emissions from the energy sector come from CO2 (96.90%), followed by CH4 (2.50%) and N2O (0.59%). Within the energy industry category, which includes emissions from fossil fuels used in power generation and petroleum refining, emissions totalled 48.87 MtCO2e. Manufacturing industries and construction, covering activities like iron and steel production, chemical manufacturing, food processing and building, emitted 72.23 MtCO2e. This consists of 71.84 MtCO2e of CO2, 0.16 MtCO2e of CH4 and 0.23 MtCO2e of N2O. The transport sector produced 51.01 MtCO2e, while other sectors and fugitive emissions contributed 36.80 MtCO2e and 4.37 MtCO2e, respectively.

2.4.2 Energy industries

The energy sector contributes to emissions primarily through the burning of fossil fuels for electricity generation and solid fuel manufacturing. Emissions from natural gas used in gas processing plants are included under the electricity generation category. Specific data on fossil fuel use for solid fuel manufacturing (e.g. coal carbonisation) is currently unavailable, so this category is not included in national emission totals. In 2021, emissions from the energy industries category, which covers fossil fuels used in power generation and petroleum refining, amounted to 48.87MtCO2e, accounting for 22.91% of energy sector emissions.

2.4.3 Manufacturing industries and construction

This category covers GHG emissions from the combustion of fossil fuels in industries such as cement, iron and steel, chemicals, brick kilns and other sectors. Total emissions from manufacturing industries and construction, at 72.23 MtCO2e, make up 33.87% of total energy sector emissions.

Table 2.5: Summary of GHG emissions from the energy sector

Category	Emissions (MtCO2e)			
	CO2	CH4	N2O	Total
Energy industries	48.68	0.04	0.14	48.87
Manufacturing industries and construction	71.84	0.16	0.23	72.23
Transport	49.50	0.66	0.85	51.01
Other sectors	36.64	0.12	0.05	36.80
Fugitive emissions from fuels	0.01	4.36	0.00001	4.37
Total	**206.67**	**5.34**	**1.27**	**213.28**

2.4.4 Transport

Transport is one of the largest sectors of the economy, accounting for 13% of GDP (MoF, 2021). Data for this sector includes all GHG emissions resulting from the combustion of fossil fuels in road transport, aviation, railways and water-borne navigation. Over the last two decades, the demand for road transport has grown significantly. The number of registered road vehicles has risen from 9.66 million in 2011 to 32.38 million in 2021 (MoF, 2021). In 2021, emissions from the transport sector, at 51.01 MtCO2e, represented 23.92% of energy sector emissions.

2.4.5 Emissions from other sectors

Emissions from energy use in other sectors, including commercial, residential and agricultural activities, are associated with processes such as cooking, lighting, space heating/cooling and refrigeration. Fuels used for these purposes include electricity (lighting, heating/cooling, refrigeration), LPG (cooking), kerosene (lighting, cooking), diesel (power generation, lighting), and coal/charcoal and fuelwood (used in areas without grid electricity). Collectively, these sectors are responsible for 36.80 MtCO2e, amounting to 17.25% of energy sector emissions.

2.4.6 Fugitive emissions

Fugitive emissions in the energy sector are divided into two subcategories: (i) solid fuels (primarily coal mining) and (ii) oil and natural gas systems. Methane (CH4) is the main GHG emitted from these fugitive source categories. For solid fuels, the main source of fugitive emissions is the venting and disposal of coal-bed CH4, with most emissions occurring at the mine and some residual emissions arising from post-mining handling and processing activities. Extraction, production, processing and transportation of coal and other fuels contribute significantly to CH4 emissions. Oil and natural gas systems, which are complex and varied, face two major challenges in reporting fugitive emissions:

- Poor quality and incomplete data on venting and flaring
- Lack of statistics for many minor facilities (e.g., well sites, field facilities) that contribute to equipment leaks.

While CH4 is the primary emission from fugitive sources, CO2 is also released from coal mines. Emissions from oil and gas activities, including production, processing, transmission and distribution, were an estimated 4.37 MtCO2e, accounting for 2.05% of energy sector emissions.

2.5 Industrial processes and product use

This category includes emissions arising from various industrial activities. Emissions directly linked to energy consumption are not classified under IPPU but are instead categorised under 'manufacturing industries and construction' within the energy sector to avoid duplication in emissions reporting. Non-energy use emissions in industrial processes primarily result from the use of reducing agents, particularly in metal production-related source categories.

Source categories responsible for CO2 emissions in the IPPU sector consist of:

- Mineral industry: cement, lime, limestone, dolomite use, soda ash production, glass
- Chemical industry: ammonia, nitric acid production, carbide production, titanium dioxide production, methanol production, ethylene oxide
- Metal industry: iron and steel, ferro-alloys

production, aluminium, lead, zinc, copper, magnesium
- Other: pulp and paper industry, food and beverages industry.

2.5.1 Overview of IPPU emissions

IPPU is the smallest contributor to GHG emissions among all sectors of the economy. Emissions from various categories within the IPPU sector are shown in Table 2.6. In 2021, the IPPU sector emitted a total of 31.98 MtCO2e, representing 6.13% of the country's overall emissions, of which 30.68 Mt are CO2 emissions and 1.30 Mt are CH4 emissions. The mineral sector, with 27.39 MtCO2e emissions, was the largest contributor, responsible for 85.65% of total IPPU emissions. Within the mineral sector, cement, lime and glass production emitted 27.39 MtCO2, with cement contributing the largest share at 25.76 MtCO2.

The chemical industry emitted 3.02 MtCO2e (9.44%), mainly from processes like ammonia production, followed by the 'other' category (pulp and paper, food and beverages) and non-energy products (from fuels and solvent use) with 1.35MtCO2e (4.22%) and 0.22MtCOe (0.69%) emissions, respectively.

2.5.2 Mineral industry

This category primarily addresses CO2 emissions from the calcination of carbonate materials during the production and use of various mineral industry products. CO2 is released from carbonates through two main processes: (i) calcination and (ii) acid-induced CO2 release. The primary source of CO2 emissions is the calcination of carbonate compounds, a thermal process that produces metallic oxides. Activities included in this category are cement manufacturing, the use of limestone and dolomite, and the use of asphalt in road construction.

Of the 27.39 MtCO2e emissions from the mineral industry, cement production is a major contributor. In 2021, cement production accounted for 80.55% of all IPPU emissions. Pakistan's cement industry is a significant part of the economy, producing over 57.43 million tons of cement annually (MoF, 2021). The cement manufacturing process relies heavily on imported coal to meet the energy needs of production facilities.

2.5.3 Chemical industry

This category includes the production of a wide range of chemicals, such as ammonia, nitric acid, carbide, titanium dioxide, methanol and ethylene. Ammonia is a key chemical in this sector, serving as a primary nitrogenous compound and playing a crucial role in various industrial processes. It is used in the production of fertilisers, in heat treatment and paper pulping, and in the manufacture of nitric acid, nitrates, esters, nitro compounds and refrigeration systems. In 2021,

Table 2.6: Summary of GHG emissions from the IPPU sector

Category	Emissions (MtCO2e)		
	CO2	CH4	Total
Mineral industry	27.39		27.39
Chemical industry	3.02		3.02
Non-energy products from fuels and solvent use	0.22		0.22
Other (pulp and paper, food and beverages)	0.05	1.30	1.35
Total	**30.68**	**1.30**	**31.98**

emissions from the chemical sector, at 3.02MtCO2e, made up 9.44% of all emissions from the IPPU sector.

2.5.4 Non-energy products from fuels and solvent use

In addition to fuels, refineries and coke ovens produce non-energy products that are used directly for their physical or diluent properties or sold to the chemical industry as intermediates. Examples include lubricants and greases, which are used in engines; paraffin waxes, which are used for candles or paper coating; and bitumen, which is applied on roofs and roads for its waterproofing and wear-resistant qualities. Refineries also produce white spirits, which are valued for their solvent properties.

The calculation of CO2 emissions from non-energy product use generally follows a basic formula, where the emission factor includes a carbon content factor and a factor representing the portion of fossil fuel carbon that is oxidised during use, such as the combustion of lubricants that enter the combustion chamber of an engine. This oxidation concept applies only to the first use of lubricants and paraffin waxes, not to subsequent uses. In the 1996 IPCC Guidelines, lubricants were categorised under the energy sector but in the 2006 IPCC Guidelines, non-energy products from fuels and solvents are included in the IPPU sector. In 2021, the use of lubricants contributed 0.22 MtCO2 of emissions, which accounted for 0.69% of IPPU sector emissions.

2.5.5 Other

This category primarily covers GHG emissions from two key industries: (i) pulp and paper, and (ii) food and beverages. The evaluation of carbon emissions from the pulp and paper industry in developing countries is an area that has not been well explored. In 2021, the 'other' category was responsible for 1.35 MtCO2e (4.22% of total IPPU emissions).

In the food and beverages industry, GHG emissions are generated by facilities involved in transforming livestock or agricultural products into food products for both intermediate and final human consumption.

2.6 Agriculture, forestry and other land use

The AFOLU sector encompasses both emissions and removals from agriculture, forestry and other land uses. This approach acknowledges that the processes driving GHG emissions and removals, as well as different forms of terrestrial carbon stocks, can take place on all types of land. By using this integrated method, consistency and completeness are maintained in estimating and reporting GHG emissions and removals (IPCC, 2006).

AFOLU emissions consist of all 3 GHGs. The exchange of CO2 between the atmosphere and ecosystems is mainly regulated through its uptake by plants during photosynthesis and its release through processes such as plant respiration, decomposition and the combustion of organic matter (IPCC, 2006). N2O emissions arise primarily from nitrification and denitrification processes in ecosystems, while CH4 emissions come from several sources, including anaerobic methanogenesis in soil, manure management by methanogenic bacteria, enteric fermentation in livestock and the incomplete combustion of organic matter (IPCC, 2006).

Both CO2 and non-CO2 emissions and removals from AFOLU are assessed separately for each of four land use classes: forestland, cropland, grasslands and wetlands. Other emission

categories, such as those related to livestock and managed soils, are estimated at the national level using aggregated national data.

It is worth noting that emissions from other categories, such as livestock (manure management) and managed soils, are estimated using aggregated national data rather than being broken down by land classes or climate zones. Reporting based on specific land classes or climate zones requires detailed data, which is not available for Pakistan.

2.6.1 Overview of AFOLU sector emissions

Overall, AFOLU is the largest contributor to GHG emissions, responsible for 243.76 MtCO2e of emissions, or 46.75% of total emissions (Table 2.7). GHG emissions from the AFOLU sector are summarised in Table 2.8. Within the sector, livestock was the largest contributor, emitting 130.14 MtCO2e, which accounts for 53.39% of AFOLU emissions. This was followed by managed soils at 66.80 Mt (27.40%), land at 34.82 Mt (14.28%) and rice cultivation at 12.00 Mt (4.92%).

2.6.2 Livestock

GHG emissions from enteric fermentation are estimated for the following livestock types: cows, buffaloes, sheep, goats, camels, horses, mules and donkeys. Poultry emissions are assessed separately under manure management. The livestock sector contributed 130.14 MtCO2e, which represents 53.39% of AFOLU emissions. Of the total emissions from livestock, 112.83 MtCO2e (86.70%) came from enteric fermentation and 17.31 MtCO2e (13.30%) from manure management.

Enteric fermentation. The livestock population and corresponding enteric CH4 emissions are shown in Table 2.9. Total enteric methane emissions amounted to 112.83 MtCO2e, making up 86.70% of all emissions from the livestock sector.

Table 2.7: AFOLU emissions as a percentage of total emissions

Category	Million tons			
	Net CO2 emissions/ removals	Emissions		
		CH4	N2O	Total
Pakistan total	**273.24**	**173.90**	**74.32**	**521.46**
Agriculture, forestry and other land use	35.77	137.23	70.76	243.76
AFOLU (% of total emissions)	13.09%	78.91%	95.21%	46.75%

Table 2.8: Summary of GHG emissions from the AFOLU sector

Category	Emissions (MtCO2e)			
	CO2	CH4	N2O	Total
AFOLU total	35.77	137.23	70.76	243.76
Livestock	0	122.54	7.60	130.14
Land	31.35	2.69	0.78	34.82
Managed soils	4.43	0	62.37	66.80
Rice cultivation	0	12.00	0	12.00

Table 2.9: Summary of GHG emissions from livestock (MtCO2e)

Category	Population (000 heads)	Emissions		Total
		Enteric fermentation (CH4)	Manure management (CH4 + N2O)	
Dairy cows	15,192	24.67	4.50	29.17
Other cattle	27,511	20.80	3.43	24.23
Buffalo	31,450	48.43	6.39	54.82
Sheep	31,595	4.42	0.67	5.09
Goats	80,326	11.25	0.88	12.13
Camels	1,119	1.44	0.08	1.52
Horses	375	0.19	0.02	0.21
Mules and donkeys	5,823	1.63	0.20	1.83
Poultry	1,577,670	-	1.14	1.14
Total		**112.83**	**17.31**	**130.14**

Manure management. The livestock population and associated methane emissions from manure are shown in Table 2.7. Emissions from manure management amounted to 17.31 MtCO2e, accounting for 13.30% of total emissions from the livestock sector.

2.6.3 Land

The methodology outlined in the 2006 IPCC Guidelines for National GHG Inventories (IPCC, 2006) classifies land according to use and management practices as well as climate, soil and other environmental factors. Under IPCC Guidelines, land types are classified into six main categories: forestland, cropland, grassland, wetlands, settlements and other lands. However, for the purposes of this inventory all CO2 and non-CO2 emissions from the land sector are sourced from four land-use categories: forestland, cropland, grassland and wetlands. This is because emissions from settlements and other lands are insignificant.

Under the IPCC Guidelines, each category is further divided into two groups: (i) land that remains in the same category (e.g., forestland remaining forestland) and (ii) land that has been converted from one category to another (e.g., forestland converted to cropland). For the purposes of this inventory, emissions were estimated only from land remaining within the same land use category. Emissions from land conversion between categories are not included.

With that in mind, GHG emissions and removals, covering both CO2 and non-CO2 emissions, are evaluated for each land-use category included in this inventory. CO2 emissions are estimated based on variations in carbon stocks from biomass, dead organic matter and soils, while non-CO2 emissions are mainly attributed to biomass burning. CO2 emissions from wildfires (in case of forestland) or controlled fires (in case of grasslands or cropland) are considered as net zero because CO2 emissions from burning in one year are assumed to be sequestered through regeneration in the following year (IPCC, 2006).

Overview of land sector emissions. The land sector contributed 34.82 MtCO2e in emissions, representing 14.28% of total AFOLU emissions. Of this, net CO2 emissions were 31.35 Mt, CH4 emissions totalled 2.69 Mt and N2O emissions were 0.78 MtCO2e (Table 2.10). Forestland is the largest emitter of all land use categories, producing 28.64 MtCO2e, which accounts for 82.25% of total land emissions. Cropland is the second largest emitter, with 5.67 Mt (16.28%), while wetlands and grassland contributed 0.48 Mt (1.38%) and 0.03 Mt (0.09%) of CO2e emissions, respectively. All CO2 and non-CO2 emissions from the land sector by land class are discussed in the sections that follow.

Forestland

For the purposes of this inventory, Pakistan's forests are categorised according to the classification system provided by the Forestrypedia of Pakistan (Forestrypedia, 2021). National definitions for managed forests are also incorporated. To assess carbon stocks and GHG emissions and removals from forestland, data used includes classification/type, area/cover, climatic region, soil type, ecosystem type, plantation type, stage of stand development and management practices.

The IPCC suggests three general approaches based on the collected data:

- Approach 1 classifies the total area of each land use category within a country but does not track specific conversions between land uses
- Approach 2 introduces tracking of land use conversions
- Approach 3 allows for spatially explicit tracking of land use conversions (IPCC, 2006).

Parties have the flexibility to apply any combination of these approaches for different regions and over time. In Pakistan's case, Approach 1 is used to maximise the available data while minimising overlaps and omissions in estimation and reporting.

Overview of forestland emissions. Forestland contributed 28.64 MtCO2e, accounting for 82.25% of total land emissions. Gross CO2 emissions totalled 43.55 Mt, with removals of 15.11 MtCO2, resulting in net CO2 emissions of 28.44 Mt, along with CH4 emissions of 0.13 MtCO2e and N2O emissions of 0.07 MtCO2e (Table 2.11).

Forestland CO2 emissions and removals. Total CO2 emissions across all forest types amounted to 43.55 Mt, with removals estimated at 15.11 Mt, resulting in net emissions of 28.44 Mt (Table 2.11). Riverain forests were the largest emitter, responsible for 13.56 MtCO2e, or 47.35% of total forestland emissions. Irrigated plantations were the second-largest emitter, contributing 12.92

Table 2.10: Summary of GHG emissions from land sector

Land class	Emissions (MtCO2e)			
	CO2	CH4	N2O	Total
Total	**31.35**	**2.69**	**0.78**	**34.82**
Forestland	28.44	0.13	0.07	28.64
Cropland	2.50	2.54	0.62	5.67
Grassland	0	0.02	0.01	0.03
Wetlands	0.41	0	0.08	0.48

MtCO2e (45.11%), while tropical thorn forests emitted 10.59 MtCO2e (36.98%) and alpine scrub forests accounted for 6.60 MtCO2e (23.04%).

Total CO2 removals from forestland amounted to 15.11 Mt. Himalayan dry temperate forests were the largest carbon sinks, absorbing 8.12 MtCO2e, making up 53.74% of total forestland removals. This was followed by Himalayan moist temperate forests at 3.21 MtCO2e (21.24%), sub-tropical pine forests at 2.33 MtCO2e (15.42%), mangrove forests at 0.98 MtCO2e (6.49%), linear plantations at 0.32 MtCO2e (2.12%) and sub-alpine forests at 0.15 MtCO2e (0.99%).

Forestland non-CO2 emissions. Combined CH4 and N2O emissions amounting to 0.20 MtCO2e were estimated from biomass burning across various forest types (Table 2.11). Apart from mangroves, all other forest types contributed to non-CO2 emissions through biomass burning. Alpine scrub forests were the largest emitters in this category, with non-CO2 emissions of 0.085 MtCO2e, or 42.50% of total non-CO2 emissions. This was followed by Himalayan dry temperate forests with 0.038 MtCO2e (19.00%), tropical thorn forests at 0.021 MtCO2e (10.50%), sub-tropical pine forests at 0.018 MtCO2e (9.00%) and Himalayan moist temperate forests with 0.017 MtCO2e (8.50%). Irrigated plantations emitted 0.014 MtCO2e (7.00%). The remaining 0.007 MtCO2e (3.5%) came from linear, sub-alpine and riverain forests.

Cropland

To estimate carbon stocks and the associated GHG emissions and removals from cropland activities, Pakistan's cropland is categorised into various types based on factors such as climatic region, soil type, ecosystem type, plantation type, stage of stand development and management practices. Crop-related data, including classification/types and area information, are used in conjunction with climatic, soil and ecosystem data for the GHG estimation process.

Overview of cropland emissions. Cropland emissions totalled 5.85 MtCO2e, with CO2 removals amounting to 0.18 Mt, resulting in net

Table 2.11: Summary of GHG emissions and removals from forest land

Forest type	Emissions (MtCO2e)		
	CO2	CH4 + N2O	Total
Alpine scrub forests	6.51	0.085	6.60
Himalayan dry temperate forests	-8.12	0.038	-8.08
Himalayan moist temperate forests	-3.21	0.017	-3.19
Irrigated plantations	12.91	0.014	12.92
Linear plantations	-0.32	0.003	-0.32
Mangrove forests	-0.98	0	-0.98
Riverain forests	13.56	0.001	13.56
Sub-alpine forests	-0.15	0.003	-0.15
Sub-tropical pine forests	-2.33	0.018	-2.31
Tropical thorn forests	10.57	0.02	10.59
Forestland total	**28.44**	**0.199**	**28.64**

emissions of 5.67 MtCO2e. Net emissions from croplands represent 16.28% of total land-related emissions. Of total emissions, CH4 contributed 2.54 Mt, CO2 accounted for 2.50 Mt and N2O emissions were 0.62 MtCO2e (Table 2.12).

The largest source of emissions from cropland is crop residue burning, which released 3.16 MtCO2e, making up 55.73% of total cropland emissions. Fruit orchards were the second-largest emitter, contributing 2.49 MtCO2e (43.92%), followed by agroforestry systems at 0.20 MtCO2e (3.53%) and tea plantations at 0.004 MtCO2e (0.07%). In contrast, banana plantations helped remove 0.18 MtCO2 from the atmosphere.

Cropland CO2 emissions. Total CO2 emissions from cropland, based on carbon stock changes, were estimated at 2.69 MtCO2, with 0.18 MtCO2 removed by banana plantations. This results in net CO2 emissions of 2.50 Mt. Fruit orchards were the largest contributor, accounting for 99.60% of total CO2 emissions from cropland, followed by agroforestry systems (8.0%) and tea plantations (0.16%) (Table 2.12).

Table 2.12: Summary of GHG emissions and removals from cropland

Crop type/category	Emissions (MtCO2e)			
	CO2	CH4	N2O	Total
Agroforestry systems	0.20	-	-	0.20
Banana plantation	-0.18	-	-	-0.18
Crop residue burning	-	2.54	0.62	3.16
Fruit orchards	2.49	-	-	2.49
Tea plantation	0.004	-	-	0.004
Total	**2.514**	**2.54**	**0.62**	**5.674**

Cropland non-CO2 emissions. Non-CO2 emissions, amounting to 3.16 MtCO2e (CH4 and N2O), were estimated from residue burning of four crop types (wheat, rice, maize, sugarcane) on cropland (Table 2.13). Wheat was the largest emitter from residue burning, releasing 1.55 MtCO2e, or 48.90% of the total emissions from crop burning. Rice was the second-largest contributor, emitting 1.12 MtCO2e (35.33%), with sugarcane at 0.36 MtCO2e (11.35%) and maize at 0.13 MtCO2e (4.10%).

Table 2.13: Summary of non-CO2 emissions from cropland

Crop type	Non-CO2 emissions (MtCO2e)
Wheat	1.55
Rice	1.12
Maize	0.13
Sugarcane	0.36
Total	**3.16**

Grassland

For the purposes of this inventory, Pakistan's grasslands are categorised based on climatic region, soil type, vegetation type and management practices. Key rangelands and pastures are further classified as degraded or non-degraded. This includes alpine pastures, and degraded and non-degraded rangelands in Balochistan, KP, Punjab, Sindh, AJK and GB. The GHG estimation uses data on grassland classification, climatic region, soil type, vegetation type and management practices along with area and biomass burning.

Overview of grassland emissions. Grasslands contributed 0.03 MtCO2e in emissions, accounting for only 0.09% of total land emissions. These emissions are entirely non-CO2, comprising 0.02 Mt of CH4 and 0.01 Mt of N2O in CO2e (Table 2.14). Net CO2 emissions from grasslands are essentially zero, as the CO2 released from grass cutting in one year is offset by the CO2 absorbed from growth in the subsequent year.

All non-CO2 emissions are estimated based on biomass burned from wildfires in different grassland types. In temperate regions, for the GHG

inventory year the burned area is evenly distributed between three grassland types: alpine pasture, KP degraded rangeland, and AJK and GB degraded rangeland. As a result, each of these grassland types emitted an equal amount of non-CO2 GHGs, contributing 0.0002 MtCO2e each, totalling 0.0006 MtCO2e, which represents 1.74% of total grassland emissions.

In tropical and subtropical regions, including Balochistan, Punjab and Sindh, the burned area of savanna, open shrubland, closed shrubland and woody savanna is evenly distributed between degraded rangelands in Balochistan, Punjab and Sindh. Each of these grassland types emitted 0.009 MtCO2e, resulting in a total of 0.029 MtCO2e, which accounts for 98.26% of total grassland emissions.

Wetlands

Pakistan's wetlands are classified according to Ramsar Convention classifications (Ramsar, 1996). These categories are inland waters (85%), lakes and reservoirs (5%), fish farms and ponds (4%), delta marshes (3%), and swamps (3%).

Overview of wetlands emissions. Wetlands emitted 0.48 MtCO2e, accounting for 1.38% of total land emissions. This includes 0.41 Mt of CO2 and 0.07 MtCO2e of N2O (Table 2.15). Lakes and reservoirs were the main contributor, emitting 0.17 MtCO2e (35.42% of total wetland emissions). Fish farms and ponds were the second largest emitters at 0.12 MtCO2e (25%), delta marshes contributed 0.11 MtCO2e (22.92%) and swamps accounted for 0.08 MtCO2e (16.67%).

Table 2.14: Summary of GHG emissions from grassland

Grassland type	Emissions (MtCO2e)		
	CH4	N2O	Total
Alpine pasture	0.00009	0.00008	0.0002
AJK and GB degraded rangeland	0.00009	0.00008	0.0002
Balochistan degraded rangeland	0.00513	0.00443	0.0096
KP degraded rangeland	0.00009	0.00008	0.0002
Punjab degraded rangeland	0.00513	0.00443	0.0096
Sindh degraded rangeland	0.00513	0.00443	0.0096
Total	**0.01566**	**0.01353**	**0.0294**

Table 2.15: Summary of GHG emissions from wetlands

Wetland type	Emissions (MtCO2e)		
	CO2	N2O	Total
Wetlands total	**0.41**	**0.07**	**0.48**
Lakes and reservoirs	0.14	0.03	0.17
Fish farms and ponds	0.10	0.02	0.12
Delta marshes	0.09	0.02	0.11
Swamp	0.08	0.004	0.08
Inland Waters	0.00	0.00	0.00

Wetlands CO2 emissions. Wetlands emitted a total of 0.41 MtCO2. Lakes and reservoirs were the main contributor at 0.14 MtCO2 (34.15% of total wetland CO2 emissions). Fish farms and ponds were the second largest emitters at 0.10 MtCO2 (24.39%), followed by delta marshes at 0.09 MtCO2 (21.95%) and swamps at 0.08 MtCO2 (19.51%). Inland waters classified as flood lands did not contribute to emissions.

Wetlands non-CO2 emissions. Non-CO2 emissions from various types of wetlands were estimated at 0.07 MtCO2e. For non-CO2 emissions, lakes and reservoirs remained the main contributor at 0.03 Mt CO2e (42.86% of N2O emissions from wetlands). Fish farms and ponds, and delta marshes each contributed 0.02 MtCO2e (28.57%), with swamps at 0.004 Mt (5.71%).

2.6.4 Managed soils

Only national aggregate data is available for managed soils in Pakistan. Therefore, a methodology based on generic national-level information is used to estimate GHG emissions, relying on aggregated national data including quantities of lime and dolomite, urea application, and synthetic fertiliser consumption.

Overview of managed soils emissions. Emissions from managed soils amounted to 66.80 MtCO2e, or 27.40% of total emissions from the AFOLU sector. Within this, CO2 emissions were estimated at 4.43 Mt, while N2O emissions at 62.37 Mt (Table 2.16). Direct N2O emissions were 40.50 MtCO2e (60.63% of total emissions from managed soils), followed by indirect N2O emissions at 21.87 (32.74%) Mt, with 4.43 (6.63%) MtCO2 emissions attributed to urea application.

Non-CO2 emissions from managed soils. Managed soils are significant sources of non-CO2 emissions, including both direct and indirect N2O emissions.

Direct N2O emissions from managed soils. Direct N2O emissions from managed soils stood at 40.5 MtCO2e, accounting for 60.63% of total soil emissions. These emissions primarily result from nitrogen application, including inorganic nitrogen from synthetic fertilisers, organic nitrogen from manure, and animal nitrogen from pasture, range and paddocks, as well as nitrogen from crop residues on managed soils.

Synthetic nitrogen fertilisers were the largest source of direct N2O emissions from managed soils, emitting 15.45 Mt N2O, or 38.15% of total direct emissions. The second-largest contributors were organic nitrogen fertilisers from grazing animals on pastures, with emissions of 11.92 MtN2O (29.43%). Organic nitrogen from animal manure followed, contributing 8.44 MtN2O (20.84%). The remaining 4.69 MtN2O (11.58%) emissions came from the application of synthetic nitrogen fertilisers and crop residues in rice fields and other managed soils.

Table 2.16: Summary of GHG emissions from managed soils

Source/emission Type	Emissions (MtCO2e)		
	CO2	N2O	Total
Total	**4.43**	**62.37**	**66.80**
Urea	4.43	0	4.43
Direct N2O emissions	0	40.50	40.50
Indirect N2O emissions	0	21.87	21.87

Indirect N2O emissions from manure management and managed soils. Indirect N2O emissions from managed soils due to manure management and other sources totalled 21.87 MtCO2e, representing 32.74% of total soil emissions. These emissions occur through two primary pathways:

- Atmospheric deposition: Nitrogen volatilised from managed soils due to agricultural inputs, including synthetic nitrogen fertilisers, organic nitrogen applied as fertiliser, and urine and dung deposited by grazing animals.
- Leaching/runoff: Nitrogen leaching and runoff from managed soils, including from synthetic nitrogen fertilisers, organic nitrogen applied as fertiliser, urine and dung from grazing animals, crop residues, and nitrogen mineralisation/immobilisation associated with changes in soil organic matter due to land use or management practices.

Indirect emissions from manure management specifically result from nitrogen losses due to volatilisation, leaching and runoff in manure management systems.

N2O emissions from managed soils due to nitrogen leaching and runoff were the largest source of indirect emissions, amounting to 10.93 MtCO2e (49.98% of total indirect emissions). This was followed by atmospheric deposition of nitrogen at 6.62 MtCO2e (30.27%). For manure management, nitrogen volatilisation was the primary source of N2O emissions at 3.31 MtCO2e (15.13%), while leaching and runoff from manure management contributed 1.01 MtCO2e (4.62%).

2.6.5 Rice cultivation

Rice cultivation contributes to CH4 emissions through the anaerobic decomposition of organic matter in flooded rice fields, a process called methanogenesis. The CH4 produced during this process primarily escapes into the atmosphere via rice plants through diffusion, while some is released directly from the flooded water in the fields. The amount of CH4 emitted annually from a given rice cultivation area depends on various factors including the number and duration of crops, water management practices, soil amendments, soil type, temperature and rice variety.

In Pakistan, CH4 emissions from rice cultivation are estimated by applying the seasonally integrated emission factor for continuously flooded rice fields without organic amendments to the annual harvested rice area, as specified in the 2006 IPCC Guidelines. During the inventory year, rice was grown on 3.33 million hectares (MoNFSR, 2021) with water management practices that include intermittent flooding and aeration. This resulted in CH4 emissions of 12.0 MtCO2e, or 4.92% of total emissions from the AFOLU sector.

2.7 Waste

The waste sector is responsible for emissions of CO2, CH4 and N2O from the following activities:

- Solid waste disposal
- Biological treatment of solid waste
- Incineration and open burning of waste
- Wastewater treatment and discharge.

Among emissions from the waste sector, typically the most significant are CH4 emissions from solid waste disposal sites (SWDSs), wastewater treatment and discharge, and incineration and open burning of waste. Incineration and open burning of waste produce not only CH4 and N2O but also CO2, especially when waste containing fossil carbon, such as plastics, is burned. Other CO2 emissions may arise from SWDSs, wastewater treatment and the burning of non-

fossil waste, although CO2 from these sources is generally not reported due to its biogenic origin. N2O emissions mainly occur during the treatment of solid waste and wastewater, with the amount depending on the type and conditions of the treatment process.

For the purposes of this inventory, emissions from the waste sector, including CO2 and non-CO2 GHGs, are assessed at the national level, focusing on (i) solid waste disposal, (ii) waste incineration and open burning, and (iii) wastewater treatment and discharge. Activity data for waste source categories is derived from factors such as waste generation rates, waste deposition rates to SWDSs and the urban population.

In Pakistan, for the inventory year, solid waste generation totalled 18,811,550 tons calculated at the average rate of 0.65 kg/capita/day (Kawai and Tasaki, 2016). Of this total, 11,286,930 tons (60% of the generated waste) was deposited in SWDSs (GoP, 2022a).

2.7.1 Overview of waste sector emissions

The waste sector generated 32.44 MtCO2e of emissions, representing 6.22% of total national emissions. This included 30.03 Mt of CH4, 2.30 Mt of N2O and 0.11 Mt of CO2 (Table 2.17). Solid waste disposal was the largest emitter in this sector, producing 17.52 MtCO2e, or 54.00% of total waste emissions. This was followed by wastewater treatment and discharge, contributing 14.61 Mt (45.04%), while the remaining 0.31 MtCO2e (0.92%) came from waste incineration and open burning.

2.7.2 Solid waste disposal

This section pertains to the solid waste deposited at SWDSs, which serve as the primary source of CH4 production and emission through the anaerobic decomposition of solid waste.

In Pakistan, municipal corporations collect around 60% of urban waste (GoP, 2022a), referred to as municipal solid waste (MSW), and dispose of it at SWDSs where its breakdown via anaerobic reactions leads to CH4 emissions. The rate of MSW generation and disposal varies across different cities. Estimates of CH4 emissions from MSW at the national level are uncertain due to the absence of annual data on MSW generation. For the current GHG estimation, total annual MSW generation is assessed by multiplying the MSW generation rate of 0.65 kg/capita/day (GoP, 2022a) by the 79.29 million urban population (MoF, 2021).

2.7.3 Incineration and open burning of waste

The main GHGs produced in the incineration process are:

Table 2.17: Summary of GHG emissions from the waste sector

Source category	Emissions (MtCO2e)			
	CO2	CH4	N2O	Total
Total	**0.11**	**30.03**	**2.30**	**32.44**
Solid waste disposal	0	17.52	0	17.52
Waste incineration and open burning	0.11	0.15	0.04	0.31
Wastewater treatment and discharge	0	12.36	2.25	14.61

- CO_2 from burned waste with fossil carbon (plastics)
- CH_4 from incomplete combustion process
- N_2O produced indirectly at low combustion temperatures.

When quantifying GHG emissions from waste incineration and open burning, it is estimated that 10% (998,332.41 tons) of the waste generated by nine major cities in Pakistan (Bahawalpur, Faisalabad, Gujranwala, Hyderabad, Karachi, Lahore, Multan, Rawalpindi and Sialkot, where waste is collected and managed by waste management companies) is incinerated. Similarly, for open burning, it is estimated that 10% of uncollected urban waste is openly burned.

Overview of emissions from incineration and open burning of waste. Emissions from incineration and open burning of waste amounted to 0.30 $MtCO_2e$, or 0.96% of total emissions from the waste sector. These emissions consisted of 0.11 Mt of CO_2, 0.15 Mt of CH_4 and 0.04 Mt of N_2O (Table 2.18). Open burning was the primary source of emissions, generating 0.20 $MtCO_2e$ (66.64% of total emissions from incineration and open burning of waste), followed by 0.10 $MtCO_2e$ (33.16%) from waste incineration.

Within the 0.20 Mt of emissions from open burning, CH_4 was the predominant GHG, accounting for 0.14 Mt of total emissions, followed by CO_2 at 0.03 Mt and N_2O at 0.02 $MtCO_2e$. For waste incineration, which contributed 0.10 Mt of emissions, the majority was CO_2 at 0.08 Mt, followed by N_2O with 0.02 Mt and CH_4 with 0.01 Mt.

2.7.4 Wastewater treatment and discharge

Domestic, commercial and industrial activities generate a significant volume of wastewater daily. This wastewater can undergo various treatments: it may be treated on-site without collection, gathered at a centralised facility for treatment or left untreated. When wastewater undergoes anaerobic treatment or disposal, it generates CH_4. For the purposes of this inventory, the following estimates have been compiled:

- CH_4 and N_2O emissions from domestic wastewater
- CH_4 emissions from industrial wastewater.

Overview of GHG emissions from wastewater. Wastewater treatment and discharge contributed 14.61 $MtCO_2e$ of emissions, amounting to 45.04% of total emissions from the waste sector. Within this category, 12.36 Mt was CH_4, while 2.25 Mt consisted of indirect N_2O emissions arising from wastewater containing human sewage (Table 2.19). The bulk of emissions in this category, totalling 12.39 $MtCO_2e$ (84.80%), came from domestic wastewater and discharge, with

Table 2.18: Summary of GHG emissions from waste incineration and open burning

Source category	Emissions ($MtCO_2e$)			
	CO_2	CH_4	N_2O	Total
Total	**0.112**	**0.1496**	**0.040**	**0.3016**
Waste incineration	0.078	0.0066	0.016	0.1006
Waste open burning	0.034	0.1430	0.024	0.201

Table 2.19: Summary of GHG emissions from wastewater

Activity	Emissions (MtCO2e)		
	CH4	N2O	Total
Total	**12.36**	**2.25**	**14.61**
Domestic wastewater and discharge	10.14	2.25	12.39
Industrial wastewater and discharge	2.22	0	2.22

industrial wastewater and discharge contributing 2.22 MtCO2e (15.20%). The majority of CH4 emissions (10.14 MtCO2e) arose from domestic wastewater and discharge, while industrial wastewater and discharge accounted for 2.22 MtCO2e of CH4.

2.8 Looking ahead

Pakistan lacks an institutionalised system for GHG inventory preparation, although inventories have been compiled since 1994. Pakistan is working to develop a more structured national GHG inventory system, in accordance with the 'Modalities, procedures and guidelines (MPGs) for the transparency framework for action and support referred to in Article 13 of the Paris Agreement' (Decision 18/CMA.1). Paragraph 18 highlights the importance for each Party to establish a national system for GHG inventory preparation, including institutional, legal and procedural arrangements for ongoing estimation, compilation and timely reporting.

To properly fulfil its reporting obligations, Pakistan's GHG inventory development needs to transition from a project-based approach to a more institutionalised arrangement, with tailored procedures for the systematic collection, processing and archiving of GHG data. Improved coordination between federal and provincial authorities, academic institutions and stakeholders is essential, along with measures and safeguards to ensure data quality and transparency.

2.8.1 Emission factors (switching to tier 2 and tier 3)

Pakistan's current GHG inventory follows the IPCC 2006 Guidelines and the Katowice Climate Package decisions. Challenges remain in ensuring data accuracy and completeness. A major limitation is the absence of country-specific tier 2 and tier 3 emission factors, which are crucial for accurate reporting, particularly in sectors such as rice cultivation and livestock. Efforts to address these gaps include submitting Forest Reference Emission Levels (FRELs) to the UNFCCC and prioritising research on CH4 emissions in agriculture. These initiatives aim to improve the precision of Pakistan's GHG inventory.

2.8.2 GHG inventory management and MRV system

A measurement, reporting and verification (MRV) system is essential to ensure accuracy in reporting. The GCISC has developed an Enhanced Transparency Framework (ETF) system in collaboration with the MoCC, GIZ and CITEPA. This initiative aims to align Pakistan's inventory with

international standards, covering legal, institutional and procedural frameworks for data estimation, reporting and archiving.

A key component of this initiative is the establishment of national GHG inventory institutional arrangement, which has been approved and is now ready for implementation (see Figure 2.1). The MoCC will serve as the national implementing entity, while the GCISC will act as the Secretariat and will oversee the coordination of operations. This structure has been developed through comprehensive stakeholder consultations and aims to institutionalise the GHG inventory system to ensure sustainability. By engaging federal and provincial ministries, the private sector and academic institutions as data providers and reviewers, the system promotes ownership and transparency.

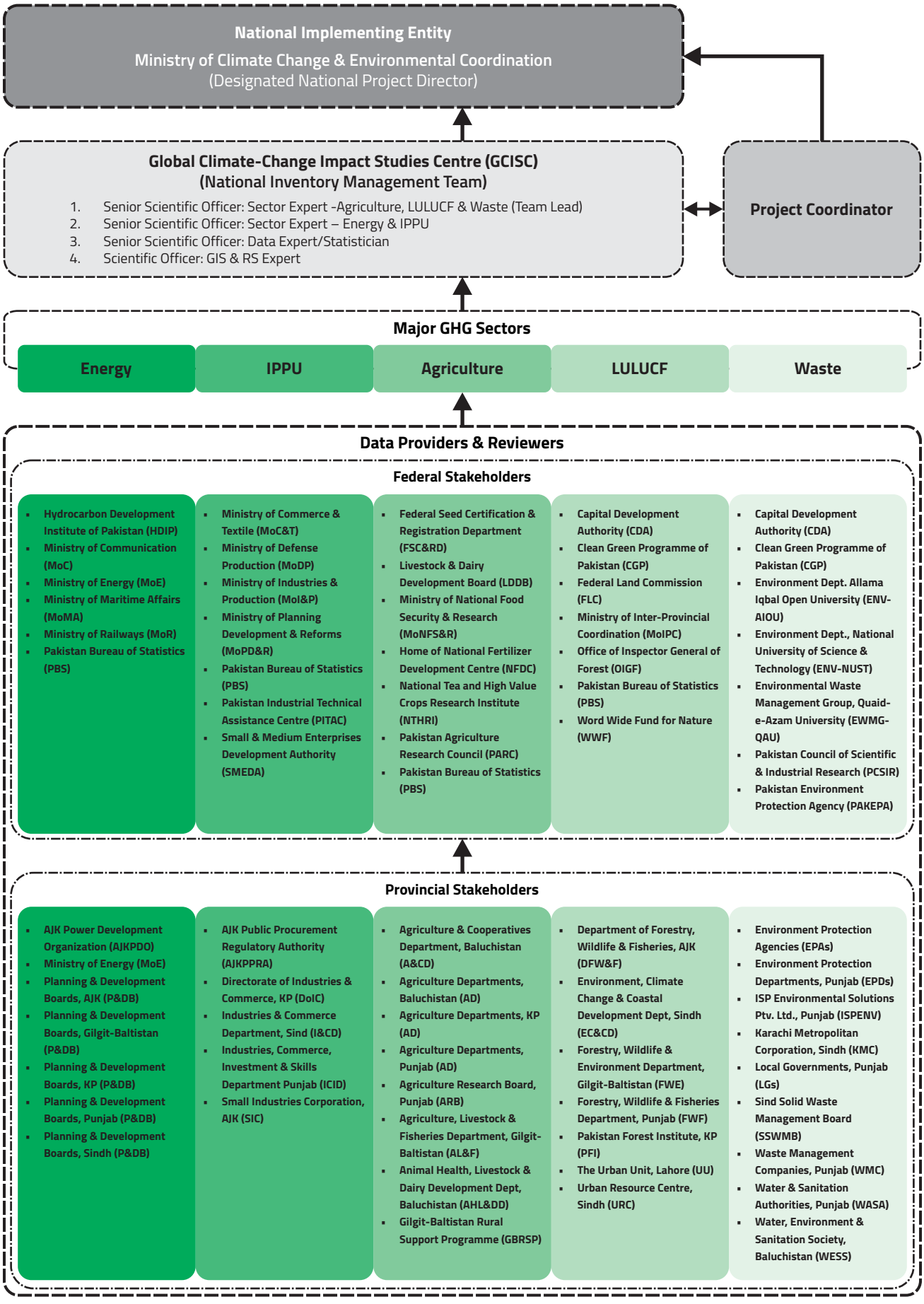
2.8.3 Capacity building

Pakistan has a limited pool of professionals proficient in inventory compilation. Recent capacity building initiatives led by GCISC, in collaboration with partners such as the UNFCCC and GIZ, have focused on enhancing technical knowledge based on the IPCC 2006 Guidelines. By providing training across sectors at both the national and provincial levels, these efforts aim to ensure more accurate data collection, and to strengthen provincial roles in data validation and reporting. Capacity development has also included advanced training in the updated IPCC Guidelines, documentation, and quality assurance/quality control to meet ETF reporting standards.

2.8.4 Strengthening national climate action

An institutionalised GHG inventory system will allow Pakistan to meet its Paris Agreement commitments. It will strengthen national climate governance, enable more informed decision making across sectors and support regular updates to Pakistan's NDCs, based on improved emissions data. The system will also ease Pakistan's integration into international mechanisms such as carbon markets, climate financing and technology transfer programmes, and strengthen its position in global climate negotiations.

Figure 2.1: National GHG inventory institutional arrangements



3

Mitigation scenarios and proposed measures

3.
Mitigation scenarios and proposed measures

This chapter analyses Pakistan's emissions trends from 1994, when the first inventory was developed, until the most recent inventory prepared for 2021. GHG emissions predictions and forecasts are evaluated for the years 2030, 2040 and 2050. Projections are developed for three scenarios: decreases of 15%, 35% and 50%. The chapter concludes with a summary of current and planned initiatives aimed at reducing emissions and enhancing sinks.

3.1 National emission trends

Pakistan began compiling GHG emissions data in the 1990s, with its first inventory covering the year 1994. Since then, inventories have been developed and updated for the years 2008, 2012, 2015, 2018 and most recently 2021 (Table 3.1).

Pakistan's emissions have increased steadily since the first inventory period (Figure 3.1). Between 2018 and 2021, overall emissions rose from 489.96 to 521.46 MtCO2e. The highest increase (28%) was observed in CH4 emissions, going from 135.88 MtCO2e in 2018 to 173.9 MtCO2e in 2021. During the same period, CO2 emissions rose by 2%, from 268.81 to 273.24 MtCO2e, while N2O emissions fell by 13%, from 85.27 in 2018 to 74.32 MtCO2e in 2021.

Emissions trends by sector are illustrated in Figure 3.2, showing that the majority of emissions come from two sectors, AFOLU (243.76 MtCO2e) and energy (213.28 MtCO2e). Between 2018 and 2021, however, the highest percentage change in emissions can be seen in the waste and IPPU sectors. Waste emissions rose by 49%, from 21.722 MtCO2e in 2018 to 32.44 MtCO2e in 2021,

Table 3.1: Pakistan's GHG inventory reported results, 1994-2021

Year	Developed by	Total (MtCO2e)	Sectoral emissions (%)				
			Energy	Agriculture	LUCF	IPPU	Waste
1994	M/s Hagler Bailly (based on 1996 IPCC Guidelines)	181.7	47.2	39.4	3.6	7.3	2.5
2008	ASAD/PAEC (based on 2006 IPCC Guidelines)	329.5	51.1	38.2	2.8	5.6	2.2
2008	ASAD/PAEC (based on Revised 1996 IPCC Guidelines)	309.4	50.7	38.8	2.9	5.8	1.8
2012	GCISC (based on Revised 1996 IPCC Guidelines)	374.1	45.8	43.5	2.6	5.2	2.8
2015	GCISC (based on Revised 1996 IPCC Guidelines)	408.1	45.5	42.7	2.5	5.4	3.8
2018	GCISC (based on Revised IPCC 2006 Guidelines)	489.87	44.7	40.4	5.2	5.3	4.4
2021	GCISC (based on Revised IPCC 2006 Guidelines, tier 1 approach)	521.46	40.9	46.8		6.1	6.2

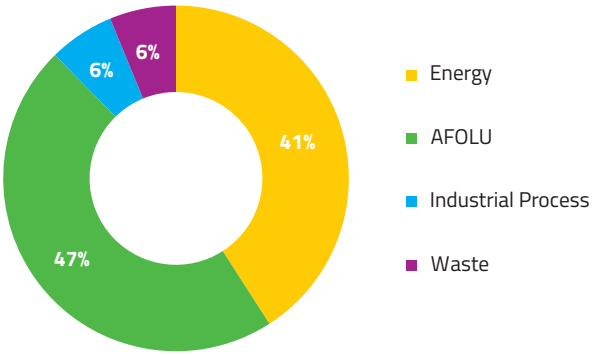
Source: GoP, 2025.

while IPPU emissions increased by 24%, going from 25.76 MtCO2e in 2018 to 31.90 MtCO2e in 2021.

3.1.1 Emissions by sector

The percentage share of overall emissions by sector is illustrated in Figure 3.3, which shows that in 2021 the AFOLU sector was responsible for 47% of overall emissions, followed by energy at 41%.

Figure 3.3: Percentage share of GHG emissions by sector, 2021

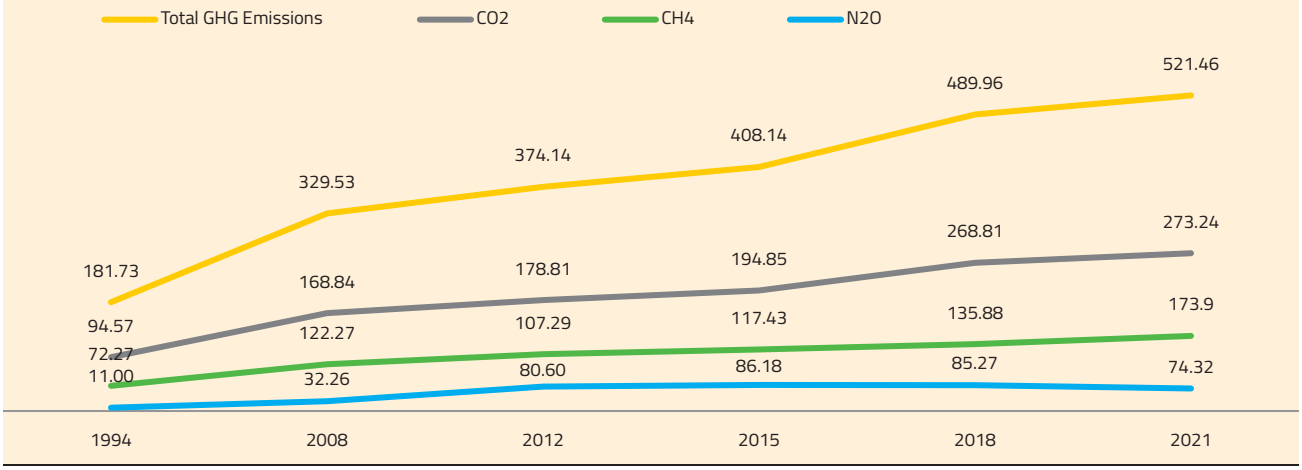


Source: GCISC.

Sectoral trends by type of GHG between 1994 and 2001 are illustrated in Figure 3.4.

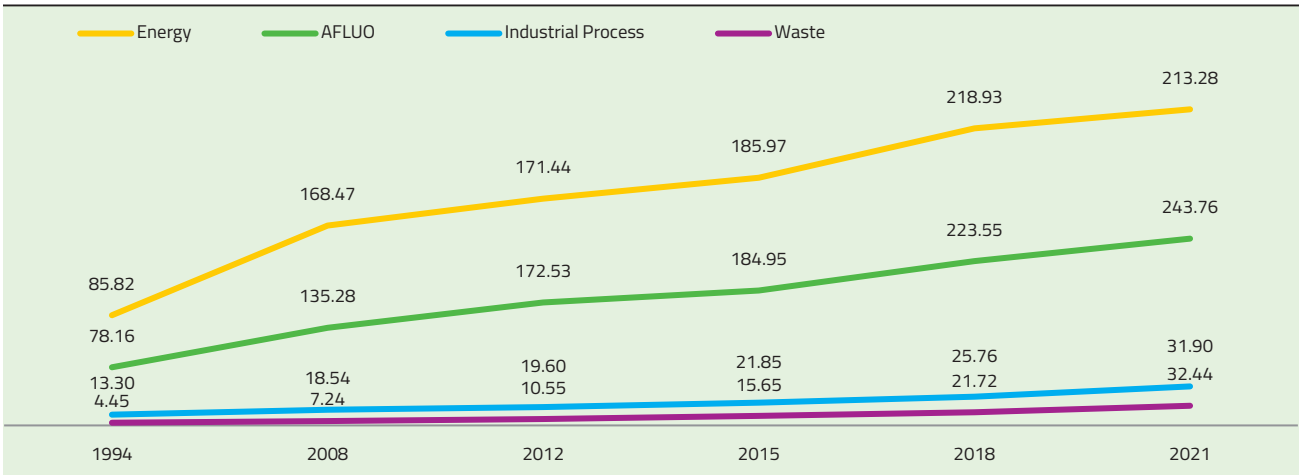
- **AFOLU** is the major contributor to overall GHG emissions (47%), mainly CH4 and N2O. In 2021, the sector accounts for 79% of the country's CH4 emissions (137.23 MtCO2e) and 95% of N2O emissions (70.76 MtCO2e).
- **Energy** is the single largest source of CO2 emissions, at206.67 MtCO2e in 2021, or

Figure 3.1: Total GHG emissions, 1994-2021



Source: GCISC.

Figure 3.2: Pakistan GHG emissions by sector, 1994-2021



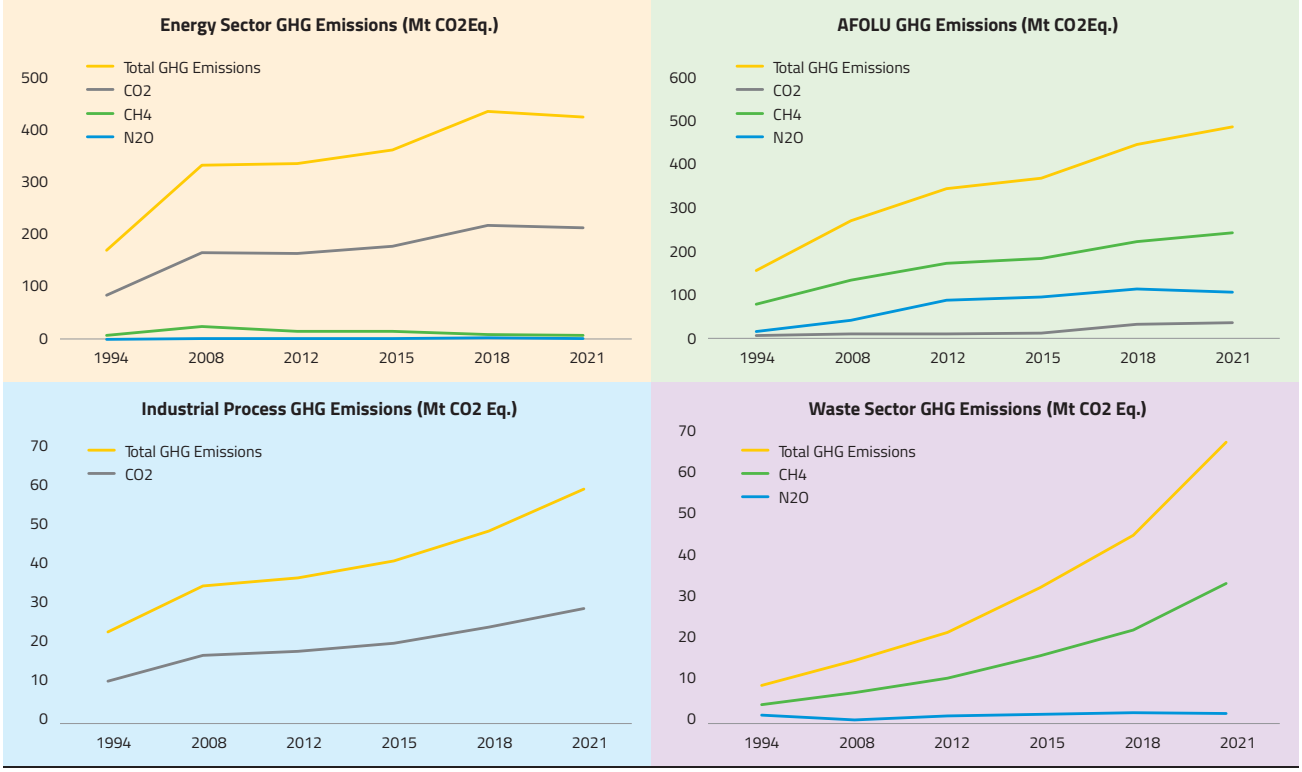
Source: GCISC.

75.6% of the total national CO2 emissions. CH4 and N2O emissions in the sector show a slight decline between 2018 and 2021, at 4.34 MtCO2e and 1.27 MtCO2e, respectively.

- **IPPU** is also a major contributors to CO2 emissions, with 30.68 MtCO2e in 2021, accounting for 15% of the country's CO2 emissions.
- **Waste** has the lowest emissions overall, but the sector shows a sharp increase in CH4 emissions and accounts for 17% of total CH4 emissions in 2021, at 30.03 MtCO2e, while N2O emissions from the sector have remained more or less the same over the recorded years.

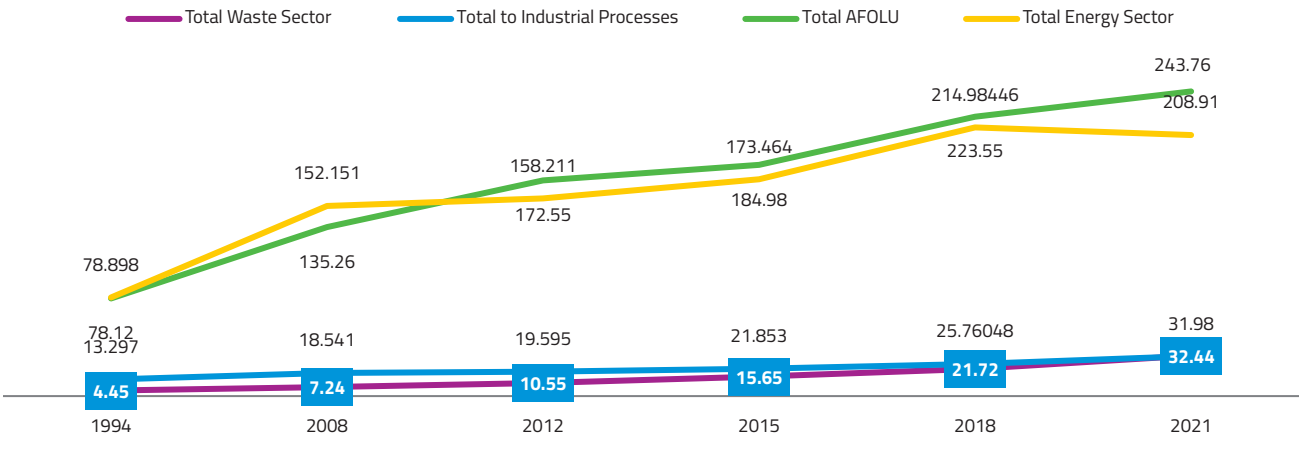
Figure 3.5 presents an overview of total emissions by sector between 1994 and 2021, showing that

Figure 3.4: Emissions by sector and GHG type, 1994-2021



Source: GCISC.

Figure 3.5: Total emissions by sector, 1994-2021 (MtCO2e)



Source: GCISC.

AFOLU and energy are the sectors with the largest emissions overall. Emissions by sub-sector are illustrated in Figure 3.6.

- Within the AFOLU sector, **agriculture** is responsible for 40% of the country's total 2021 GHG emissions (121.12 MtCO2e).
- In the energy sector, **manufacturing** and **transport** are the highest emitters, contributing 14% and 9%, respectively, to total emissions.
- For the IPPU sector, the **minerals industry** contributes 5% to total emissions (27.39 MtCO2e).
- In the waste sector, **solid waste disposal** is responsible for 3% of overall emissions (17.52 MtCO2e).

3.1.2 Regional comparisons

To better understand Pakistan's emissions in the context of other countries in Asia, a comparative analysis was carried out using Our World in Data (Jones et al., 2024). The results show that Pakistan's emissions are well below those of the larger Asian economies of China and India, and slightly higher than those of Bangladesh, Nepal and Sri Lanka (Figure 3.7).

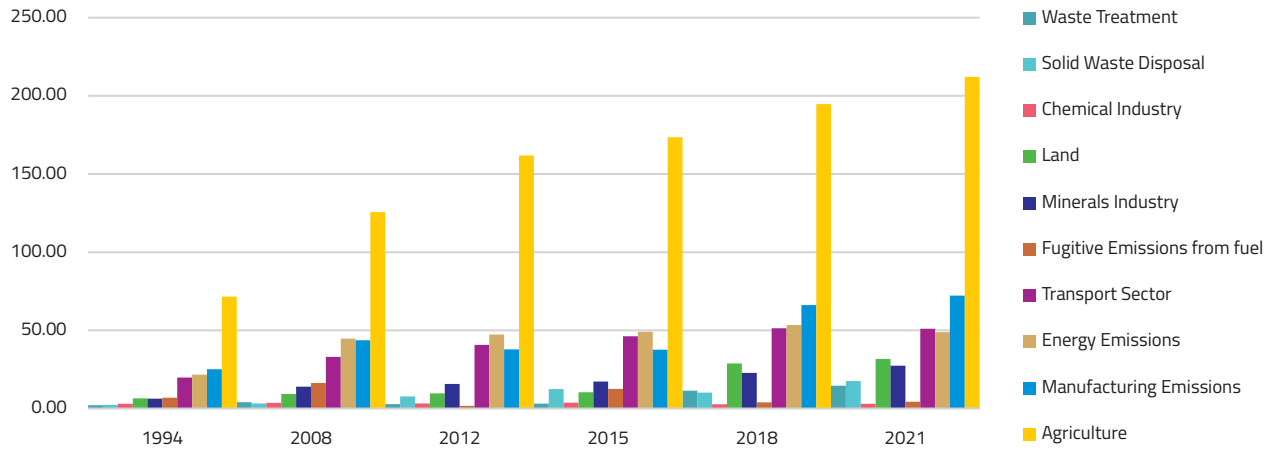
3.2 National emission forecasts

Pakistan's Updated Nationally Determined Contributions (NDCs), submitted in 2021, set ambitious targets to cut GHG emissions across key sectors of the economy (GoP, 2021b). In particular, Pakistan commits to the following actions:

- A 50% reduction of projected emissions by the year 2030, with 15% from the country's own resources (voluntary) and 35% with international financial assistance (conditional)
- By 2030, 60% of all energy produced in the country to be generated from renewable sources including hydropower
- Phasing out of coal power plants, with no generation of power through imported coal
- By 2030, 30% of all new vehicles sold in Pakistan to be electric vehicles (EVs)
- From 2016 onwards, continued investment in nature-based solutions and afforestation to sequester 148.76 MtCO2e emissions over 10 years.

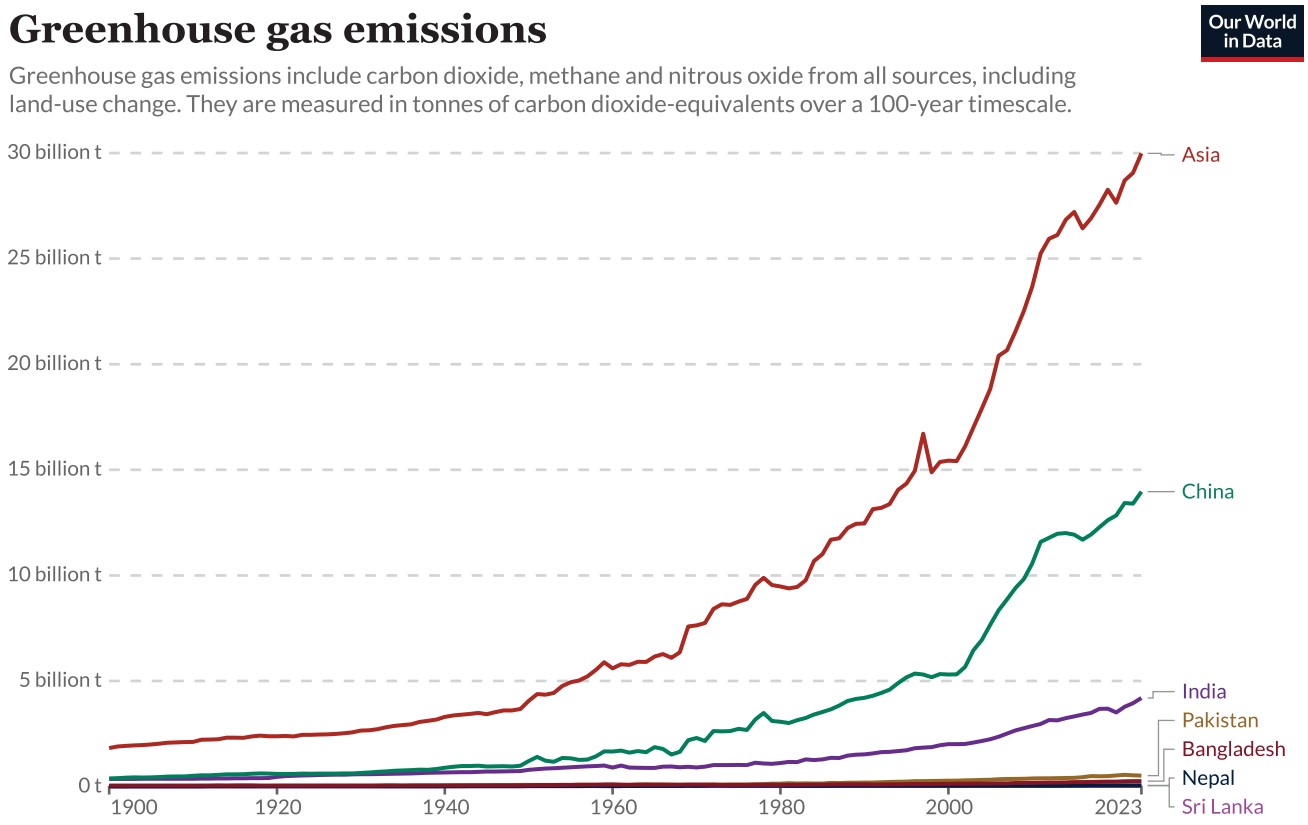
In the sections that follow, Pakistan's emission trends between the years 1994 and 2021 are analysed, and forecasts developed under various scenarios.

Figure 3.6: Total emissions by sub-sector, 1994-2021 (MtCO2e)



Source: GCISC.

Figure 3.7: GHG emissions of Asian countries, 1900-2023



Annual greenhouse gas emissions including land use tonnes of CO_2 equivalents

Country/area	1900	2023	Absolute Change	Relative Change
Bangladesh	55,437,440.0 t	263,613,550.0 t	+208,176,110.0 t	+376%
China	388,401,060.0 t	13,968,915,000.0 t	+13,580,513,940.0 t	+3,497%
India	368,109,380.0 t	4,196,448,800.0 t	+3,828,339,420.0 t	+1,040%
Nepal	12,883,486.0 t	61,135,030.0 t	+48,251,544.0 t	+375%
Pakistan	25,889,248.0 t	521,927,200.0 t	+496,037,952.0 t	+1,916%
Sri Lanka	11,305,586.0 t	41,167,228.0 t	+29,861,642.0 t	+264%
Other				
Asia	1,823,683,300.0 t	29,987,090,000.0 t	+28,163,406,700.0 t	+1,544%

Source: Jones et al., 2024.

3.2.1 Methodology and framework for forecasting emissions

Pakistan's GHG inventory has only six data points, spread over 27 years (1994 to 2021). This restricts forecasting to regression and trends forecasting alone, since 30 years of data is required for forecasting using specialised time series models.

In addition, there are asymmetrical gaps between data points for Pakistan, which affects the reliability and validity of forecasted values. There is a 14-year gap between the 1994 and 2008 inventories and a 4-year gap between 2008 and 2012, while the remaining inventories have been conducted 3 years apart (2012-15, 2015-18 and 2018-21).

For these reasons, a simplistic econometric methodology and framework for forecasting emissions is used for the purposes of this analysis. The available data is extrapolated via various best fitted regression models.

3.2.2 Model finalisation and scenario analysis

GHG inventory data for the years 1994-2021 is used for forecasting at the sectoral and sub-sectoral levels. Specialised econometric models such as linear, polynomial and logarithmic, are estimated for each sector. For all sectors, the models were validated based on the highest precision values. Once the model was finalised, further analysis was applied for prediction and forecasting.

3.2.3 Assumptions and realistic representation

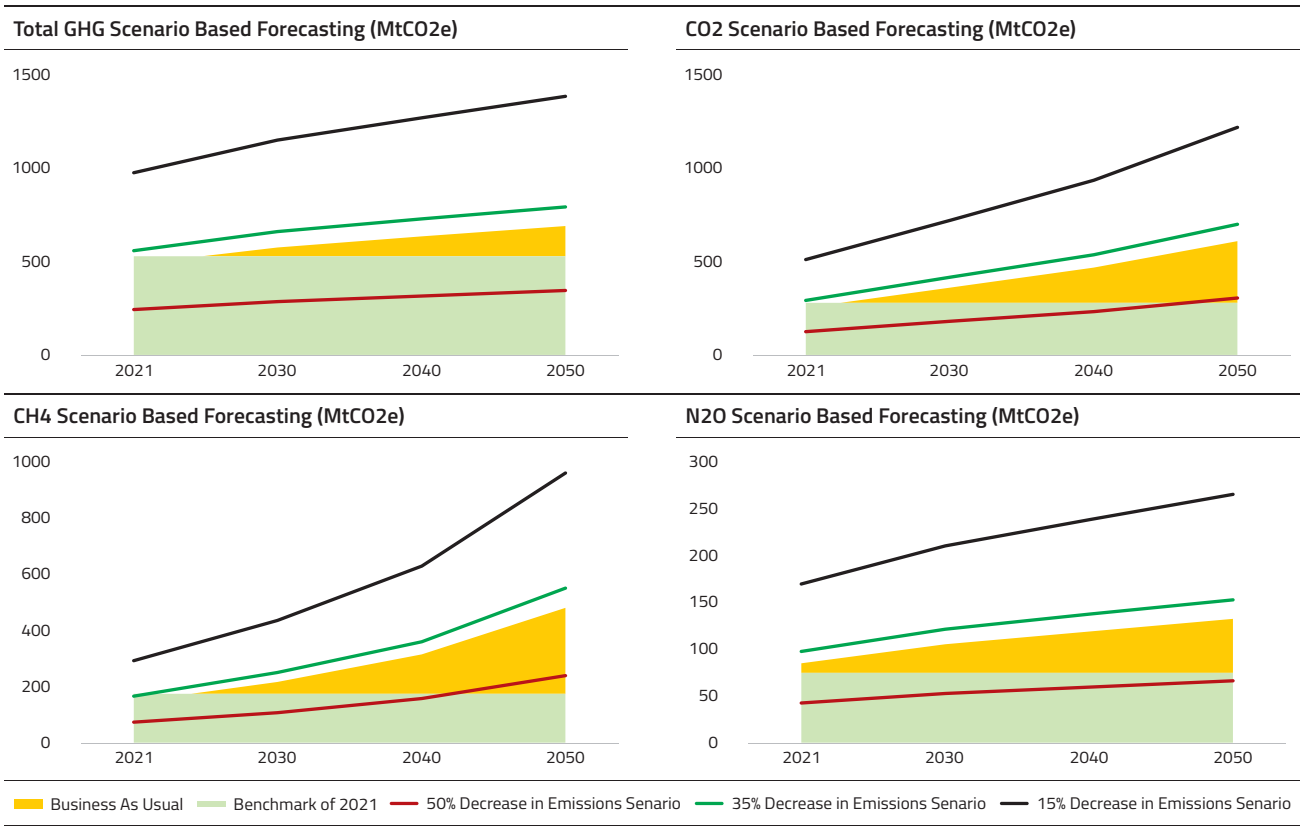
Predictions for various sectors were based on the following assumptions:

- The business as usual (BAU) scenario was evaluated for three periods: 2030, 2040 and 2050. For BAU trends and predictions, the assumption is that the country takes no GHG reduction measures and that various economic activities are allowed to run at their own pace.
- In line with Pakistan's NDC commitments, emission reductions of 15%, 35% and 50% were used to calculate target reductions by the years 2030, 2040 and 2050. This will help to plan systematically for short-, medium- and long-term mitigation and adaptation actions.

3.2.4 Country-level forecasts with emissions scenarios

Country-level GHG emissions estimates for the years 2030, 2040 and 2050, and projections under different emissions decrease scenarios (15%, 35% and 50%) are illustrated in Figure 3.8. The blue

Figure 3.8: GHG emissions forecasted trends, 2021-2050



Source: GCISC.

solid bar represents the benchmark value of 2021, for comparison with prediction scenarios. The yellow shaded area represents the BAU scenario. The grey, orange and blue lines represent the 15%, 35% and 50% emissions decrease scenarios, respectively. CO2, CH4 and N2O emissions were projected and forecast separately, with 2021 as the benchmark year for comparison with prediction scenarios. Projected values and the percentage reduction in GHG emissions required by 2030, 2040 and 2050 to achieve benchmark year 2021 emission levels are shown in Table 3.2.

3.2.5 Sectoral forecasts with emissions scenarios

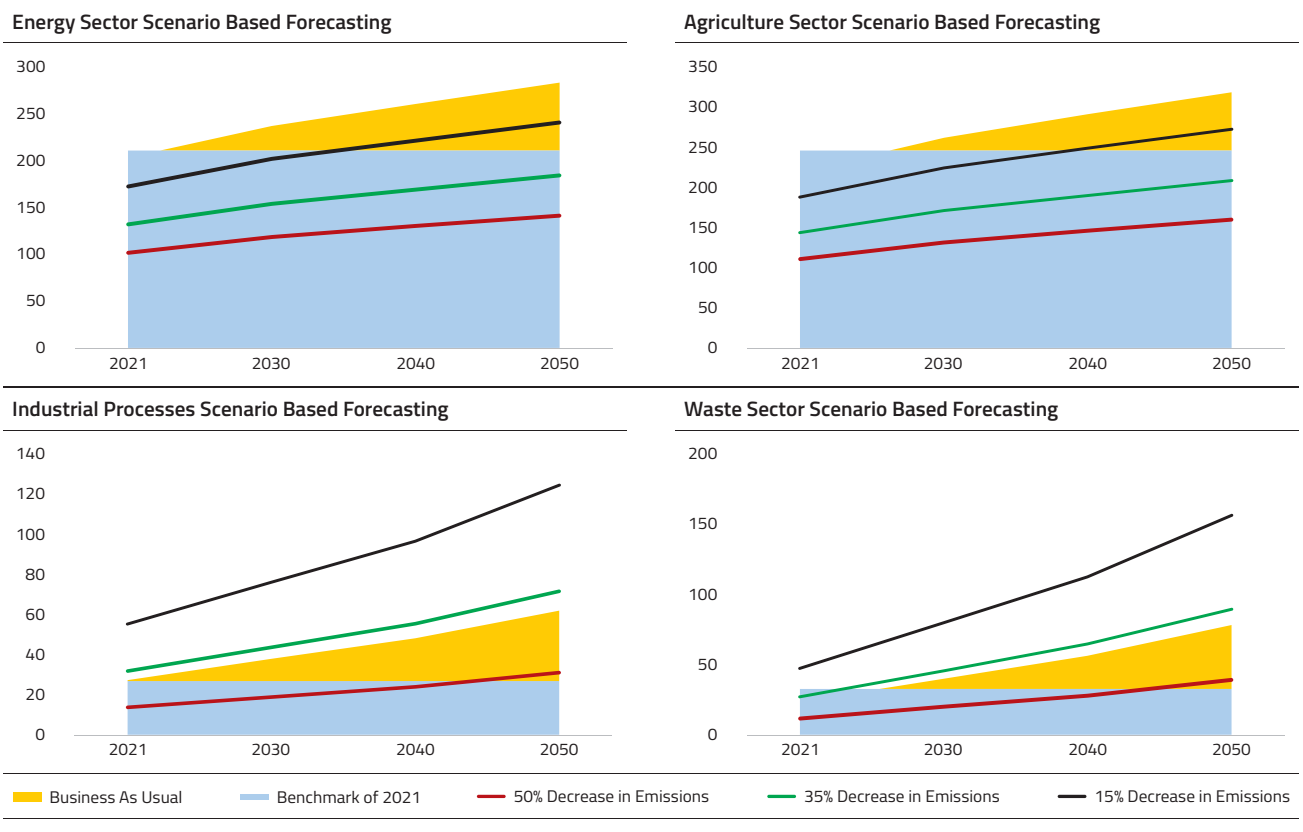
GHG inventory data sorted and arranged by sector, different forecasting scenarios for emissions reductions, and future trends of each sector are illustrated in Figure 3.9. The yellow shaded area represents the BAU scenario. The black, orange and blue lines represent 15%, 35% and 50% emissions reduction scenarios, respectively. The blue solid bar represents the benchmark value of 2021, for comparison with prediction scenarios.

Table 3.2: Projected GHG emissions (MtCO2e)

Total GHG Emissions				CO2			CH4			N2O		
Year	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec
2030	479.0	366.3	281.8	299.2	228.8	176.0	183.9	140.6	108.2	88.7	67.8	52.2
2040	528.4	404.1	310.8	387.3	296.2	227.8	265.1	202.7	155.9	100.5	76.8	59.1
2050	576.5	440.9	339.1	504.8	386.0	296.9	404.7	309.5	238.1	111.9	85.6	65.8

*dec: decrease

Figure 3.9: GHG emissions forecasted trends by sector, 2021-2050



Source: GCISC.

Projected values and the percentage reduction in GHG emissions by sector required by 2030, 2040 and 2050 to achieve benchmark year 2021 emissions levels are shown in Table 3.3.

Based on this analysis, the following insights can be derived:

- **Energy**: In order to maintain benchmark emissions as of 2021, a 15% reduction in emissions by 2030 is suggested, as illustrated in Figure 3.10 by the intersection of the benchmark bar with the black line.
- **AFOLU**: A 15% reduction in emissions by 2040 in this sector will potentially maintain emissions at 2021 benchmark levels.
- **IPPU**: To reduce emissions to the 2021 benchmark level, a 35% reduction in emissions by 2045 is suggested.
- **Waste**: To maintain benchmark emission levels of 2021, it is suggested that a 50% reduction in GHG emissions is achieved by 2045.

Cumulative suggested emissions reductions to maintain 2021 benchmark emissions levels are summarised in Table 3.4. The following suggestions will help policy makers to formulate an evidence-based sector-specific emissions reduction framework and maintain GHG emissions at 2021 levels:

- 15% reduction in the energy sector by 2035
- 15% reduction in the AFOLU sector by 2040
- 50% reduction in the IPPU sector by 2045
- 50% reduction in the waste sector by 2045.

Table 3.4: Emission reduction required to maintain emissions at 2021 levels

Sector	Predicted time	Emissions reduction
Energy	2035	15%
AFOLU	2040	15%
IPPU	2045	50%
Waste	2045	50%

3.3 Mitigation actions to reduce emissions and enhance sinks

Pakistan is taking significant steps to cut GHG emissions and enhance sinks. In the energy sector, the government is promoting renewables and energy efficiency. The Alternative and Renewable Energy (ARE) Policy 2019 sets ambitious targets of 20% on-grid renewable capacity by 2025 and 30% by 2030. Currently, 54 operational ARE projects contribute 2,624 MW to the national grid: 36 wind power projects (1,835 MW), 10 solar projects (680 MW) and 8 bagasse co-generation projects (259.1 MW) (AEDB, 2021). Expanding off-grid renewable solutions, especially in remote and rural areas, is also being prioritised to reduce dependence on fossil fuels. Energy efficiency improvements are being promoted through energy audits and standards, encouraging the adoption of energy-efficient technologies in the industrial, commercial and residential sectors. Financial incentives are available to promote LED lighting programmes, appliance efficiency standards and smart grid systems.

Table 3.3: Projected GHG emissions by sector (MtCO2e)

	Energy			AFOLU			IPPU			Waste		
Year	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec	15% dec	35% dec	50% dec
2030	200.0	152.9	117.6	222.4	170.0	130.8	31.4	24.0	18.5	33.7	25.8	19.8
2040	219.5	167.8	129.1	246.8	188.7	145.2	39.9	30.5	23.5	47.4	36.3	27.9
2050	238.5	182.4	140.3	270.5	206.9	159.1	51.3	39.2	30.2	65.7	50.3	38.7

*dec: decrease

For agriculture, Pakistan is investing in climate-smart technologies and methods to lower emissions. Sustainable practices such as no-till farming, efficient irrigation (drip and sprinkler systems), crop diversification and agroforestry are being promoted to improve soil carbon sequestration and reduce methane emissions from paddy fields and livestock (FAO, 2020). The adoption of bio fertilisers and organic farming techniques is being encouraged to reduce reliance on synthetic fertilisers, which contribute to nitrous oxide emissions.

A number of forestry initiatives are also being implemented. The Ten Billion Tree Tsunami Programme, one of the largest afforestation projects in the world, aims to restore degraded forests, expand tree cover and enhance carbon sequestration (GoP, 2019a). Similarly, mangrove restoration projects in the Indus Delta aim to increase blue carbon sequestration, helping to capture atmospheric CO2 while protecting coastal ecosystems (IUCN, 2020). Pakistan is also engaged in Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiatives, which promote forest conservation and sustainable land management.

In waste management, the government is seeking to cut emissions by promoting waste-to-energy projects. These initiatives are part of broader efforts to implement sustainable biomass energy technologies and integrated waste management solutions. Work is also underway to conserve water resources and reduce energy consumption for water distribution, with investments in rainwater harvesting, improving irrigation efficiency and wetland restoration.

Pakistan is exploring carbon capture and storage, particularly for power plants and industrial processes. The government is identifying sector-wise strategies for underground carbon storage and its potential use in industrial applications such as enhanced oil recovery and mineral carbonation (GCI, 2021).

In the transport sector, efforts are underway to transition to electric vehicles, with the Electric Vehicle Policy setting ambitious targets for the replacement of two-wheelers, three-wheelers and buses with electric alternatives by 2030. The expansion of charging infrastructure and low-carbon public transit systems is being encouraged in urban areas.

Pakistan is partnering with organisations such as the Green Climate Fund (GCF) and Global Environment Facility (GEF) to support climate-resilient infrastructure and low-carbon development. In addition to financial investments, the government is focusing on capacity building and public awareness campaigns, and providing technical training for farmers, industry workers and urban planners on sustainable practices.

Key actions and initiatives to reduce emissions and enhance sinks are shown in Table 3.5. These include ongoing and planned activities, achievements to date, and proposed actions to achieve Pakistan's NDCs targets.

Table 3.5: Key mitigation actions by sector and recommended actions for the future

Initiatives and achievements	Proposed actions
Energy	
• Alternative and Renewable Energy (ARE) Policy 2019 adopted. - Sets target of achieving 20% on-grid capacity from ARE technologies by 2025 and 30% by 2030 (GoP, 2019c). • 54 ARE projects with cumulative capacity of 2,624 MW currently operational, including: - 36 wind power projects (1,835 MW) - 10 solar projects (680 MW) - 8 sugar mill-based bagasse cogeneration projects (259.1 MW). • Several ARE projects in the pipeline, including: - 5 solar photovoltaic (PV) projects (231 MW) - 2 wind projects (200 MW) - 1 bagasse power project (32 MW). • Share of ARE technologies has already reached 7% of power generation mix (ITA, 2024). • Framework Guidelines for Fast-Track Solar PV Initiatives 2022 approved (GoP, 2022d). - Substitution of expensive imported fossil fuels with solar PV energy. - Plans to add approximately 6,000 MW solar PV capacity primarily through competitive bidding. - 3 solar PV projects finalised and to be awarded: Kot Addu, Muzaffargarh (600 MWp), Jhang (600 MWp) and Layyah (1,200 MWp). - Solarisation of public buildings expected to result in installation of 1,000 MW rooftop-based solar PV capacity. • National Electric Power Regulatory Authority (Alternative and Renewable Energy) Distributed Generation and Net Metering Regulations 2015 issued. - Provide framework for implementing net-metering using solar and wind generation of up to 1 MW capacity. - Up to 105,000 net metering-based solar installations with a cumulative capacity of over 1,600 MW as of January 2024 and 410 AEDB certified installers.	• Clean Energy Plan - Policy to support renewable energy use in energy-intense industries. - Tax incentives, phased adoption plans, green financing schemes. • Green building and infrastructure - Tax incentives and exemptions for industries manufacturing smart building solutions - Restrict imports of smart building equipment to support local industry - Implement green building codes - Mandatory standardisation and certification of the new and existing infrastructure. • Energy efficiency is a key area of intervention to reduce GHG emissions. The government's energy efficiency audits and standards have been effective in identifying and implementing energy efficiency measures in industrial facilities. • Financial incentives can help to make energy efficiency upgrades more affordable for businesses. The government's financial incentives programme has helped to increase the uptake of energy efficiency measures in this sector.
Transport	
• NDCs target: By 2030, 30% of all new vehicles to be electric vehicles. • National Electric Vehicle Policy 2019 adopted (GoP, 2019b).	• Upgrade vehicle performance - Set standards and fuel specification targets for local refineries to upgrade their production - Regular vehicle maintenance to be mandatory for all vehicle owners and operators.

Initiatives and achievements	Proposed actions

	• National Electric Vehicle Policy
	  - Provide financial incentives, technical support, mechanical workshop support, electric vehicle charging infrastructure
	  - Launch awareness campaigns to promote the adoption of new technologies
	  - Promote green rickshaws as an initial step to introduce the public to the idea of EV technology.
	• A comprehensive approach is required, covering a wide range of areas including mass transit, non-motorised transport, electric vehicles and public awareness.
	• Enhance certification requirements over time to include annual vehicle inspections for fuel economy and emissions.

Agriculture	

• Climate resilience through horticultural interventions in KP (2022-24):
  - Establishment of model orchards for apple, stone fruits, pear, citrus, persimmon, mango, litchi, avocado, hazelnut, cherry, walnuts, pecan nut, olive and dates
  - Expected annual emissions reduction between 22,520 and 51,060 MtCO2e (GoKP, 2025).
• Olive farming in selected districts of KP (2024-27):
  - Grafting and maintenance of 192,000 wild olive plants
  - Establishment of new olive orchards on 4,000 acres
  - Mature plantations expected to sequester 81,200 to 262,000 MtCO2e annually (GoKP, 2025).
• Introduction and promotion of saffron cultivation in selected districts of KP (2024-27):
  - Plantation and maintenance of saffron on 693 kanals (86.65 acres)
  - Potential to sequester 43.3 to 129.9 MtCO2e annually (GoKP, 2025).
• Sindh water and agriculture transformation (SWAT) project (2023-28):
  - World Bank funded project aims to boost rural economy and promote sound water resources management for agricultural development and environmental sustainability through carbon sequestration
  - Potential as sizeable net carbon sink of 460,680 end-tidal carbon dioxide (ETCO2) equivalent over 30 years, or 15,356 ETCO2 annually, from improved crop management practices
  - Project estimates show that in project areas agriculture will constitute an absolute carbon sink, with a carbon balance of 371,385 ETCO2 and land use change will constitute an absolute carbon sink (carbon balance 726,692 ETCO2)
  - Increased use of fertiliser and insecticides/herbicides to lead to an increase of 637,397 ETCO2 (WB, 2025).
	• Pursue multi-sectoral collaboration to address climate challenges in the agriculture sector.
	• Support farmers for the adoption climate-smart agriculture practices, providing training, financial assistance and access to inputs.
	• Implement agroforestry practices through plantation of multipurpose and fast-growing tree species.
	• Promote use of green manure, and better manure storage and management to reduce non-CO2 emissions.
	• Develop a farm-level bio-economic model. This quantitative model can assess the cost-effectiveness of GHG mitigation policies at the farm level, aiding in the reduction of emissions from crop production.
	• Map country-level adoption rates. Predictive models that map country-level adoption rates for agricultural practices with GHG mitigation or carbon sequestration benefits can help to identify areas for efficient mitigation strategies.
	• Manage water in rice cultivation to control release of methane from soils, and introduce low water dependent varieties.
	• Dietary manipulation. Adjust the composition of animal feed to optimise digestion and reduce methane production in enteric fermentation.
	• Improve feed digestibility. This can decrease the amount of feed material that undergoes fermentation, thereby reducing methane emissions.
	• Genetic selection. Introduce breeding programmes aimed at selecting animals with lower methane emissions or higher feed efficiency.
	• Methane inhibitors. Develop and use feed additives or supplements that inhibit methane-producing microorganisms in the digestive tract of animals.
	• Climate-smart agriculture practices should continue to be promoted, including improved water management, drought-tolerant crop varieties, and climate-resilient livestock management.
	• Investment in adaptation and mitigation measures in the agriculture sector is required. Investment is essential to helping farmers to adapt to the impacts of climate change and reduce GHG emissions from agriculture.

Initiatives and achievements	Proposed actions
Forestry and other land use	
• The National Forest Policy and Forests for Climate Resilience programme are promoting sustainable forest management practices across Pakistan. • The Protected Areas Initiative is helping to increase the number of designated protected areas in Pakistan. • Mangrove conservation and plantation projects have expanded mangrove forests from 48,000 ha in 1986 to 144,000 hectares in 2020. - Sindh province aims to boost mangrove cover by a further 100,000 ha - These projects have generated blue carbon credits worth USD 40 million (Khan, 2024) - Goal of restoring 350,000 ha of mangrove forest under the REDD+ project - Ten Billion Tree Tsunami Programme includes mangrove plantation. • Blue carbon commitments included in updated NDCs: - Potential to store 20 million tons of organic carbon - Potential to remove an additional 25 million tons of CO2 by 2050. • Multiple Annual Development Programme (ADP) projects between 2018-24 (GoS, 2025b), including: - Role of mangroves in curbing sea intrusion in Indus Delta - Mass scale tree plantation outside forest area to mitigate climate change effects in Sindh - Enhancing tree cover on state forest lands in Sindh - Development and improvement of protected forestry by creating controlled grazing blocks with community participation in Kohistan and Registan - Green Pakistan Programme: Revival of forestry resources in Pakistan - Sarsabz Sindh programme: Making Sindh green and environment friendly - Restoration of riverine, inland, mangroves, dry land and urban ecosystems of Sindh province. • Ongoing ADP projects (GoS, 2025b) include: - Enhancing tree cover on non-state forest lands and strengthening social forestry activities in Sindh - Revegetation of reserve forests of Sindh including infrastructure development for repairing environmental damage and restoring ecosystem services - Afforestation and reforestation of degraded forest ecosystem for enhancing carbon sequestration to secure carbon financing.	• Provide alternate fuels for cooking and heating, particularly in the northern areas, to help prevent deforestation. • Improve supply of commercial fuels in remote areas. • Promote sustainable forest management practices to protect and help regenerate forest resources. • Expand the national protected areas system to conserve forest resources and protect biodiversity. • Introduce strict penalties for the illegal use of forests and forest resources. • Encourage public-private partnerships for large-scale plantation and afforestation drives, particularly in depleted forest areas. • Explore soil carbon sequestration potential in crop lands and grasslands, promote agroforestry and sustainable land use practices. • Build on synergies. Reforestation not only offsets emissions but also creates jobs for local communities, while providing habitat for plants and wildlife.

Initiatives and achievements	Proposed actions
Industrial processes	
• National Carbon Policy Guidelines 2024 adopted: - Facilitates decarbonising efforts while yielding profits through sale of carbon credits (GoP, 2024). • Decarbonising the Textile Manufacturing Sector in Pakistan project: - Supports shift towards low-carbon development through adoption of energy efficiency and resource efficiency and recovery technologies - Prioritised options based on mitigation potential, validated technology and implementation readiness include: economiser/air preheater for gas-fired boilers, condensate recovery system with flash steam recovery, waste heat recovery boiler for gas fired engines, and heat exchanger for hot wastewater.	• Proper metering, particularly in the textile and sugar industries, can reduce the energy consumption. • Replacing low-pressure boilers (LPB) with high-pressure boilers (HPB) will increase the energy efficiency in the sugar industry. • Install variable frequency drives (VFD) on pumps and motors. • Install heat recovery systems (HRS) to exhaust flues in the sugar and paper industries. • Thermal insulation of steam lines and valves can reduce energy losses in almost all industrial units. • Improve maintenance requirements to reduce air leakages in industrial units. • Convert single stage dry kilns to high efficiency multistage kilns in the cement industry.
Waste	
• National Hazardous Waste Management Policy 2022 adopted: - Provides guidelines for the management of chemical and hazardous waste (GoP, 2022a). • Valorisation of Lakhodair landfill emissions into valuable carbon credits project: - Management of solid waste and landfill sites - Removal of 5,000 tonnes of solid waste - Potential to earn 3.2 million carbon credits between 2024 and 2053 (Hasnain, 2024). • Combating Climate Change through the Promotion and Application of Sustainable Biomass Energy Technologies in Pakistan project: - Utilising biomass for energy production • Accelerating Clean Technology Innovations for Integrated and Sustainable Waste Management Solutions for GHG Emission Reduction from Municipal and Industrial Solid Waste project: - Developing sustainable waste management practices.	• Strengthen monitoring and enforcement capabilities of civic agencies and municipalities, to better enforce waste treatment laws and rules. • Implement solid and hazardous waste management systems for the collection, transportation and disposal of solid and hazardous waste in urban and rural areas. • Install waste-to-energy plants across the country to strengthen the circular economy and achieve renewable energy targets. • Encourage biofuel production as an alternative energy source and waste management solution. • Establish waste recycling facilities to promote the recycling and make financing available for recycling initiatives. • Formalise waste collection to mitigate the GHG emissions and reduce pollution.

4

Vulnerability and adaptation

4.
Vulnerability and adaptation

Pakistan's vulnerability to climate change impacts arises in part from its geographic location and topography. With snow-bound mountains in the north, floodplains in the central regions, and deserts and coastal marshes in the south, the country is home to a number of different ecosystem types, each with distinct weather patterns, flora and fauna, and climate change challenges. This complexifies the task of developing effective adaptation measures since no one solution will work across land types and geographies.

This chapter assesses Pakistan's vulnerability to climate change, tracking climate change trends over the last several decades and analysing projections based on these trends. It then examines the vulnerability of key sectors to projected climate change impacts.

4.1 Observed climate change trends

Pakistan's climate has undergone significant changes over the last several decades, influenced by global climate patterns, geographic location and local environmental factors. This includes a marked rise in temperatures across the country, and increasingly erratic precipitation leading to more frequent droughts and floods.

4.1.1 Temperature

The highest temperature ever recorded in Pakistan was 54.0°C in Turbat, Balochistan, on 28 May 2017 (WMO, 2019). This is part of a clear trend. Over the last century the average annual temperature has increased by around 0.6°C. During the period 2001-2023, average annual temperature increased by 0.16°C/decade. The increasing trend was also observed in the seasonal mean temperatures. The average temperature increase is 0.20°C per decade in the winter (December-February), 0.12°C in spring (March-May), 0.14°C in summer (June-August) and 0.18°C in autumn (September-November) respectively.

The winter temperature in Pakistan has been increasing at a rate of about 0.5°C/decade. This trend is more pronounced in the northern parts of the country, with an increase of about 0.7°C/decade. The summer temperature has been increasing at a rate of about 0.3°C/decade. This trend is more pronounced in the southern parts of the country, with an increase of about 0.5°C/decade.

The rate of warming is also accelerating. Between 1951 and 2020, the overall temperature increased by 0.17°C/decade (1951-1970), 0.23°C/decade (1971-1990) and 0.31°C/decade (1991-2020) (Figure 4.1).

Provincial

Provincial temperature trends are as follows (Figure 4.2):

- **Balochistan**: Average mean temperature increased by 0.25°C/decade (1951-1970), 0.31°C/decade (1971-1990) and 0.37°C/decade (1991-2020).

Figure 4.1: Mean temperature change trends (1950-2020)

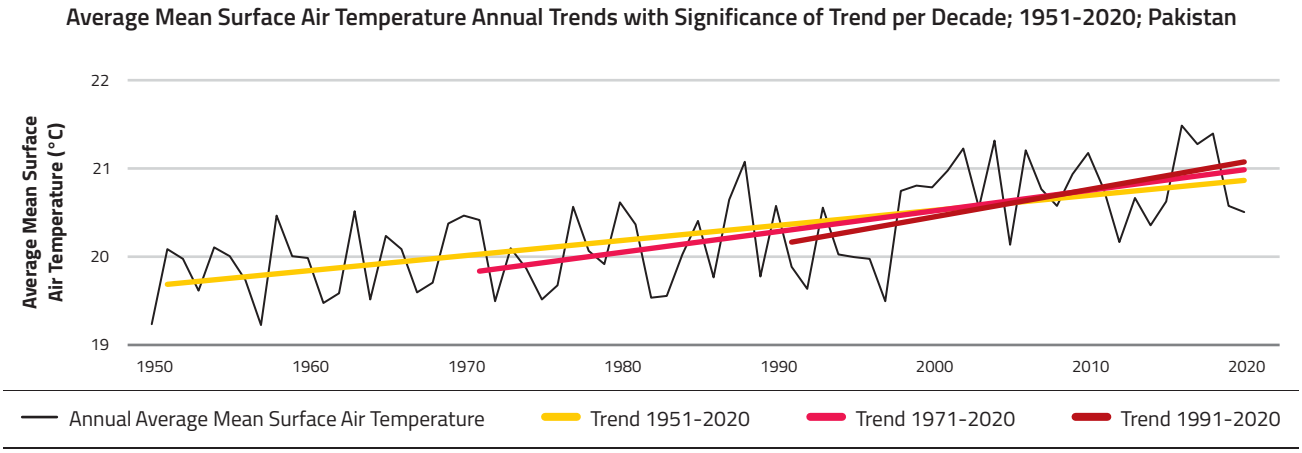


Figure 4.2: Mean temperature change trends, provinces of Pakistan, 1950-2020

- **Punjab**: Average mean temperature increased by 0.02°C/decade (1951-1970), 0.13°C/decade (1971-1990) and 0.13°C/decade (1991-2020).

- **KP**: Average mean temperature increased by 0.25°C/decade (1951-1970), 0.31°C/decade (1971-1990) and 0.59°C/per decade (1991-2020).

- **Sindh**: Average mean temperature increased by 0.06°C/decade (1951-1970), 0.11°C/decade (1971-1990) and 0.10°C/decade (1991-2020).

- **AJK** and **GB**: Average mean temperature increased by 0.24°C/decade (1951-1970), 0.28°C/decade (1971-1990) and 0.44°C/decade (1991-2020).

4.1.2 Rainfall

The annual average precipitation for Pakistan as a whole is about 238 mm. Southern parts of the country receive the least amount of precipitation, while the north receives the most. Winter months are generally dry with average rainfall of about 100 mm. Spring months have shown a gradual increase in rainfall. Summer is the wettest season. The monsoon rains, which bring about 60% of the country's annual rainfall, typically start in June and last until September. The weighted monsoon (June-September) precipitation over the country as a whole is almost twice as high as in winter (December-March). Western disturbances typically bring light to moderate rain or snow in the winter season.

During the period 1951-1970, precipitation increased by 80 mm/decade. There has been a decline in rainfall since then, with a decrease of 5 mm/decade during the period 1971-1990 and 4.68 mm/decade during 1991-2020 (Figure 4.3).

Provincial

Annual mean precipitation trends in the provinces and territories are as follows (Figure 4.4):

Figure 4.3: Precipitation trends (1950-2020)

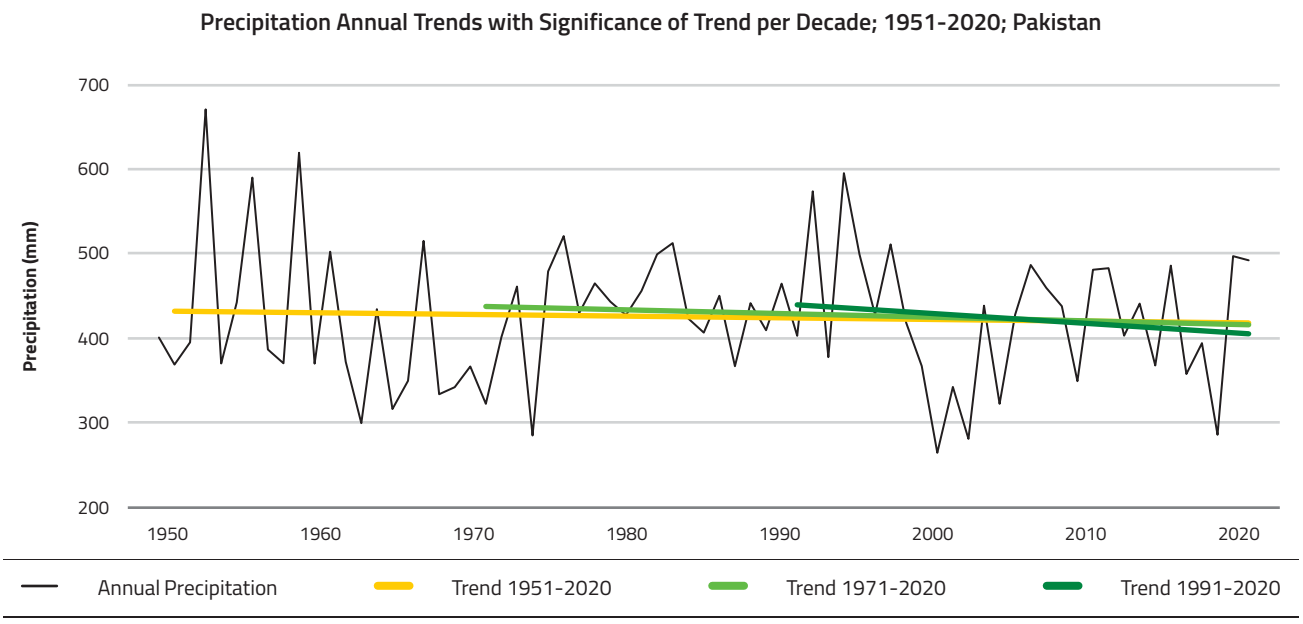
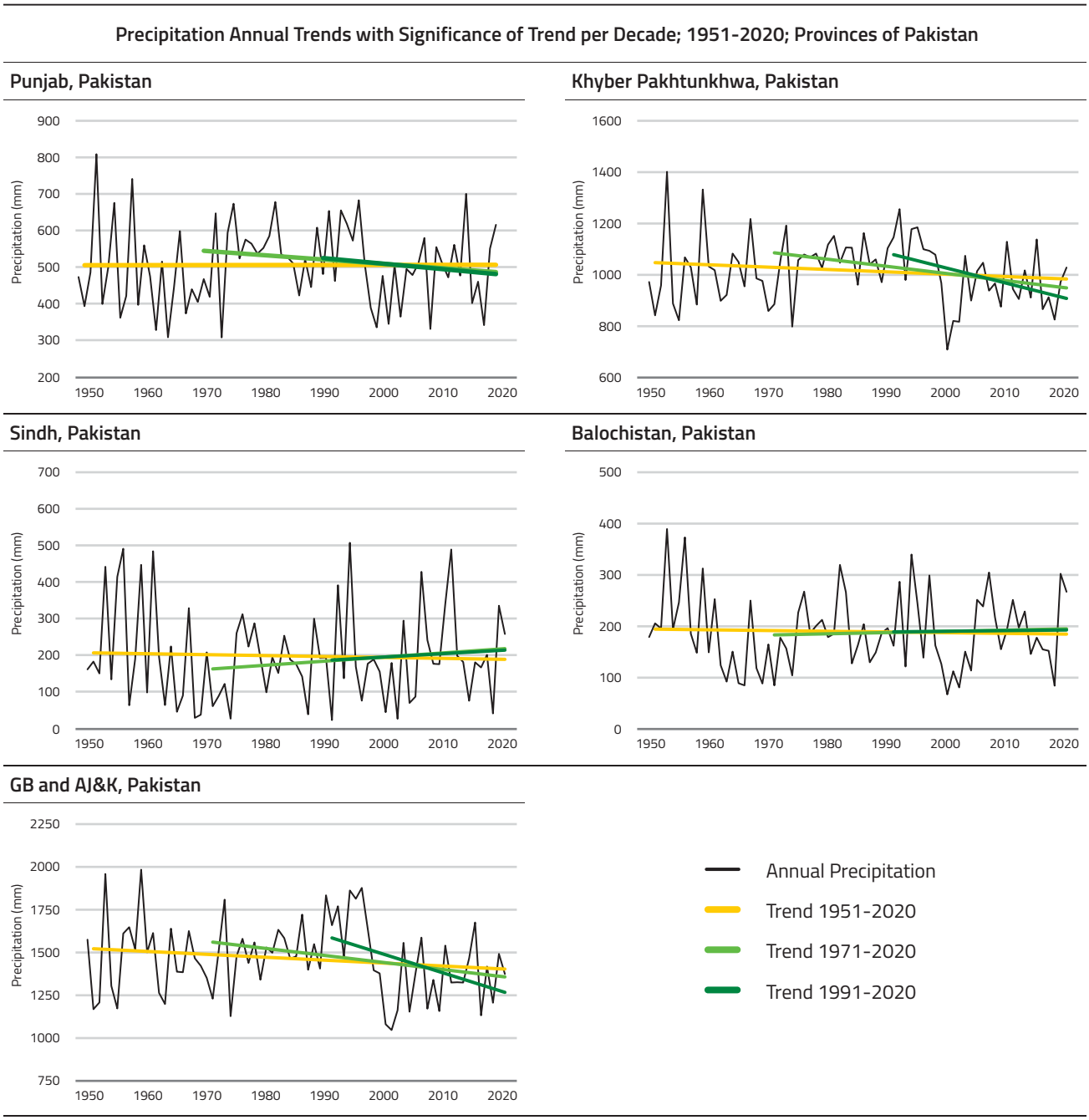


Figure 4.4: Precipitation trends, provincial (1950-2020)



- **Balochistan**: Decreased by 0.4 mm/decade (1951-1970), and increased by 1.38 mm/decade (1971-1990) and 3.95 mm/decade (1991-2020).

- **KP**: Decreased by 5.04 mm/decade (1951-1970), 31.11 mm/decade (1971-1990) and 63.75 mm/decade (1991-2020).

- **Punjab**: Increased by 2.5 mm/decade (1951-1970), and decreased by 15.71 mm/decade (1971-1990) and 9.95 mm/decade (1991-2020).

- **Sindh**: Increased by 0.08 mm/decade (1951-1970), 6.93 mm/decade (1971-1990) and 16.90 mm/decade (1991-2020).

- **AJK** and **GB**: Decreased by 15.58 mm/decade (1951-1970), 39.76 mm/decade (1971-1990) and 90.03 mm/decade (1991-2020).

4.2 Climate change projections

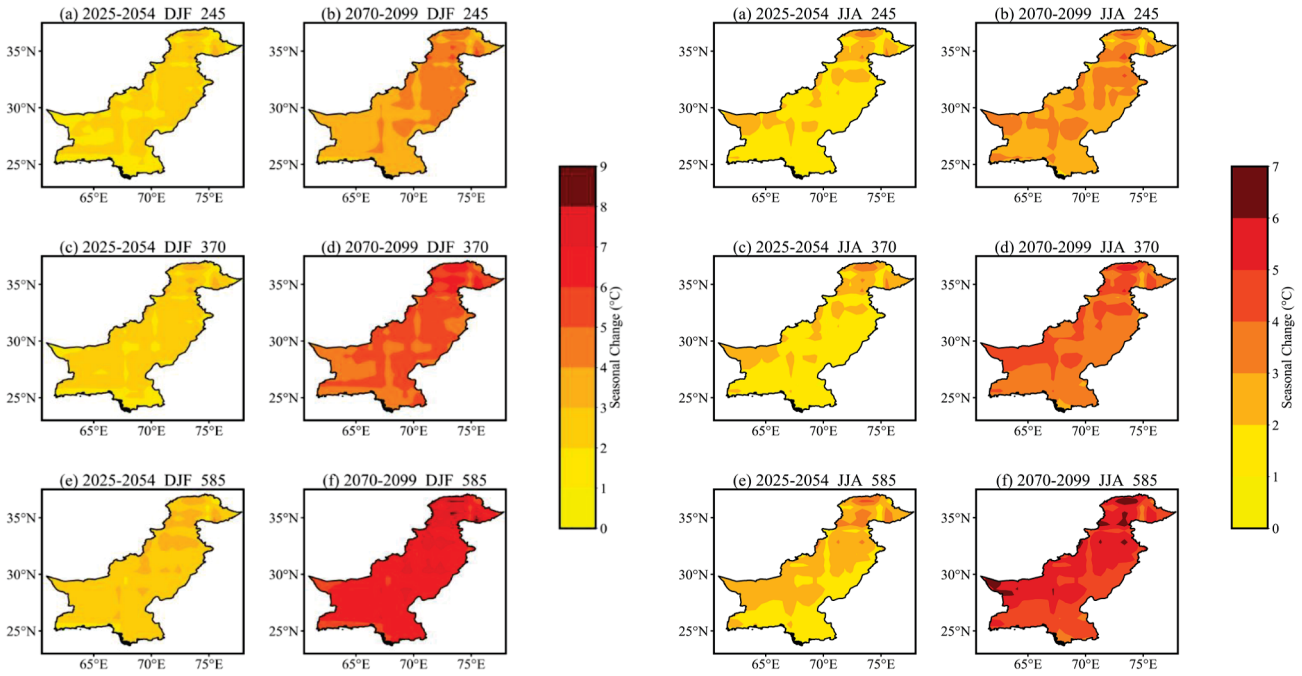
Climate change scenarios are future projections of how Earth's climate might change based on different levels of GHG emissions and various assumptions about societal, economic and technological developments. Some scenarios are consistent with continued dependence on fossil fuels, while others require deliberate actions to reduce emissions (Hayhoe et al., 2017). The resulting range reflects the uncertainty inherent in quantifying human activities (including technological change) and their influence on climate. These scenarios help researchers, policymakers and the public understand the potential impacts of climate change, and to make informed decisions.

4.2.1 Temperature

The most recent climate change scenarios used in the IPCC 6th assessment report (IPCC, 2023) are the shared socioeconomic pathways (SSPs). A number of climate projection studies have been carried out for Pakistan. Various projections of mean temperature changes under different SSP scenarios are shown in Figure 4.5 (Karim et al., 2021; Karim et al., 2023). The summer (June, July, August) mean temperature under SSP 245 is projected to be 1 to 3°C, with mainly 3°C in the northern regions and 1 to 2°C in the rest of the country by the end of this century. During the period 2070-2099, a higher increase of 3 to 5°C across Pakistan under SSP 370 is visible. The northern and southwestern regions will experience a higher increase in temperature, reaching 4 to 5°C. The central-eastern and southernmost parts of the country are projected to warm by 4°C and 3°C, respectively.

Projected warming is higher under the SSP 585 scenario, compared to SSP 370. The summer mean temperature over Pakistan is projected to reach 4 to 6°C under SSP 585. Many regions in the north, central and southwest show projected values of 5 to 6°C, while a few places show an

Figure 4.5: Spatial distribution of projected changes in winter (left) and summer (right) mean temperature (°C) under SSP-245, SSP-370 and SSP-585 scenarios



even higher projection of 7°C by the end of this century. Winter (December, January, February) projections under all three scenarios and for all periods are higher than summer projections for the same scenarios and periods.

Time series projections for the period 2015-2100 are illustrated in Figure 4.6. Projected changes in mean temperature show a warming tendency across the country. By the end of the century, the projected change is expected to increase above 3.2, 5.1 and 7.0°C under SSP 245, 370 and 585, respectively, and the mean temperature over northern Pakistan is projected to warm by 3.1, 5.6 and 7.5°C, respectively. In the central regions, projections show increases of 3.2, 5.0 and 7.2°C under the SSP 245, 370 and 585 scenarios, respectively. For the southernmost parts of the country, projections also estimate an increase in temperature by 2.9, 4.4 and 6.1°C at the end of this century under the SSP 245, 370 and 585, respectively (Karim et al., 2021; Karim et al., 2023).

Projections for near-future (2015-2039), mid-century (2040-2069) and late-century (2070-2099) temperatures under SSP 2-4.5 and SSP 5-8.5 scenarios show robust warming towards the end of the century, as illustrated in Figure 4.7 (Karim et al., 2023). Median temperature changes of 5-95% interval in the 21st century project an increase in the range of 1.8 to 3.0°C (1.5 to 3.5°C) under SSP 2-4.5 (SSP 5-8.5). Late-century winter

Figure 4.6: Annual projected changes in mean temperature over (a) Pakistan, (b) northern, (c) central and (d) southern regions under SSP 245, 370 and 585 scenarios

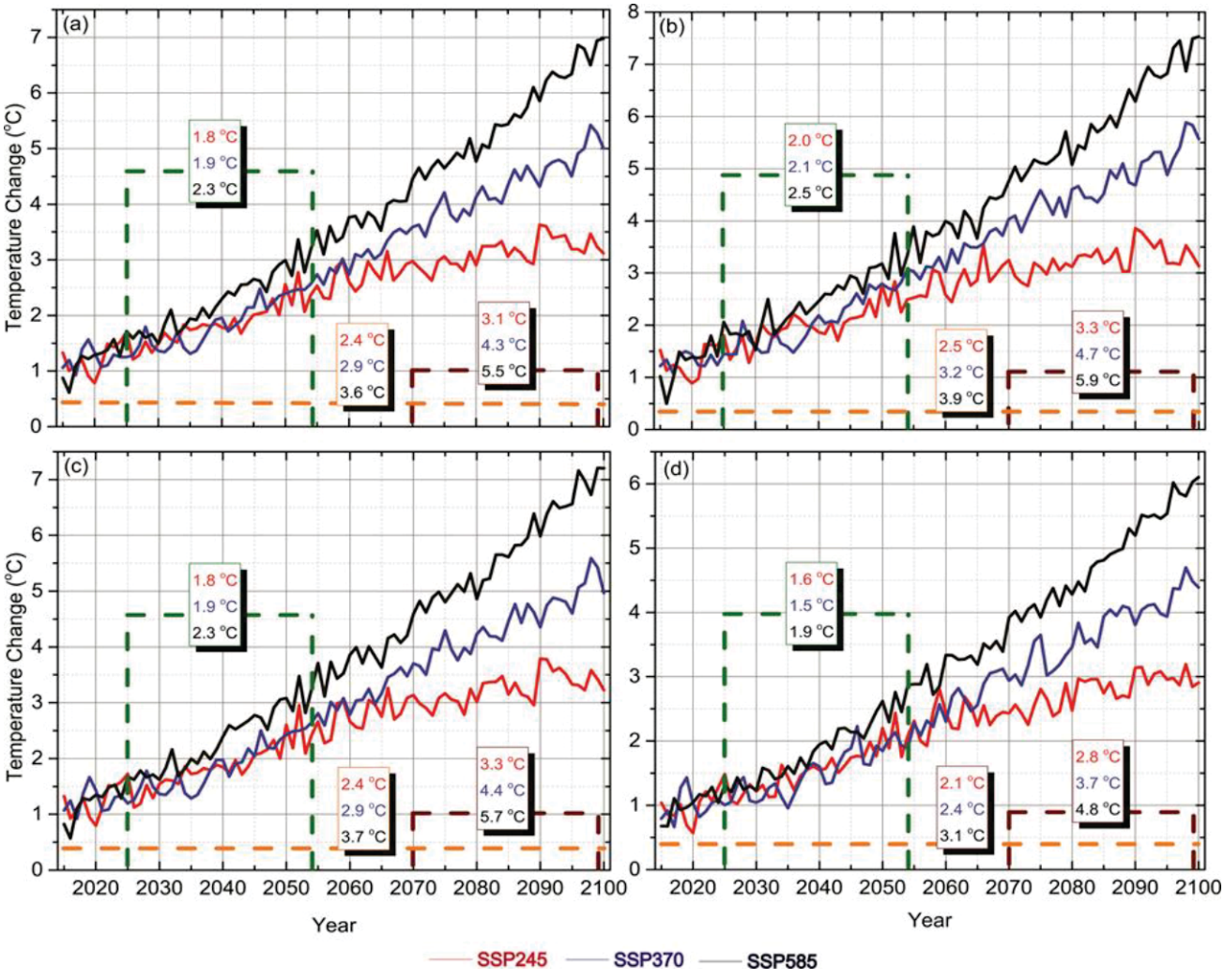
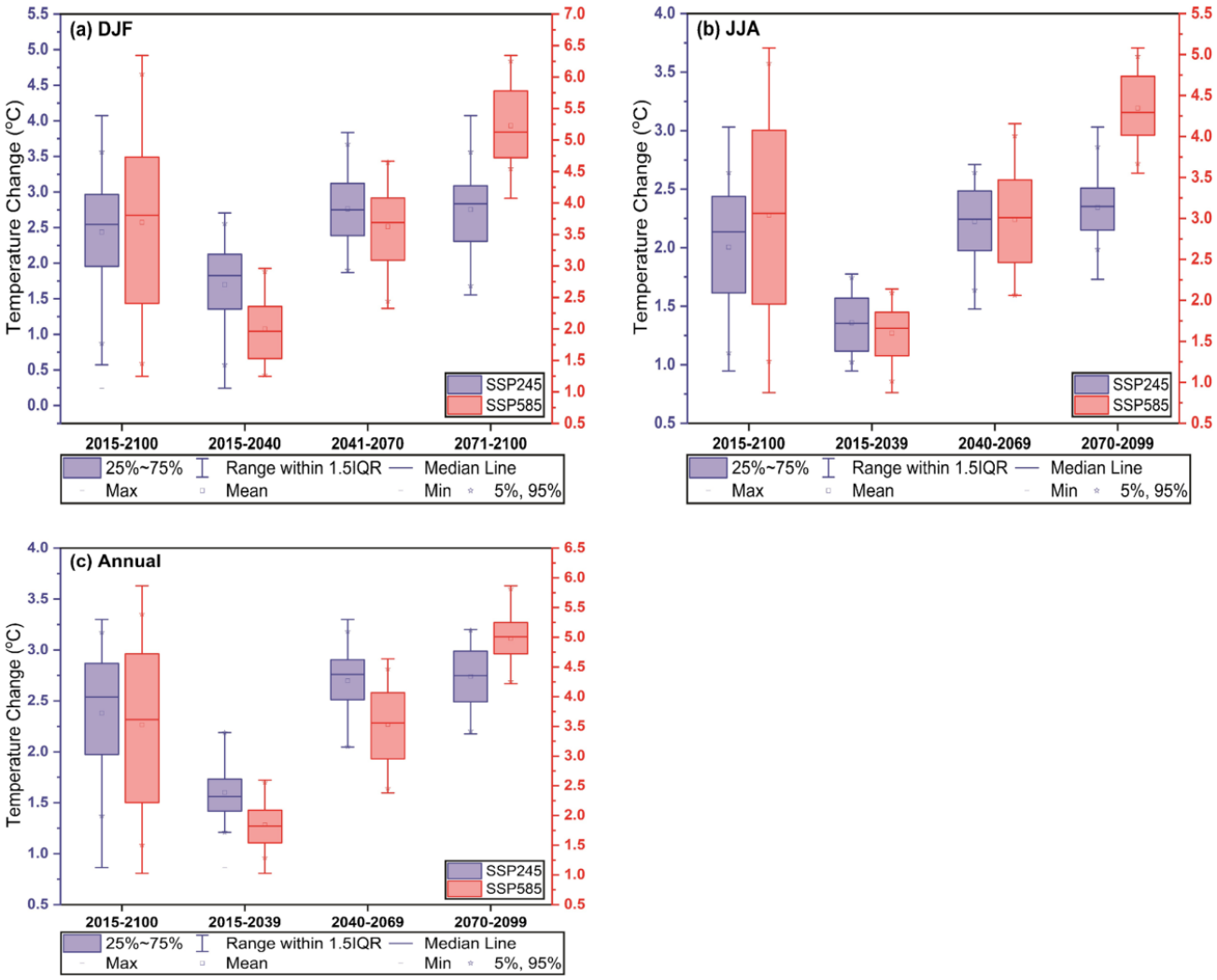


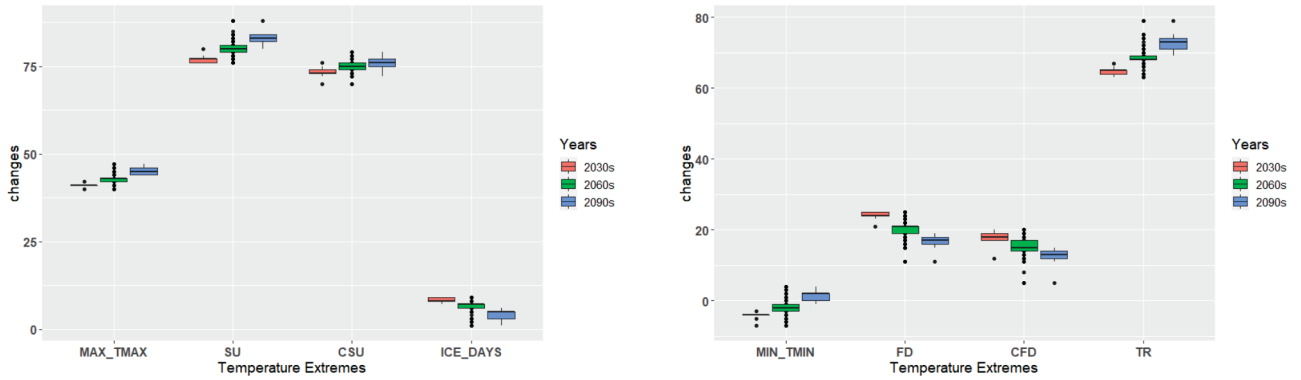
Figure 4.7: Bias corrected mean change in temperature (°C) in winter, summer and annual timescales under SSP2-4.5 and SSP5-8.5 scenarios



is projected to experience the strongest warming of 3.4 to 4.2 °C (4.7 to 5.7 °C) under SSP2-4.5 (SSP5-8.5). Summer is projected to exhibit warming in the range of 1.60 to 2.45 °C (1.55 to 2.95 °C) under SSP 2-4.5 (SSP 5-8.5). Late-century summer will have robust warming in the range of 2.9 to 3.4 °C (4.0 to 4.7 °C) under SSP 2-4.5 (SSP 5-8.5). Projections for annual temperature also demonstrate robust warming (stronger than summer) in the range of 1.95 to 2.80 °C (1.5 to 3.0 °C) under the SSP 2-4.5 (SSP 5-8.5). Late-century annual temperatures are projected to yield strong warming of 4.0 to 4.8 °C (4.7 to 5.2 °C) under SSP 2-4.5 (SSP 5-8.5) across the country.

The percentage change in temperature extremes during the 2030s, 2060s and 2090s is illustrated in Figure 4.8. It can be observed that the percentage of temperature extremes gradually increases from the 2030s to the 2090s. A drastic variation from 75-90% is observed in the category of consecutive summer days, while the variation is lowest in ice days when extremes related to maximum temperature are considered in SSP 585 scenarios. Similar results are noted over the Upper Indus Basin when the analysis is carried out with Coupled Model Intercomparison Project Phase 5 (CMIP5) data sets (Saddique et al., 2020), showing increasing frequency of warm days, summer days

Figure 4.8: Projected changes of temperature extreme indices during summer under SSP245 (left) and SSP585 (right) of CMIP6 models during 2030s (near future), 2060s (mid future) and 2090s (far future) with reference to the baseline 1995–2014



and warm nights. An analysis of the Hindukush region using CMIP5 models under RCP 4.5 and 8.5 scenarios shows a general increase in temperatures with the highest during the period 2066-2099 as well as an increase in temperature extremes (Wu et al., 2017). The increase in precipitation and warming over the Indus Basin may have a significant impact on the hydrology of the Indus Basin in terms of flows (Khan et al., 2020), discharge (Wijngaard et al., 2017) and water budget (Dimri et al., 2019). All studies indicate a considerable change in extreme indices by the end of the 21st century over the Indus Basin, which is supported by the latest CMIP version models.

Figures 4.9 and 4.10 show results from RCP scenarios from IPCC AR5. The temperature is projected to increase by up to 5°C across Pakistan by the end of the 21st century. This rise is higher than the projected global temperature rise of 4°C (IPCC, 2013). Provinces and regions located at higher latitudes show greater increases in temperature: KP, AJK and GB are getting warmer than Balochistan, Punjab and Sindh (Rehman et al., 2018).

4.2.2 Precipitation

Changes in elevation-distributed glacier melt for future periods relative to the baseline are shown in Table 4.1 (Nazeer et al., 2022). There is a higher elevation-distributed glacier melt contribution for all future periods, scenarios and global circulation models (GCMs).

Figure 4.9: Temperature (°C) and precipitation (%) projections with uncertainties between 36 GCMs over Pakistan for the near future, mid-century and far future against RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5

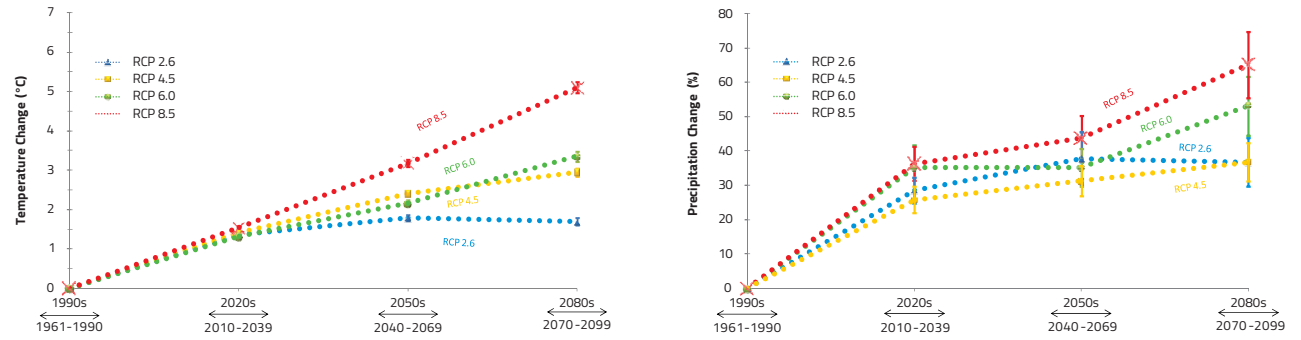
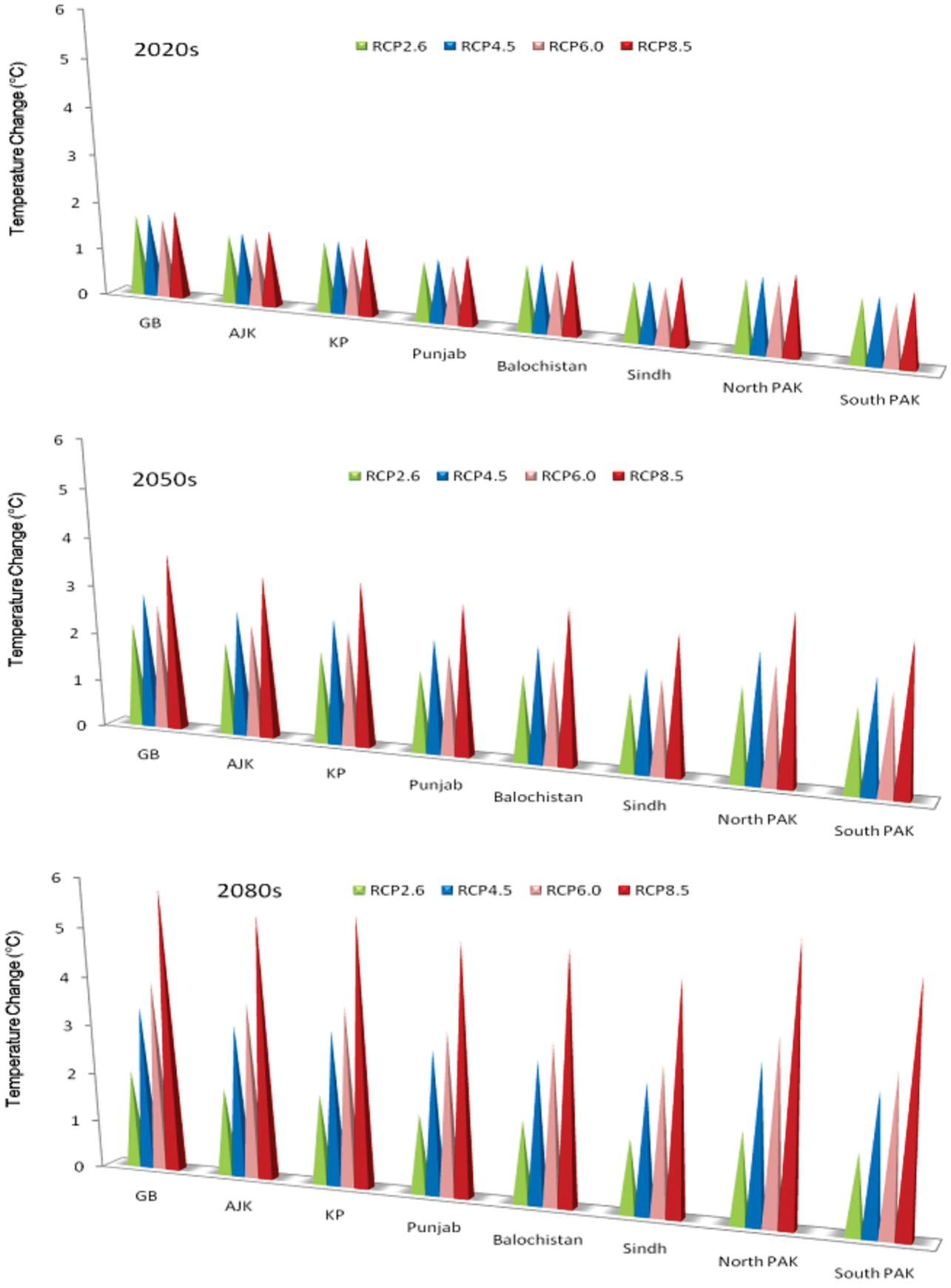


Figure 4.10: Provincial, northern and southern Pakistan ensemble projections of temperature for the near future (2020s), mid-century (2050s) and far future (2080s) against RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.5



GCM differences from baseline to the future are minimum for lower elevations and maximum for higher elevations. The future glacier melt contribution will significantly increase from the higher elevations since about 68% of glaciers are located in the upper half of the Hunza basin.

Table 4.2 shows changes in the percent of future mean monthly snow cover area (SCA) relative to the baseline of European Earth Consortium (ECE3)- and Earth System Model (ESM)-based simulations for all scenarios and periods. Table 4.3 shows the same for snow water equivalent (SWE). Relative to the baseline SCA, future mean monthly SCA decreases significantly in all warming scenarios and GCMs. Changes in SWE from baseline indicate that winter months will have more SWE relative to the baseline period. However, the mean monthly SWE will differ significantly in both GCMs.

Future changes in precipitation extremes during the summer (June, July, August, September) season under SSP 2-4.5 and SSP 5-8.5 emission

Table 4.1: Elevation-distributed mean annual glacier melt (mm) in Hunza basin for baseline and future periods under all scenarios

GCM/SSP/Month			GM1	GM2	GM3	GM4	GM5	GM6	GM7	GM8	GM9	GM10	Mean
ECE3	Baseline		*29*	*67*	*65*	*54*	*51*	*50*	*56*	*66*	*73*	*1*	*512*
	Mid-Century	*SSP1*	31	99	75	65	67	72	85	107	126	107	**834**
		SSP2	32	100	77	66	67	71	86	106	124	93	**822**
		SSP5	32	100	77	69	71	77	92	118	139	115	**891**
	End-Century	*SSP1*	31	97	72	61	60	62	72	89	101	67	**712**
		SSP2	33	103	80	72	72	78	92	118	137	128	**912**
		SSP5	36	119	95	89	93	104	125	165	200	254	**1281**
ESM	Baseline		*28*	*66*	*65*	*55*	*53*	*53*	*61*	*74*	*84*	*13*	*553*
	Mid-Century	*SSP1*	31	94	74	63	62	67	80	97	114	56	**740**
		SSP2	32	95	77	68	70	72	87	108	127	81	**816**
		SSP5	32	95	78	69	70	75	88	110	130	92	**839**
	End-Century	*SSP1*	32	94	75	65	66	70	83	101	118	60	**765**
		SSP2	33	98	81	72	75	81	98	124	146	120	**929**
		SSP5	36	108	93	87	90	98	120	152	186	205	**1174**

Table 4.2: Percentage change in mean monthly future snow cover area (SCA) relative to baseline for all scenarios based on both GCMs

GCM/SSP/Month			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ECE3	Baseline		*96*	*96*	*90*	*82*	*68*	*47*	*14*	*9*	*28*	*67*	*76*	*91*	*63.7*
	Mid-Century	*SSP1*	-5	-5	-6	-9	-21	-57	-75	-67	-61	-27	-15	-12	**-18.0**
		SSP2	-9	-7	-7	-12	-19	-50	-60	-55	-67	-33	-13	-12	**-18.6**
		SSP5	-6	-6	-8	-12	-25	-69	-75	-73	-68	-40	-14	-13	**-21.2**
	End-Century	*SSP1*	-7	-6	-6	-9	-8	-31	-29	-47	-43	-16	-7	-12	**-12.1**
		SSP2	-7	-8	-10	-15	-28	-63	-75	-71	-71	-37	-12	-12	**-21.7**
		SSP5	-18	-15	-21	-39	-78	-96	-100	-100	-94	-81	-48	-29	**-45.4**
ESM	Baseline		*96*	*96*	*90*	*82*	*68*	*48*	*14*	*9*	*28*	*67*	*76*	*91*	*63.7*
	Mid-Century	*SSP1*	-3	-3	-3	-5	-5	-13	-14	-43	-39	-6	2	-10	**-6.6**
		SSP2	-5	-4	-4	-8	-14	-41	-45	-65	-41	-12	2	-11	**-9.6**
		SSP5	-5	-4	-4	-8	-14	-41	-45	-65	-41	-12	2	-11	**-11.2**
	End-Century	*SSP1*	-4	-4	-2	-5	-5	-28	-28	-46	-16	-8	2	-10	**-7.2**
		SSP2	-6	-4	-4	-10	-20	-55	-64	-73	-60	-12	-1	-12	**-14.6**
		SSP5	-10	-9	-12	-19	-41	-75	-89	-99	-90	-45	-11	-14	**-26.8**

Table 4.3: Percentage change in mean monthly future snow water equivalent (SWE) relative to baseline for all scenarios based on both GCMs

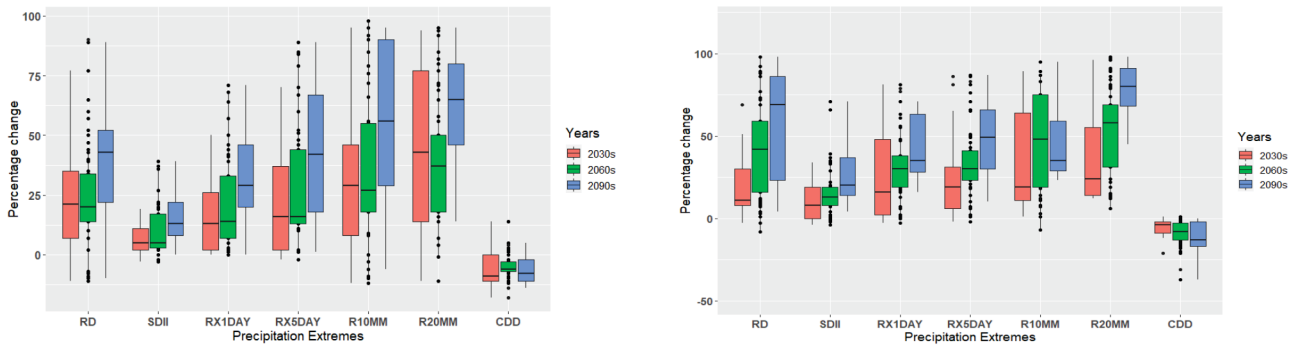
GCM/SSP/Month			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
ECE3	Baseline (mm)		*44*	*48*	*30*	*22*	*7*	*6*	*4*	*4*	*13*	*9*	*12*	*35*	*233*
	Mid-Century	*SSP1*	21	11	6	9	-69	-85	-49	-60	-53	-23	54	13	**2.3**
		SSP2	9	11	22	11	-45	-79	-72	-58	-59	-11	52	7	**2.0**
		SSP5	58	7	14	-1	-85	-78	-70	-65	-55	-35	20	26	**7.6**
	End-Century	*SSP1*	35	15	8	46	-17	-78	-57	-46	-38	-2	88	11	**14.3**
		SSP2	28	20	4	-10	-57	-71	-92	-76	-56	-22	96	11	**4.8**
		SSP5	37	37	-11	-65	-95	-99	-100	-99	-80	-70	-1	-8	**-10.5**
ESM	Baseline (mm)		*40*	*46*	*28*	*23*	*7*	*4*	*3*	*4*	*11*	*13*	*11*	*35*	*227*
	Mid-Century	*SSP1*	52	29	9	-2	11	32	282	12	35	-7	54	40	**30.8**
		SSP2	60	15	11	0	-10	-5	130	-24	-35	-20	39	32	**19.7**
		SSP5	32	10	0	-25	-14	9	84	-12	36	-14	84	18	**13.6**
	End-Century	*SSP1*	36	35	-1	2	-27	11	154	-12	39	-7	96	29	**25.5**
		SSP2	59	15	1	-17	-36	-34	61	-22	11	0	47	22	**16.9**
		SSP5	48	34	-12	-36	-44	-67	-23	-97	-81	-39	91	47	**10.9**

scenarios are obtained from Coupled Model Intercomparison Project Phase 6 (CMIP6) models (Kundeti et al., 2021) (Figure 4.11). The extreme indices show a perceptible increase during the different future epochs with clear variations. Event-based precipitation indices such as R10MM and R20MM show higher variability than the other indices. It is also worth noting that the variation is greater in the SSP 245 scenario compared to the SSP 585 scenario. Consecutive dry days (CDDs) decrease in the SSP 585 scenario. Rising temperature might lead to increased snow and ice melting, which could increase the intensity and frequency of extreme precipitation events in the future.

4.2.3 Uncertainty in future projections

Uncertainty is a fundamental aspect of any prediction about the future, particularly for complex systems like climate. The timing and extent of projected future climate trends is uncertain in part due to the ambiguity introduced by natural variability, anthropogenic changes and scientific uncertainty (Giorgi, 2010). To cope with uncertainty in projections, scientists and experts frequently employ a range of scenarios or modeling techniques that cover a spectrum of potential outcomes. They also conduct sensitivity analyses to determined how different assumptions and inputs affect results. There are

Figure 4.11: Projected changes of precipitation extreme indices during summer under SSP 245 (left) and SSP 585 (right) of CMIP6 models during the 2030s (near future), 2060s (mid future) and 2090s (far future) with reference to the baseline 1995-2014



various sources of uncertainty in future projections, such as natural variability, human choices, emission scenarios, model uncertainty, extreme events and data limitations. Communicating uncertainty transparently is important for policymakers and the public to make informed decisions.

4.3 Vulnerability assessment of key sectors

Pakistan's diverse geography makes it susceptible to different climate impacts in different parts of the country. The impact on natural resources and ecosystems, and on critical sectors and sub-sectors of the economy varies, depending on where these activities are taking place. This section discusses climate-related challenges in key sectors.

4.3.1 Agriculture

Agriculture contributes 24% to GDP and employs 37.4% of the labour force (GoP, 2023). Pakistan's agricultural system is predominantly rain-fed and depends heavily on the Indus River, rendering it highly susceptible to climate variations. Livestock comprises 60.84% of the agricultural sector and contributes 14.63% to GDP. It supports the livelihoods of more than 8 million rural families, providing for 35-40% of household income (GoP, 2023). The impacts of observed climate change trends on agriculture include the following:

- **Crop yields**: Every 1°C rise in temperature could reduce wheat yields by 3-4%, with an even greater impact on crops like rice and cotton.

- **Water availability**: The availability of water for irrigation, especially from the Indus River, is increasingly erratic due to both glacial melt and altered monsoon patterns. This is most pronounced in Punjab and Sindh, where over 90% of agricultural land is irrigated.

- **Erratic precipitation**: Shifts in the timing and intensity of the monsoon, especially in southern and coastal areas, will lead to excessive flooding or drought conditions, disrupting the farming calendar.

- **Glacial melt**: The glaciers of the Karakoram and Himalayas are receding, which impacts downstream water availability. These effects will be particularly severe in areas like GB, where 36% of the population depends on agriculture.

- **Sea-level rise**: Coastal agriculture in Sindh already faces salinisation from saltwater intrusion, rendering parts of the Indus delta unsuitable for crop cultivation. This is significantly affecting rice and wheat production in the region.

- **Soil degradation**: Climate-induced erosion, salinisation and desertification threaten the productivity of agricultural land. These issues are particularly acute in Balochistan, where soil fertility has declined dramatically, and in southern Punjab where intensive agriculture has led to soil nutrient depletion.

The impacts of climate change on agriculture in different parts of the country vary, depending on local climatic conditions as well as the types of agricultural activities practised:

- **Punjab** is Pakistan's agricultural hub. Here, water scarcity caused by erratic rainfall and glacier melt has reduced water availability for irrigation, with an impact on major crops like wheat and cotton. Rising temperatures are shifting the growing season, while flash floods from monsoon rains damage crops and displace communities.

- **Sindh**, a key producer of rice, sugarcane and cotton, is also grappling with climate change impacts. Waterlogging and salinity, driven in part by decreased river flows, have severely affected agricultural productivity. The province is frequently hit by droughts, especially in the southern regions, affecting the cultivation of water-intensive crops. Heatwaves are becoming more frequent, harming crops as well as farmers. Sea intrusion in coastal areas has made parts of the Indus delta unsuitable for cultivation, significantly affecting rice and wheat production in the region.

- **KP** faces the threat of glacial melt which causes irregular water flows, leading to both floods and water shortages. The province is also highly vulnerable to flash floods, which destroy crops. Climate change has shortened the growing season, while soil erosion, exacerbated by deforestation and unpredictable rainfall, has further reduced the land's agricultural potential.

- **Balochistan**, with its arid conditions, is particularly vulnerable to climate extremes. Severe water shortages and frequent droughts have destroyed the region's agriculture and livestock. Desertification is expanding, in part due to reduced rainfall, displacing farmers and reducing arable land. The province also faces extreme temperatures and soil erosion, which further threaten agricultural livelihoods.

- **AJK** is rich in natural resources. Heavy rains and flash floods during the monsoon season damage farms and contribute to soil erosion. Deforestation is worsening erosion, while irregular rainfall leads to droughts or floods, both of which affect agricultural productivity.

- **GB**, which is heavily dependent on glacial water, is particularly vulnerable to changing hydrological regimes. The area faces serious risks from glacial melt and glacial lake outburst floods (GLOFs), which destroy farmland and kill livestock. Changing rainfall patterns and landslides caused by increased rainfall disrupt farming cycles and access to markets. Warmer temperatures are also shortening growing seasons, limiting crop cultivation.

For details on the impact of climate change on various crops under different scenarios, see Annex A.

4.3.2 Livestock

Livestock systems are extremely vulnerable to climate change due to their dependence on natural resources like water and rangelands, both of which are becoming increasingly scarce. Heat stress affects livestock health and productivity, reducing milk and meat production. Climate-sensitive diseases are more prevalent, especially in high-temperature and high-humidity environments. Future climate projections suggest that pastures, grasslands, feed quality and livestock productivity will be severely impacted. This will challenge the sustainability of rangelands, affect grazing management and alter feed choices (Nguyen et al., 2019).

In KP, which is heavily impacted by droughts and extreme heat, reduced pasture land and water shortages have led to lower livestock productivity and increased mortality rates. In Tharparkar, Sindh, recurring droughts have led to significant livestock losses. In Punjab and Sindh, where high temperatures can reach extreme levels, meat production has been affected. In Balochistan and Sindh, water shortages and fodder scarcity during drought periods have led to livestock losses and

reduced productivity, particularly in regions already struggling with limited grazing land. KP and Sindh have also reported increased livestock morbidity linked to disease.

Major challenges to livestock productivity are as follows:

- **Temperature rise**. In arid to semi-arid regions, the livestock sector is highly vulnerable to rising temperatures (Balamurugan et al., 2018). Domestic livestock are most comfortable in temperatures ranging from 10-30°C, with each degree increase in temperature reducing feed intake by 3-5%. Conversely, lower temperatures increase feed requirements by up to 59%.

- **Heat stress**. Heat stress significantly impacts livestock production, reducing feed intake, growth rates and milk production, while increasing vulnerability to diseases like mastitis and heat stroke (Habeeb et al., 2018).

- **Atmospheric CO2**. High CO2 concentrations degrade fodder quality, reducing nutrients like protein, iron, zinc and vitamins B1, B2, B5 and B9 (Ebi and Loladze, 2019).

- **Water scarcity and forage degradation**. Climate change exacerbates water scarcity, which affects both feed production and livestock water needs. During extended dry periods, livestock suffer from dehydration, weight loss and increased mortality. Forage production is affected by erratic rainfall and reduced soil fertility. Across the country, the quality and quantity of forage crops are declining.

- **Risk of disease**. Climate variability also affects the prevalence and spread of livestock disease. Rising temperatures and humidity create favourable conditions for disease vectors like mosquitoes and ticks. Hot and humid conditions increase outbreaks of diseases like foot-and-mouth disease, theileriosis, haemorrhagic septicaemia, lumpy skin disease, pneumonia and respiratory disease, as well as parasitic infestations (ticks, lice, internal parasites).

4.3.3 Fisheries

The fisheries sector is vital for the livelihoods and food security of communities in the coastal areas of Balochistan and Sindh. The sector is increasingly threatened by the impacts of climate change, which is causing economic losses for fishing communities. Major vulnerabilities affecting marine and inland fisheries include rising sea temperatures, ocean acidification, changes in river flows and habitat degradation.

- **Rising sea temperatures** and ocean warming cause shifts in fish distribution, decreasing key species like tuna and shrimp in local waters and affecting fish health, reproduction and growth.

- **Ocean acidification**, caused by increased CO2 absorption, harms shellfish populations (oysters, crabs, shrimp), and threatens marine biodiversity and aquaculture.

- **Sea level rise** leads to flooding in coastal habitats like mangroves, damaging fish breeding grounds.

- **Saltwater intrusion** into freshwater systems alters salinity levels, affecting species reliant on these ecosystems.

- **Reduced freshwater availability**, changes in river flows from glaciers and changing rainfall

patterns impact the Indus River and its delta, crucial for inland fisheries, and create water scarcity issues for aquaculture.

- **Extreme weather events** (cyclones, storms, floods, heatwaves) damage breeding grounds, reduce water oxygen levels and cause fish kills. Climate change may result in ecosystem disruptions that degrade critical habitats like coral reefs and wetlands, destroying biodiversity and increasing the spread of invasive species.

4.3.4 Forests and ecosystems

The forestry sector's contribution to the economy is underestimated because non-timber forest products (NTFPs) are excluded from GDP calculations and many critical services that forest ecosystems provide, such as carbon sequestration, flood regulation and biodiversity conservation, are not assigned monetary value (Ahmad et al., 2020). Pakistan's total forest area is estimated to be 4.8 million ha, or 5.1% of the total land area (WB, 2018). Forest cover varies across the country as follows: KP 32.7%, Sindh 14.8%, Punjab 12.4%, Balochistan 11.1%, AJK 9.6% and GB 7%.

Climate change has increased the vulnerability of forest ecosystems, where degradation and shifts in species composition can be observed as a result of temperature rise, erratic rainfall and the frequency of extreme weather events (Almazroui et al., 2020). Forests in the northern regions rely on glacial meltwater. As glaciers retreat, water availability decreases, severely affecting forest health (Ali et al., 2019). Prolonged dry spells and higher temperatures also increase the risk of forest fires, particularly in AJK and the Potohar Plateau, threatening biodiversity (Sheikh et al., 2019). In some regions, such as AJK and GB, warming is causing some tree species to migrate to higher elevations, shrinking the forested area and reducing snowpack, with knock-on effects on the entire ecosystem (Ashraf et al., 2020). Meanwhile, mangroves in Sindh and Balochistan, crucial for coastal protection, are under threat from sea level rise, coastal erosion and changes in salinity levels.

Climate change is accelerating biodiversity loss in Pakistan's forests. Temperature changes and erratic precipitation patterns disrupt habitats and decrease the availability of food sources for wildlife. Altered habitat conditions force species to migrate and pose a threat to endemic wildlife, particularly in the Himalayan regions (Bajwa et al., 2022). These changes affect both terrestrial and aquatic ecosystems, with ripple effects throughout the food chain.

The impacts of climate change on various forest ecosystems are summarised in Table 4.4. The overall vulnerability of various forest types to climate change, as well as to the impacts of rising temperatures and changes in precipitation, are illustrated in Figure 4.12.

4.3.5 Water resources

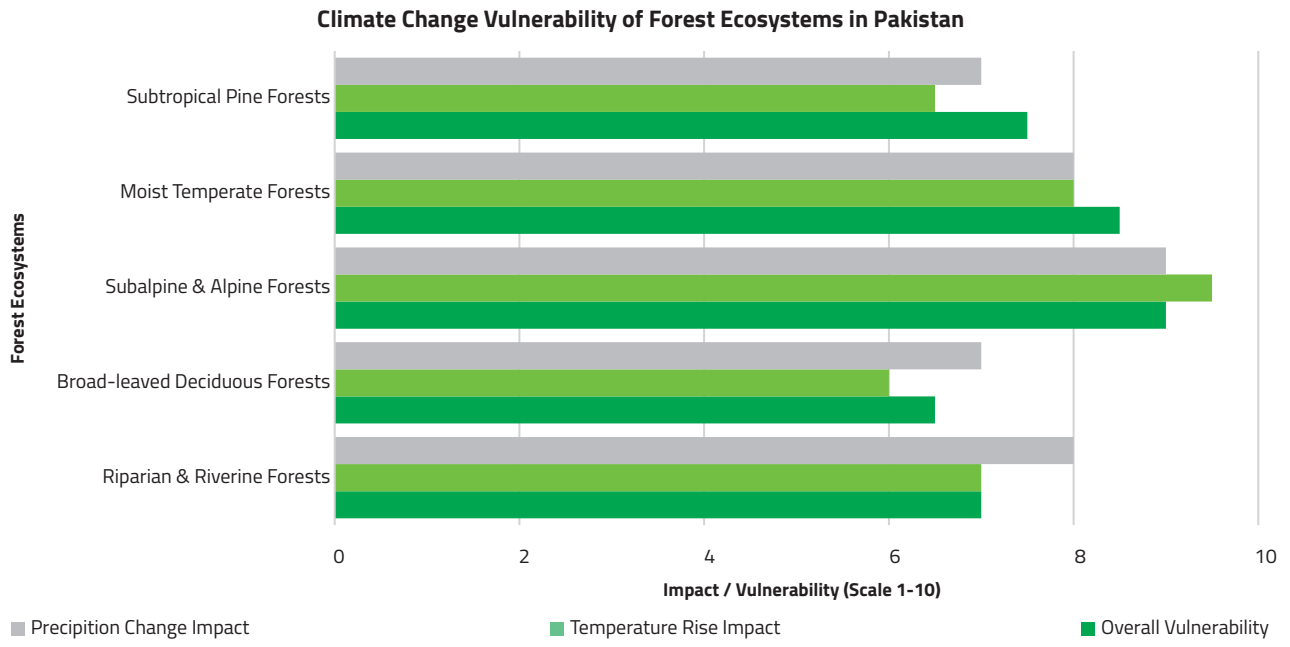
Pakistan's water resources are under stress and climate change is increasing the risk of extreme scarcity. Glacial melt, erratic river flows, floods and droughts threaten water supply, making water security a critical concern. Key climate-related changes include the following:

- **Glacial dynamics**. While glaciers worldwide continue to retreat (IPCC, 2023), glaciers in the Karakoram region, which includes Pakistan, present a paradox. Some studies suggest stable or slightly advancing glaciers (Scherler et al., 2011; Hewitt, 2014; Kääb et al., 2015), while others find that glaciers are retreating here as well (GCISC, 2009; Ashraf

Table 4.4: Impact of climate change on forest ecosystems

Forest type	Location and characteristics	Impacts
Alpine and subalpine	High-altitude regions (3,000-4,500 m) of northern Pakistan, mainly Chitral, GB and upper Swat Mostly shrublands with species like juniper, birch and willow	Glacial retreat and permafrost thaw caused by rising temperatures at higher elevations Shifting snowline and reduced snow cover threaten water availability Increasing temperatures causing species to migrate to higher elevations (Ashraf et al., 2020)
Temperate coniferous	Highlands of the Himalaya and Hindukush ranges (1,500-3,500 m), including Murree, Swat and AJK Deodar, blue pine, fir and spruce	Highly sensitive to changing temperature and snowfall patterns Increasing temperatures causing tree line shifts, forcing species to migrate to higher elevations Erratic snowfall affecting the hydrological cycle, impacting forest growth and survival (Khan et al., 2021)
Subtropical broad-leaf	Foothills of Himalayas (600-1,500 m), especially parts of the Potohar Plateau and Salt Range Olive, ficus and pistacia dominate	Erratic rainfall and increasing temperatures Mid-altitude ranges particularly sensitive to changes in soil moisture and precipitation Increased drought stress and fire risks (Khan et al., 2021)
Moist temperate	Foothills of Himalayas (600-1,500 m)	Precipitation variability because of changing in monsoon patterns Soil erosion and landslides, especially in Neelum Valley, affecting water regulation and ecosystem services (Ali et al., 2019) Accelerated glacial melt impacting water availability, with adverse effects on both forest regeneration and agriculture (Rasul et al., 2021)
Subtropical pine	Lower elevations of the Himalaya and Hindukush mountains (900-1,700 m), especially in KP Chir pine dominates	Prolonged dry spells and higher temperatures leading to greater risk of forest fires (Sheikh et al., 2019) Erratic monsoon rains and snowfall changes affect forest regeneration (Hussain et al., 2022).
Tropical thorn	Mostly plains (below 1,000 m) in Punjab, Sindh and parts of Balochistan Thorny trees and shrubs like acacia, prosopis and ziziphus	Desertification in lowland areas, severely affecting productivity and vegetation cover
Riverine forests	Along Indus River in Punjab and Sindh	Increased siltation due to frequent floods, leading to forest degradation and loss of biodiversity (Shahbaz and Ali, 2022)
Mangrove forests	Coastal areas of Sindh, especially Indus Delta region, and Balochistan Dominated by Avicennia marina	Sea level rise, coastal erosion and increased salinity due to reduced freshwater inflows from the Indus River Highly sensitive to changes in tidal patterns and water salinity

Figure 4.12: Vulnerability of forest ecosystems



et al., 2021; Qureshi et al., 2022). Recent evidence of glacier expansion in the Central Karakoram, known as the 'Karakoram anomaly,' further complicates the question. The country's dependence on the Karakoram glaciers for 60-80% of Indus River System flows highlights its vulnerability to unpredictable glacial dynamics

- **Glacial lake outburst floods**. GLOFs occur when meltwater accumulates in unstable glacial lakes or when an advancing glacier blocks a river stream, causing a flood and endangering downstream communities and infrastructure (Bolch et al., 2011; Salzmann et al., 2013). For example, the 2022 GLOF event in Shisper occurred due to the advancement of Shisper Glacier and the subsequent blocking of another glacier's stream in the Upper Indus Basin, causing flooding of the downstream valley (Hussain, 2022). GLOFs are becoming more common, with the Pakistan Meteorological Department (PMD) reporting a growing number of potentially hazardous glacial lakes.

- **Variability in river flows**. Monsoon and winter rainfall patterns are becoming increasingly erratic, and difficult to predict and manage. The reduction of natural reservoirs in the form of glaciers and perennial snow exacerbates the situation. The melting of glaciers, influenced by rising temperatures, threatens to disrupt historical water supply patterns.

- **Droughts**. Pakistan is a predominantly arid country with low annual rainfall and high solar radiation in many regions. The country has witnessed prolonged periods of drought in recent decades (1998-2002, 2014-17, 2020-22). In 2022, the UN listed Pakistan as one of 23 drought-hit countries (UNCCD, 2022).

- **Extreme weather events**. Climate change has increased the frequency and severity of extreme weather events, including floods, droughts, cyclones and intense precipitation. Higher temperatures directly correlate with more frequent and intense climatic extremes,

as confirmed by the latest IPCC assessments (IPCC, 2023).

These climate effects create uncertainties in a sector that already faces significant challenges, as discussed in the sections that follow.

Siltation and reservoir capacity depletion

Pakistan has number of reservoirs including two major storage dams, Mangla and Tarbela. The loss of storage capacity due to sedimentation is unavoidable but climate-related changes in the hydrological cycle accelerate the pace of sedimentation, reducing storage capacity, and affecting water supply and hydropower generation capacity.

Sediment transported by the Indus River has two origins, the catchment (glacier/ice melt and decrease in natural vegetation) and its perimeter (river bank and bed). The Indus carries a heavy sediment load, estimated at about 200 MT/year in Tarbela and 330 MT/year at Kotri (Mahessar et al. 2020). This sediment load is expected to increase due to high intensity rains and the rapid melting of glaciers.

Water storage capacity

Pakistan is a water-stressed country. Per capita surface water availability has plummeted from 5,260 m^3 in 1951 to around 1,000 m^3 in 2016, and is projected to drop to about 860 m^3 by 2040 (PCRWR and USPCAS-W, 2016). Water storage is one of the ways in which a crisis can be averted but Pakistan's storage capacity is declining, in part due to the pressures of climate change. The country's three major reservoirs, Mangla (built in 1967), Tarbela (1978) and Chashma (1971), have a total designed capacity of 15.75 MAF. This has been reduced to 13.1 MAF due to sedimentation. These reservoirs can only store water for up to 30 days, compared to the international minimum of 120 days. Most advanced countries have water storage capacity of 1 to 2 years.

Sea level rise and saltwater intrusion

Climate change is affecting the ecological balance of the Indus Delta, regarded as the backbone of Pakistan's ecological and economic systems. Reduced freshwater flows from upstream allow seawater to enter the delta, making the soil and water unsuitable for cultivation. At the same time, sea level rise has a similar effect, allowing saltwater intrusion from the Arabian Sea (IPCC, 2019). As a result, the delta has shrunk by a staggering 92%, with almost 60% of the tidal floodplain devoid of vegetation and 32% submerged (Siyal, 2018).

Groundwater depletion

Around 73% of agricultural land in Pakistan is irrigated with groundwater (Qureshi, 2020). The impact of climate change on the hydrological cycle affects groundwater resources, with studies showing that the water table is falling rapidly. In Punjab alone, a study by the Punjab Irrigation Department revealed that the area with groundwater levels exceeding 80 ft in depth was 52.65 sq km in 2010, but had increased to 670.58 sq km by 2015 and 1,868.64 sq km by 2020.

Similarly, a NASA study for the period 2003-13 identified the Indus Basin aquifer as the second most overstressed globally, depleting without replenishment (Khan, 2023). Due to climate change, average annual water availability declined from 145.20 to 124.90 MAF between 1976 and 2020.

Waterlogging and salinity

More than 6.3 million ha of agricultural land in Pakistan is affected by salinity and an additional 1 million ha is damaged by waterlogging (ENVPK, 2021). While the problem is partly the result of mismanagement, erratic rainfall patterns and unpredictable river flows accelerate the pace and make water resource management planning more difficult.

Salinity and waterlogging concerns are reported across Pakistan, with Punjab and Sindh disproportionately affected as they account for the majority of the country's agricultural production. The Indus River Basin, in particular, is severely affected.

Urban and industrial water supply

Rapid urbanisation and industrial development put increasing pressure on water supply systems. Repeated cycles of flooding and drought affect urban water supply systems, leading to scarcity and supply interruptions. Extreme weather events destroy distribution and storage infrastructure, particularly in urban areas. As climate change effects intensify, these supply systems will come under increasing pressure.

Transboundary water management issues

Pakistan's geographical location between India and Afghanistan creates complex transboundary water management challenges. Shared river basins across international borders often result in unpredictable and variable flow conditions. This variability includes the risk of both flooding and drought originating from neighbouring regions.

The lack of control over river catchments in neighbouring countries means that Pakistan is significantly affected by water management decisions made upstream in India and Afghanistan. Measures taken in neighbouring countries, such as the construction of dams and reservoirs in the upper reaches of shared rivers, affect water flow and availability downstream in Pakistan. Water disputes and disagreements over the use of shared water resources have been longstanding issues that are likely to intensify as climate change creates additional pressure on water resources across the region.

4.3.6 Coastal areas

Pakistan's 1,050 km coastline (800 km in Balochistan, 250 km in Sindh) is home to a diversity of fauna and flora, with many commercially important species. Coastal mangrove forests also have potential to capture and store large amounts of CO2, thereby providing cost-effective blue carbon solutions.

This fragile ecosystem, already under threat from a number of anthropogenic factors, is also increasingly endangered by sea level rise, estimated at 1.1 mm/year (Danish, n.d.). Some studies have calculated higher rates of observed sea-level rise at Karachi port of 2.0 mm/year (1916 to 2006) and 3.6 mm/year (2007 to 2016), suggesting an acceleration similar to observed changes in global trends (Weeks et al., 2023).

This is likely a result of the rise in global temperatures (IPCC, 2019). Sea levels rise as melt water from glaciers and land ice runs into the ocean and as the ocean itself warms and expands. Even if mitigation measures are effective globally, surface warming already triggered will continue to warm the ocean, causing sea levels to rise further. Climate modeling studies show that sea level will continue to rise after the 2080s.

Mangroves

Mangrove ecosystems perform ecological functions such as shoreline protection and upland runoff regulation, besides serving as breeding, feeding and nursing grounds for many aquatic and terrestrial species (Walters et al., 2008). Healthy mangroves are productive systems, with one hectare of well-protected mangrove forest able to produce an estimated 15 kg of crab, and 400 kg of fish, molluscs and shrimp (Khan, 2011). Coastal communities rely on these resources for their livelihood.

Pakistan's mangrove forests are highly sensitive to both climatic and non-climatic factors (Amjad et al., 2007; Khatoon and Akbar, 2008). Climatic factors include sea level rise, extreme weather events, and changes in air temperature, precipitation and sea surface temperature (Gilman et al., 2008; Adger et al., 2005). Mangroves are also affected by climate-induced changes in hydrological flows upstream. They depend on freshwater supply from rivers and rainfall, and decreasing freshwater flows to the Indus Delta lead to soil erosion and salinity. Runoff from the Indus River has declined over the last several decades (Danish, n.d.), and some water reaches the Indus Delta only during flood season (summer).

Coral reefs

Recent surveys report the presence of corals in many places along the coast, near Astola Island, Charna Island, Gwadar, Jiwani and Mubarak Village. At least 35 species of hard coral have been found with significant reefs at two locations (Astola and Charna islands). Corals are delicate organisms and cannot survive drastic environmental changes and high sediment load. Higher ocean temperatures, strong currents and resuspended sediment during the monsoon months affect coral growth.

4.3.7 Energy

Climate change poses significant risks to Pakistan's energy sector and particularly to the country's clean energy transition. Under the NDCs, Pakistan intends to cut GHG emissions across key sectors, including energy, aiming for 60% of all energy produced in the country to be generated from renewable sources, including hydropower, by 2030 (GoP, 2021b).

In line with this commitment, an analysis of the country's energy mix between 2018 and 2023 reveals a reduction in the use of oil and gas, and an increase in renewable energy sources including hydroelectricity, the share of which increased from 7.7% to 10.6% during that period (HDIP, 2023). The country's Indicative Generation Capacity Expansion Plan 2022-31 also focuses on increasing the use of indigenous resources for power generation, forecasting a significant growth in the share of hydel over the next decade (NTDC, 2022).

Pakistan's reliance on hydropower makes the energy sector particularly susceptible to climatic variations (Ebinger, 2011). Increasing the share of hydel in the power mix will become difficult with climate change affecting water supply and river flows, as noted above. Climate models predict more frequent extreme events like droughts and floods which will further disrupt hydel generation capacity (Farooqi et al., 2005). These events, coupled with increased cyclonic activity and sea-level rise affecting coastal areas, can damage or destroy generation and supply infrastructure (Khan, 2015).

Meanwhile demand is likely to grow, not only as a result of industrial development and population growth but also in the face of climate change, with rising temperatures increasing electricity demand (Mahmood et al., 2016).

Climate-related challenges to energy generation and supply also vary in different parts of the country. In northern areas, energy generation is highly vulnerable to precipitation changes and glacier melt, impacting hydropower production. Water scarcity, seasonal climate variations and extreme weather events are additional risk factors. In high mountain areas, landslides, GLOFs and sediment accumulation damage infrastructure. Demand is driven by population growth, economic development, and the expansion of tourism and small industries. Climate change will increase demand for heating as well as for agriculture. In coastal regions, energy infrastructure is vulnerable to extreme weather events like cyclones and floods. In arid regions, extreme high temperatures reduce thermal power plant efficiency and increase transmission losses, while also increasing demand for cooling.

4.3.8 Infrastructure

Extreme weather events, such as severe storms and heavy rainfall, pose a significant threat to critical infrastructure. Roads, bridges, railway tracks and public utilities are vulnerable, and the increasing frequency of events like flooding contributes to riverbank erosion, jeopardising settlements and essential agricultural areas. The resultant erosion not only endangers human habitation but also disrupts vital transportation and communication networks.

4.3.9 Health

Rising temperatures increase the prevalence of vector-borne diseases like malaria and dengue, as well as diarrheal illnesses, respiratory infections, and heatstroke (Ali et al., 2022; Hussain et al., 2020). By the end of the century, Pakistan is expected to experience a 3-5°C temperature rise, which will increase the frequency and intensity of heatwaves, floods and droughts, exacerbating these health risks (Ebi and Hess, 2020). The most vulnerable regions are Balochistan, southern Punjab and rural Sindh, which are socio-economically disadvantaged and where healthcare provision is poor. As agricultural systems come under stress, malnutrition is also a concern (Khan et al., 2024).

4.4 Legal and policy framework for adaptation measures

4.4.1 National Climate Change Policy

Pakistan's National Climate Change Policy emphasises adaptation and resilience, recognising the need to address climate impacts like water scarcity, extreme weather events and sea level rise. It focuses on climate-resilient practices, efficient water management and the role of climate finance in promoting sustainability. The **Framework for Implementation of Climate Change Policy** is a strategic plan that translates the climate policy into actionable measures. It sets priorities, assigns responsibilities, allocates resources, and ensures monitoring and evaluation.

4.4.2 Pakistan Climate Change Act

The Pakistan Climate Change Act 2017 establishes mechanisms to coordinate and oversee the planning and implementation of climate initiatives. It provides for the establishment of the Climate Change Authority, the Climate Change Council and the Climate Change Fund, setting up the institutional framework for climate action across the country.

4.4.3 National Adaptation Plan

The National Adaptation Plan (NAP) takes a people- and community-centred approach to address climate change impacts in six areas: the agriculture-water nexus; natural capital (land,

water and air); urban resilience; human capital; disaster risk management; and gender, youth, and social inclusion. It assesses climate effects, identifies vulnerabilities and promotes ecosystem resilience through nature-based solutions.

Key interventions outlined in the NAP include improving irrigation efficiency through the promotion of drip and sprinkler systems in Punjab and Sindh to address water scarcity. It calls for the development and distribution of climate-resilient crop varieties, including heat-tolerant wheat varieties in Punjab and Sindh, and drought-resistant millet and sorghum in Balochistan. To build adaptive capacity within farming communities in drought-prone regions like Cholistan and Tharparkar, it recommends livelihood diversification programmes to create alternative income sources. Initiatives centred around community-based adaptation include strategies for sustainable land management.

4.4.4 Resilient Recovery, Rehabilitation and Reconstruction Framework

The Resilient Recovery, Rehabilitation, and Reconstruction Framework (4RF) was developed in response to the 2022 floods with the goal of building long-term resilience in Pakistan's flood-affected regions. With a budget of USD 16.6 billion, the 4RF emphasises resilient recovery, particularly in housing, agriculture and livelihoods. It takes a community-driven approach that prioritises equality, rapid restoration, green and resilient principles, and risk-informed resilience strategies. It calls for effective monitoring and evaluation to ensure transparency and accountability in resource allocation.

4.4.5 National Flood Protection Plan

The National Flood Protection Plan-IV, for the period 2015-25, addresses flood protection challenges in Pakistan through innovative and integrated measures. This plan incorporates structural and non-structural strategies to reduce flood impacts, enhance resilience and protect critical infrastructure. Following the 2022 super flood, the plan is being updated to better prepare for extreme flooding events.

4.4.6 National Food Security Policy

The National Food Security Policy prioritises climate-smart agriculture, sustainable water use, and improvements in crop yield and quality. The policy promotes research on drought- and heat-tolerant crop varieties, and emphasises the adoption of integrated pest management to reduce crop losses.

4.4.7 National Water Policy

The National Water Policy outlines Pakistan's strategy for the management, conservation and sustainable use of water resources. It aims to build water security and ensure equitable and sustainable access to water resources. Key components of the policy include water governance, efficient water use, infrastructure development, water quality management, disaster risk reduction and the protection of ecosystems. It focuses on measures for sustainable water management, improving water use efficiency, building storage capacity, modernising irrigation infrastructure and promoting climate-smart agricultural practices.

4.5 Adaptation measures at the national and subnational level

There are a number of programmes and projects across the country that aim to strengthen adaptation capacity and build resilience. Key initiatives are discussed in this section.

Recharge Pakistan, aimed at building resilience to climate change-induced flooding and drought, focuses on ecosystem-based adaptation and green infrastructure. Activities include forest and wetland restoration, water flow pathway rehabilitation, and climate resilience in agriculture and forestry.

The **Scaling-up of glacial lake outburst flood risk reduction in Northern Pakistan** (GLOF-II) project is being implemented in 24 valleys of GB and KP. The project aims to enhance climate resilience of communities at risk from GLOF events. Its multi-layered approach includes strengthening institutional capacity for climate responsive planning and development, scaling up community-based early warning systems, and promoting long-term adaptation measures through training to reduce GLOF risks.

The **Living Indus** initiative includes 25 high-impact interventions for policy makers, practitioners and civil society to support ecological restoration of the Indus Basin. These interventions were developed in consultation with national and provincial policymakers, experts and civil society.

The **Climate Adaptation and Resilience for South Asia** (CARE) project aims to boost climate resilience, focusing on climate planning tools, regional cooperation and innovative technologies. The project supports national efforts in agriculture, water management, transport and finance to address risks like floods and droughts. CARE promotes sustainable policies, data sharing and local capacity building, with activities in Pakistan focusing on climate-smart agriculture, water management and resilient infrastructure.

The **Water Resource Accountability in Pakistan** (WRAP) programme aims to improve water resource management at the federal, provincial and district levels by establishing reliable water accounts and supporting water policy implementation. The programme includes workshops to assess water accounting mechanisms, build capacity and promote gender equity in water management. The goal is to strengthen water governance through climate-resilient solutions and generate evidence for national policies on climate and water.

The **Federal Drought Emergency Relief Assistance** (DERA) programme aims to revive the economy and encourage sustainable water and resource use in drought-affected areas across the country. It focuses on resource management, water conservation and infrastructure development to support agricultural growth.

The **Ten Billion Tree Tsunami Project** aims to restore degraded forests, increase forest cover and enhance forest resilience to climate change. Although primarily focused on reforestation, the initiative has also improved the agroforestry landscape, reducing erosion, improving soil quality and providing farmers with alternate income.

4.5.1 Building more resilient agriculture systems

Pakistan is also implementing several preparedness and adaptation measures to address the vulnerabilities of the agricultural sector. One key strategy is the **strengthening of early warning systems** for extreme weather events. For example, in Sindh drought forecasts are shared with farmers, allowing them to adjust planting schedules and take steps to protect crops. This helps mitigate the impact of unpredictable weather patterns.

In Punjab, water management innovations such as **laser land levelling** and **drip irrigation** have been introduced to enhance water use efficiency. These technologies are especially useful in water-scarce

regions. **Solar-powered irrigation systems** are being rolled out in Punjab to reduce reliance on fossil fuels and improve efficiency. Water resource management practices, such as **improving irrigation efficiency**, have been introduced in AJK, GB and KP to prevent forest degradation due to water scarcity. To combat water scarcity and soil erosion, measures for **watershed management** are being implemented, involving tree plantation to reduce soil erosion and retain water (Hussain et al., 2022). In arid areas like Balochistan, **rainwater harvesting** and the construction of **small-scale water storage dams** help farmers cope with prolonged droughts.

Crop diversification is another key adaptation measure, particularly in areas like AJK and GB, where the government promotes horticulture and floriculture. Encouraging farmers to diversify beyond traditional crops reduces their risk of total crop failure from climate shocks, providing more stability for their livelihoods.

National research organisations have developed **climate-resilient crop varieties**, especially wheat, maize and pulses. Work is also ongoing to introduce **saline-resistant rice varieties**, particularly in Sindh, where there is increasing salinisation in coastal areas. Sindh is piloting the use of **bio-saline agriculture** in the Indus Delta, allowing farmers to grow salt-tolerant crops in previously degraded lands.

In regions with challenging terrain, such as GB and KP, **agroforestry** initiatives are being promoted. By integrating trees with crops, farmers can reduce soil erosion, improve land productivity and enhance biodiversity. This approach stabilises the soil and provides long-term environmental and economic benefits. Efforts to **control illegal logging** contribute to forest resilience (Shahbaz and Ali, 2022).

5

Constraints, gaps and financial, technical and capacity needs

5.
Constraints, gaps and financial, technical and capacity needs

This chapter identifies capacity needs for the development of national communications and, more broadly, for the planning, implementation and monitoring of climate action. The analysis is based on desk research, and interviews with experts and stakeholders. Findings were validated through national-level consultations. A structured questionnaire was distributed to stakeholders in all provinces and territories (see Annex B).

Stakeholders and experts identified several critical gaps, which are discussed in the sections that follow. To address these challenges, the chapter proposes several actions, including strengthening coordination mechanisms, building capacity for analysis and reporting, and engaging more systematically with a diverse range of stakeholders.

5.1 Progress since the Second National Communication

Pakistan's Second National Communication (SNC) to the UNFCCC, submitted in 2018, highlighted gaps and constraints that affect the implementation of mitigation and adaptation measures, and make it difficult for the country to properly fulfil its international obligations for transparent reporting. Table 5.1 outlines key deficiencies identified in the SNC, progress made since its submission, and barriers that remain and need to be addressed.

Table 5.1: Progress on gaps identified in Pakistan's Second National Communication

Gaps identified	Description	Progress made	Ongoing challenges
Data deficiencies for GHG Inventory	Inadequate sectoral data affects accuracy of GHG emissions calculations	Some progress with improved data collection in select sectors but gaps remain	Comprehensive data collection frameworks still lacking, particularly for agriculture and industry sectors
Absence of quantitative vulnerability assessments	Lack of measurable indicators to assess vulnerabilities	Limited efforts made to develop and incorporate vulnerability indices	No standardised methodology for vulnerability assessments across sectors
Technological and technical capacity limitations	Shortage of advanced technology and expertise to meet UNFCCC obligations	Capacity building initiatives launched but impact remains limited	Continued reliance on external technical support Need for sustained investment in local capacity
Financial constraints for climate initiatives	Insufficient financial resources for climate action and reporting	Some international climate finance secured but funding remains inadequate	Lack of predictable and sustained financing mechanisms for long-term climate initiatives

5.1.1 Challenges in the development of the Third National Communication (TNC)

Pakistan continued to face challenges in the development of the Third National Communication (TNC). These included technical limitations, such as lack of expertise for GHG inventory preparation, vulnerability assessments and mitigation reporting. Institutional barriers persist, including poor coordination between agencies responsible for climate data and reporting. There are also issues with timeliness and compliance, leading to delays in meeting reporting deadlines. While these challenges are important and need to be addressed, they are part of a broader set of needs that include financing, technical support and capacity development.

5.2 Constraints and gaps

Despite progress made since the submission of the SNC, significant gaps continue to impede progress, as discussed in the sections that follow.

5.2.1 Data quality for GHG inventory preparation

The TNC preparation process highlighted significant data deficiencies, including insufficient information on adaptation and mitigation measures. While government documents and MoCC dashboards contain relevant data, information is fragmented, public access is limited and there are substantial gaps in provincial reporting. Although extensive research exists, challenges remain in accessing, consolidating and using it effectively. Many studies are dispersed across institutions, unpublished, or require permission or payment to access. Sector-specific data, particularly at the provincial and local levels, is often limited. Improved data-sharing mechanisms and centralised access to research are required.

Ensuring data quality remains a significant challenge. This is in part due to the lack of reliable disaggregated national data. According to IPCC guidelines, the GHG inventory process should ensure adequate activity data collection, method selection and accurate emission factors. However, Pakistan lacks country-specific emission factors for almost all key inventory categories, relying instead on regional information. Most data used for inventory preparation comes from secondary sources (tier 1 level data).

Quality assurance is also a concern. The IPCC Guidelines call for the development and implementation of a quality assurance/quality control plan but this has not been possible, due to lack of technical expertise.

Key challenges and gaps affecting the quality and reliability of Pakistan's GHG inventory are summarised in Table 5.2.

5.2.2 Technological constraints in implementation of adaptation and mitigation measures

The lack of technological resources hinders Pakistan's ability to implement effective adaptation and mitigation measures. Uptake of technology-driven solutions is also an issue. Access to technology is critical at the local, regional and national levels for all sectors. Key technological gaps and constraints are summarised in Table 5.3.

5.2.3 Research, systematic observation and networking

The Pakistan Meteorological Department (PMD) is the sole institution responsible for the collection of climate change and weather-related information. Current data collection efforts are inadequate due to poor spatial coverage of

Table 5.2: Challenges in GHG inventory preparation

Challenge	Details	Recommended actions
Inadequate data collection systems	• Absence of standardised methods: Lack of standardised data collection methods across sectors results in inconsistent data • Insufficient monitoring infrastructure: Limited infrastructure to monitor emissions, especially in crucial sectors like agriculture, energy and industrial processes	Develop standardised data collection methods Strengthen monitoring infrastructure
Data accessibility issues	• Restricted data access: Accessing data from private sector entities and some government departments is challenging • Fragmented data: Data dispersed across various agencies hinders development of consolidated inventory	Improve data accessibility Centralise data sources
Quality control and assurance	• Limited quality control procedures: Inadequate implementation of quality control procedures to ensure data accuracy and reliability • Human resource constraints: Shortage of trained personnel to perform quality control checks	Strengthen quality control and assurance procedures
Technical and capacity gaps	• Lack of technical expertise: Limited expertise in methodologies and tools for GHG inventory preparation and uncertainty analysis • Insufficient for capacity building: No continuous training and capacity-building programmes for GHG data collection and analysis teams	Build technical expertise through continuous training
Uncertainty in emission factors	• Outdated emission factors: Use of outdated or generic emission factors fails to accurately reflect local conditions • Variability in emission sources: High variability and uncertainty in emission sources, particularly in sectors like agriculture and waste management	Update and localise emission factors
Coordination and institutional challenges	• Weak institutional framework: Absence of robust coordination mechanisms across sectors and levels of government • Poor inter-agency coordination: Lack of coordination between various agencies responsible for data collection and reporting	Strengthen institutional frameworks and inter-agency coordination
Uncertainty in historical data	• Inconsistent historical records: Gaps and inconsistencies in historical data make trend analysis and future projections difficult	Improve the consistency and accuracy of historical data

Table 5.3: Barriers to technology adoption

Challenge	Details	Implications	Recommendations
Technological gaps	Limited access to advanced technologies such as renewable energy and efficient irrigation methods	Reduced capacity to mitigate and adapt to climate change	Increase investment in research and development
Financial barriers	Inadequate investment in climate-smart technologies	Hinders large-scale deployment of adaptation and mitigation solutions	Enhance funding mechanisms for technology acquisition
Institutional weakness	Weak institutional support and lack of capacity-building programmes	Slows down implementation of climate policies and initiatives	Strengthen institutions Provide technical training
Infrastructure deficiencies	Poor infrastructure and lack of supportive policies and regulatory frameworks	Creates bottlenecks in the adoption of climate technologies.	Develop robust regulatory frameworks Improve infrastructure
Data and information gaps	Deficiencies in reliable data and information systems	Limits informed decision making for climate strategies	Improve data collection, monitoring and evaluation
Public awareness and acceptance	Low awareness and reluctance to adopt new technologies	Slows down technology diffusion and climate action	Launch public awareness campaigns Provide incentives for technology adoption
Mitigation technology challenges	Energy-efficient vehicles, alternative energy sources, methane recovery still in development stages	Delays widespread adoption of mitigation strategies	Support innovation Implement pilot projects for emerging technologies
Cost-benefit considerations	Resource constraints require cost-effective climate solutions	Ensures sustainable investment in mitigation and adaptation	Use cost-benefit and multi-criteria analysis in planning
Weak monitoring and evaluation	Lack of effective monitoring mechanisms	Reduces accountability and effectiveness of climate strategies	Establish robust monitoring and evaluation frameworks

meteorological stations and the quality of data being captured.

The PMD operates more than 100 stations measuring air temperature and precipitation. These are well distributed in lower altitude regions but coverage is poor in higher altitude and/or remote areas (AJK, GB, Balochistan), severely limiting understanding of climate trends. Climate projections using general circulation models (GCMs) are generally realistic but due to poor spatial resolution these models fail to capture climatic details influenced by local topographical variations. Expanding the network of stations, improving the dissemination system and the downscaling of GCM products is required. Key challenges in climate research, observation and risk assessment are presented in Table 5.4.

5.2.4 Institutional structures and coordination mechanisms

Pakistan's institutional framework for climate governance involves multiple entities at the

Table 5.4: Key challenges in climate research, observation and risk assessment

Challenge	Details	Recommendations
Limited meteorological coverage in high-altitude areas	Poor coverage in mountainous regions affects climate data accuracy Inadequate monitoring in GLOF risk areas	Expand network of automated weather stations (AWS) and high-altitude monitoring stations, particularly in northern regions, to improve real-time climate data collection
Low spatial resolution of climate models	GCMs fail to account for local topographical variations, leading to inaccuracies in predicting extreme weather events	Invest in regional climate modeling and downscaling techniques to improve localised climate projections
Gaps in historical climate data	Meteorological data records are incomplete or lack digitisation, making long-term trend analysis difficult Solar radiation, wind speed and soil moisture data are particularly scarce	Digitise and consolidate historical climate data archives, integrate satellite-based datasets Develop open-access climate data portal for researchers and policy makers
Inadequate research on climate extremes	Limited studies on heatwaves, droughts and flash floods Insufficient long-term risk assessments for climate-sensitive sectors	Establish dedicated research programmes for extreme weather analysis Strengthen early warning systems Improve disaster risk assessment models
Weak integration between research and policy	Findings from climate research institutions (GCISC, PMD, universities) not effectively integrated into climate adaptation strategies	Create climate research-policy interface to bridge the gap and ensure data-driven decision making
Limited international collaboration and data sharing	Lack of collaborative research projects with international climate research centres limits exposure to advanced methodologies	Strengthen partnerships with WMO, NASA and regional climate networks Enter into data-sharing agreements Participate in global climate modeling initiatives

federal and provincial levels. The Ministry of Climate Change and Environmental Coordination (MoCC) is the primary body responsible for climate policy formulation and the country's international climate commitments, while statutory bodies like the Pakistan Climate Change Authority (PCCA) and Pakistan Climate Change Council (PCCC) have oversight functions. Coordination remains weak between MoCC and sectoral ministries, provincial departments and other stakeholders. Overlapping mandates, the lack of structured data-sharing mechanisms and the absence of interdepartmental collaboration hinder effective climate action. Key institutional gaps and coordination challenges are summarised in Table 5.5.

5.2.5 Legal, policy and regulatory frameworks

Pakistan has developed a number of climate policies, strategies and frameworks, in addition to sector-specific strategies, plans and regulations. Effective climate action is hindered by the lack of a legally binding framework to consolidate and rationalise adaptation and mitigation priorities and targets, and to ensure proper integration of these priorities and targets across sectors. Key challenges in policy coherence and integration are presented in Table 5.6.

While the Pakistan Climate Change Act provides for the establishment of an institutional framework to govern climate action, additional

Table 5.5: Key institutional gaps and coordination challenges

Challenge	Details	Recommendations
Unclear enforcement mechanisms	MoCC leads climate policy, PCCA and PCCC have oversight functions, but roles and enforcement powers are not clear	Clarify roles of MoCC, PCCA and PCCC with respect to policy formulation, implementation and oversight functions
Weak inter-ministerial collaboration	Inadequate coordination between MoCC and key ministries (finance, planning, water resources, energy, agriculture) causes delays in policy implementation and resource allocation	Establish formal inter-ministerial coordination mechanism
Absence of a centralised climate data-sharing system	Absence of integrated platform for real-time climate data exchange affects evidence-based policymaking, tracking of mitigation and adaptation efforts and UNFCCC reporting	Develop national climate data-sharing platform
Provincial capacity and resource constraints	Limited technical expertise and institutional capacity lead to weak implementation of climate policies and projects at the local level	Build provincial capacity with technical and financial support
Lack of formalised coordination mechanisms	Coordination between federal, provincial and sectoral institutions is ad-hoc and reactive, reducing the efficiency of climate governance structures	Strengthen coordination through formalised communication channels Establish clear roles Develop integrated climate governance mechanism

Table 5.6: Key challenges in policy coherence and integration

Challenge	Details	Recommendations
Implementation	Policies lack implementation mechanisms, leading to slow adoption	Develop legally binding framework to ensure policy continuity, strengthen compliance mechanisms and integrate climate considerations across all sectors Strengthening enforcement and regulatory mechanisms Enhance monitoring mechanisms
Compliance	No legally binding framework to ensure compliance with climate policies across sectors	
Integration	Climate policies not fully integrated into key sectors like energy, agriculture and industry	
Monitoring	Absence of centralised system to track progress and ensure accountability	

measures are needed to ensure effective implementation. These include:

- **Amendments to policies, laws, rules and regulations**. Existing policies and legislation require amendment to ensure alignment with evolving climate risks, local needs, national climate policy and the country's international commitments.

- **Strengthening coordination and implementation mechanisms**. While the law provides an institutional framework, robust mandatory coordination mechanisms are required, along with institutional arrangements for planning, implementation and monitoring.

- **Mobilisation of climate finance**. Policy measures are needed, backed by legislation, to provide incentives for domestic investment in climate-friendly activities, and to facilitate broader access to international funding for adaptation and mitigation. These measures must include provisions for equitable access and financial transparency.

- **Measurement, reporting and verification**. Across the board, a transparent and publicly accessible system is essential for monitoring climate policies, programmes and expenditure. This will build trust, ensure accountability, allow progress to be measured, and enable improvement and course correction where necessary.

5.3 Financial constraints and support received

Pakistan lacks the resources to implement mitigation and adaptation measures at the scale that is required. The country must also grapple with the financial implications of increasingly frequent extreme climate events, not only in terms of loss and damage but also with respect to knock-on effects on the economy, with recovery being sluggish at best. The exact scale of financial resources required is also difficult to assess in the absence of a comprehensive needs assessment.

Pakistan's updated NDCs set an ambitious target of reducing GHG emissions by 50% by 2030 but the country can only meet 15% of this reduction through its own resources. The remaining 35% is contingent on the mobilisation of international finance to the tune of USD 101 billion just for the energy transition. Financial inflows to date fall far short of this requirement. While mechanisms such as the Green Climate Fund (GCF) and Global Environment Facility (GEF) have provided critical support, the scale of funding is small compared to needs.

5.3.1 Domestic financial mechanisms

Pakistan has made efforts to mobilise climate finance domestically. The Pakistan Climate Finance Portal has been launched to improve transparency in financial flows. Several challenges continue to hinder resource allocation and utilisation. While the Pakistan National Climate Finance Strategy 2024 provides a framework to streamline funding sources and strengthen financial governance, significant gaps remain in private sector participation and financial tracking. Table 5.7 provides a summary of key challenges in mobilising domestic climate finance.

5.3.2 International climate finance

Accessing international climate finance is fraught with challenges, including:

Table 5.7: Key challenges in mobilising domestic climate finance

Challenge	Details
Limited private sector involvement	Despite efforts to attract investment, private sector engagement in climate finance remains low due to perceived risks and lack of incentives
Absence of dedicated National Climate Fund	Pakistan does not yet have a centralised domestic climate fund to pool resources and ensure long-term financing for climate resilience
Fragmented financial tracking and reporting	Climate finance data is not consistently tracked across ministries and sectors, making it difficult to assess financial flows and impact
Challenges in accessing international finance	Lengthy approval processes, complex donor conditionalities and limited readiness capacities hinder Pakistan's ability to fully leverage climate finance
Lack of innovative financial instruments	Mechanisms such as green bonds, carbon markets and blended finance are underutilised, limiting domestic resource mobilisation
Limited coordination across government agencies	The absence of a formalised inter-ministerial coordination platform leads to overlapping roles and inefficiencies in climate finance management

- Lengthy and complex application procedures, hindering timely access to funds
- Conditionalities tied to bilateral aid, reducing flexibility in tailoring projects to local needs
- Fragmented financial tracking systems, undermining effective resource allocation and utilisation.

Pakistan has to date primarily accessed international climate finance through mechanisms like the GCF and GEF, which have supported projects in renewable energy, climate-resilient agriculture and urban infrastructure.

Between 2015 and 2024, GCF contributed USD 950.3 million directly to Pakistan, in addition to 1.95 billion for regional programmes in which Pakistan is a participant (Table 5.8). This is significantly lower than the estimated requirement of USD 7-14 billion annually for adaptation alone, according to some studies (Khan, 2011). More recent studies estimate Pakistan's total investment needs between 2023 and 2030 for a comprehensive climate response to be USD 350 billion, or nearly 10% of cumulative GDP for the same period (WB, 2022). This consists of an estimated USD 153 billion for adaptation and resilience, and USD 197 billion for the decarbonisation of key sectors.

GEF support for projects in Pakistan currently stands at USD 17.43 million. Ongoing and approved projects supported by GEF are listed in Table 5.9. Pakistan has also received support for climate initiatives from other international donors and development partners to the tune of USD 1.54 billion (Table 5.10).

5.3.3 Challenges in access to climate finance

Pakistan's case for international climate finance support rests on the principle of climate justice. Despite its minimal contribution to global emissions, the country is among the most

Table 5.8: Support received from GCF

Project	Total value (million USD)	Beneficiaries (million)	Status
Green BRT Karachi	583.5	2.6	Ongoing
Pakistan Distributed Solar Project	54.0	0.85	Ongoing
Transforming the Indus Basin with Climate Resilient Agriculture and Water Management	47.7	17.3	Ongoing
Scaling-up of Glacial Lake Outburst Flood (GLOF) Risk Reduction in Northern Pakistan	37.5	29.2	Ongoing
Community Resilience Partnership Programme (7 countries)	750.0	7.7	Ongoing
Acumen Climate Action Pakistan Fund	90.0	13.1	Approved
Recharge Pakistan	77.8	7.7	Approved
Harnessing the Domestic Private Sector Ecosystem for Climate Action in Pakistan	50.0	5.9	Approved
Integrating Climate Risk Management for Strengthened Resilience to Climate Change in Buner and Shangla Districts of KP, Pakistan	9.8	1.6	Approved
Scaling Resilient Water Infrastructure Facility (12 countries)	1,200	44.2	Approved
Total	**2,900.3**	**130.15**	

Table 5.9: Support received from GEF

Project	Total value (million USD)	Time frame	Status
Transforming the Leather Processing Industries Towards Low Emissions and Climate Resilient Development Paths in Pakistan (UNIDO)	2.0	2016-24	Ongoing
Mainstreaming Climate Change Adaptation through Water Resource Management in Leather Industrial Zone Development (UNIDO)	3.3	2016-24	Ongoing
Addressing the Drivers of Deforestation: Reducing the pressure on the High Conservation Value Forests of Chilgoza Pine of Pakistan (FAO)	3.9	2019-24	Ongoing
Combating Climate Change through the Promotion and Application of Sustainable Biomass Energy Technologies (UNDP)	3.43	2024-29	Approved
Accelerating Low Carbon Circular Economy through Clean Tech Innovation towards Sustainable Development in Pakistan (UNIDO)	2.7	2024-28	Approved
Combating Land Degradation Through Integrated and Sustainable Range and Livestock Management to Promote Resilient Livelihoods in Northern Punjab (FAO)	2.1	2024-28	Approved
Total	**17.43**		

Table 5.10: Support received from other donors and development partners

Donor/partner	Number of projects	Total project value (million USD)	Status
IFAD	28	686	Ongoing
FCDO	3	312.65	Ongoing
USAID	5	204	Ongoing
FAO	22	93.88	Ongoing
WWF	62	71.10	Ongoing, concluded
GIS	11	57.88	Ongoing
UNDP	9	53.52	Ongoing
NRSP	8	31.05	Ongoing
UNICEF	8	21	Ongoing
IUCN	9	7.38	Ongoing
UNEP/GGGI	1	2.24	Ongoing
UNESCO	6	1.41	Ongoing
Total	**172**	**1,542.11**	

vulnerable to the impacts of climate change. While Pakistan has received strong support in international forums, significant challenges persist in accessing climate finance, as summarised in Table 5.11. Addressing these challenges will require the development of innovative financial mechanisms, blending international and domestic funds. Institutional frameworks also need to be strengthened. A unified fund management system is essential to attract diverse funding sources, ensure efficient disbursement, and improve transparency in utilisation and reporting.

5.4 Capacity building and human resource development

Capacity remains a significant challenge, including at the provincial and local levels where most climate adaptation and mitigation activities are implemented. Issues include the lack of technical knowledge and weak institutional capacity within many government bodies. Without adequately trained personnel and access to technology, integrating climate change into development activities will remain difficult. Capacity gaps hindering effective climate action at the provincial and local levels are summarised in Table 5.12.

To address these challenges, targeted capacity building initiatives are needed, particularly in agriculture, water management and disaster risk reduction, as these sectors are among the most vulnerable to climate change impacts. Proposed solutions for capacity development are presented in Table 5.13.

Table 5.11: Key challenges in access to climate finance

Challenge	Details	Implications
Insufficient impact of climate justice advocacy	Despite advocating for climate justice at global forums, Pakistan struggles to secure adequate financial and technical support	Limited success in obtaining substantial international climate finance
Absence of climate finance needs assessment	Lack of systematic assessment of financial requirements to address vulnerabilities and implement adaptation measures	Unclear financial roadmap delays effective climate action
Difficulty in mobilising climate finance	Challenges in accessing diverse funding sources, including GCF, GEF, Adaptation Fund and private sector investment	Reliance on inconsistent or insufficient funding streams
Poor coordination mechanisms	Absence of multi-stakeholder framework to coordinate climate finance initiatives	Fragmented efforts and inefficiencies in fund allocation
Gaps in stakeholder capacity	Limited expertise in accessing and utilising climate finance, especially among private sector actors	Missed opportunities due to poorly developed project proposals
Lack of stakeholder engagement	Weak collaboration between public and private sectors in mobilising and deploying climate finance	Reduced efficiency in resource utilisation
Barriers to public-private partnership	Inadequate incentives and frameworks to encourage partnerships between government, private entities and international donors	Limited investment in large-scale climate projects and infrastructure
Weak institutional and financial frameworks	Lack of innovative financial mechanisms and unified fund management system	Difficulty in attracting diverse funding sources

Table 5.12: Key capacity gaps at the provincial and local levels

Area	Details	Implications
GHG inventory preparation	Provinces lack technical expertise and institutional frameworks needed to compile accurate GHG inventories	Difficult to accurately assess emission trends and design mitigation strategies
Data collection and analysis	There are substantial gaps in climate-related data collection, management and analysis, particularly in key sectors such as agriculture, water management and disaster risk reduction	Prevents evidence-based policymaking and development of effective adaptation measures
Tracking implementation	Provinces and local governments struggle with setting up monitoring and evaluation systems to track progress on climate projects	Difficult to measure effectiveness of climate action and make adjustments
Developing financial proposals	Provincial and local entities lack expertise to prepare competitive climate finance proposals, limiting their ability to access funding from international climate finance mechanisms	Affects development and implementation of climate adaptation and mitigation measures

Table 5.13: Capacity gaps and proposed solutions for key sectors

Sector/area	Issue identified	Proposed solution
Institutional capacity	Weak institutional frameworks, poor coordination for climate action	Integrate NAP capacity building framework to strengthen institutional mechanisms, develop inter-agency coordination structures and improve policy enforcement at national and provincial levels
Agriculture	Lack of knowledge and skills for climate-smart agriculture	Expand sector-specific training under NAP framework, including precision agriculture, drought-resistant crops and efficient irrigation systems Increase community engagement programmes
GHG inventory and climate data	Limited technical expertise in GHG inventory preparation and data management	Strengthen GHG Inventory Management Unit at GCISC to provide specialised courses, certifications and continuous professional development Invest in data collection frameworks to improve inventory accuracy
Disaster risk reduction	Insufficient early warning systems, inadequate local disaster preparedness	Promote public-private partnerships to leverage private sector expertise in early warning systems, mobile-based climate alerts and GIS-based risk mapping Expand training programmes for local government officials
Climate finance	Lack of capacity to develop climate finance proposals	Provide specialised training on climate finance with public and private sector participation Support local institutions in preparing competitive funding proposals
Education and public awareness	Climate education not integrated in academic curricula	Incorporate climate adaptation and resilience training into universities, technical institutes and vocational training centres Develop knowledge sharing platforms

5.5 Stakeholder engagement and public awareness

Stakeholder engagement is critical for the success of climate mitigation and adaptation efforts. However, various reports, including the Pakistan Climate Public Expenditure and Institutional Review (WB, 2023) and the Nationally Determined Contributions (NDC) Implementation Framework (GoP, 2022b), indicate limited engagement of key stakeholders, particularly at the subnational level. While the federal government collaborates with international donors and multilateral institutions, the involvement of the private sector, civil society and local communities in climate policy formulation and implementation remains minimal.

5.5.1 Private sector engagement

Public-private partnerships can leverage private sector expertise, resources and innovation in key areas such as renewable energy, sustainable agriculture, urban planning, disaster risk reduction and climate finance. Companies specialising in solar, wind and hydropower can contribute to capacity building through technology transfer and training programmes. Agri-tech firms can support climate-smart farming, while real estate developers can take the lead in implementing green building solutions. The IT and telecom sectors can support disaster preparedness by collaborating on SMS and digital-based early warning systems. To maximise private sector engagement, stronger collaboration with research institutions is needed, along with policy incentives and co-financing mechanisms.

5.5.2 Stakeholder participation at the subnational level

At the provincial level, consultations have largely been confined to government officials, as in the development of provincial climate change policies in Punjab and Sindh, where private sector engagement remained low (UNDP, 2023). There are no structured mechanisms for integrating community-based adaptation initiatives into provincial and local climate action plans (LEAD Pakistan, 2021; IUCN Pakistan, 2022).

This lack of broad-based participation has led to a gap in ownership over climate policies among non-government actors, slowing down the development and adoption of locally appropriate solutions. Limited engagement with farming communities and industrial stakeholders has affected the implementation of climate-smart agriculture and emission reduction strategies in the manufacturing sector (GoP, 2022c). Increasing the frequency of stakeholder consultations, providing private sector incentives and strengthening community participation is essential.

5.5.3 Public awareness of climate change

Public awareness of climate change remains relatively low. Lack of awareness affects efforts to build resilience, preventing ownership and limiting the willingness of communities to take proactive measures.

While national climate policies and strategies highlight the need for public engagement, there has been limited progress in implementing awareness-raising campaigns. Some initiatives, such as the Ten Billion Tree Tsunami Programme, the Clean Green Pakistan campaign and climate education programmes in urban schools, have carried out limited pubic engagement. But campaigns have been city-focused, with minimal outreach to rural communities, especially in climate-vulnerable regions such as Balochistan, GB and Thar. Expanding these efforts through community-led awareness campaigns in local languages, using locally appropriate communications platforms, can bridge this gap.

5.5.3 Proposed solutions for stakeholder engagement and awareness

To enhance stakeholder participation and raise public awareness, Pakistan should focus on the following measures:

- **Conduct nationwide consultations**. Engaging local governments, civil society organisations and the private sector in nationwide consultations will ensure that a broad range of stakeholders are involved in decision making. Consultations can help identify locally relevant solutions and build ownership of climate policies at the community level.
- **Develop public awareness campaigns**. Public awareness campaigns are needed, using various media platforms (radio, television, social media) to educate the public on the impacts of climate change and the benefits of proactive climate action. Special attention should be paid to reaching rural and vulnerable communities through local languages, culturally appropriate messaging and easily accessible media platforms.
- **Strengthen the role of academic institutions and research organisations**. Universities, research institutions and think tanks can play an important role in developing evidence-based research to inform national and subnational climate policies. These institutions should be integrated into the national climate action framework.

6

Development and transfer of environmentally sound technologies

6.
Development and transfer of environmentally sound technologies

Access to environmentally sound technologies (ESTs) is essential for Pakistan's clean energy transition, and for adaptation measures across key economic sectors like agriculture. Without access to ESTs, Pakistan will find it increasingly difficult to cope with the climate challenges that lie ahead. The development and adoption of ESTs can also serve as an indicator of progress on climate action.

This chapter assesses Pakistan's EST needs in key sectors, identified on the basis of their contribution to national GHG emissions and/or their vulnerability to climate change. It assesses barriers to adoption of ESTs and provides recommendations.

6.1 Needs assessment

This section analyses the technology needs of key sectors based on current status, future direction and anticipated requirements. Information for this assessment comes from desk review of policies, plans and national reports, as well as a comprehensive survey carried out across public organisations, academic institutions and the private sector (see Annex C).

6.1.1 Energy

The government is making efforts to accelerate Pakistan's clean energy transition. Net metering rules were approved in 2015 and by June 2021 NEPRA had issued licenses for net metering with a cumulative capacity of 183.90 MW, enabling consumers to generate their own electricity and contribute to the national grid (MoE, 2022). Customs duty exemptions for solar water heaters has increased imports and given a boost to local manufacturing. Sui Northern Gas Pipelines Ltd (SNGPL) has initiated distribution of solar geysers at subsidised rates to reduce reliance on natural gas. The Ministry of Energy (MoE) has launched a comprehensive campaign to curb electricity theft and improve recovery rates. This initiative will improve the financial stability of the power sector and reduce energy losses, thereby contributing to overall efficiency and sustainability (MoE, 2022).

Efforts are also underway at the provincial level to promote clean energy (MoCC, 2016b). These include:

- **Punjab**. The provincial government has established Quaid-e-Azam Solar Private Ltd, a profit-based company to promote solar energy projects in the province. The Quaid-e-Azam solar park (1,000 MW) is one of its projects. The Punjab Energy Department launched the Ujala scheme to provide solar energy to government schools and distribute solar lanterns.
- **Sindh**. The government, in collaboration with the private sector, has solar energy projects of 1,450 MW in the pipelines.
- **KP**. The government has focused on the supply of solar power to remote villages

through off-grid systems. It has plans to solarise education and health facilities.

- **Balochistan**. The government has plans to convert electric and diesel irrigation water pumps to solar energy.

- **AJK, GB**. There are plans to install 3,000 solar home systems in AJK. In AJK and GB, micro and small hydro power plants have been in operation for more than a decade. This work is being expanded, and micro and small hydro is being promoted in all provinces.

Future directions: energy

Plans and priorities for the energy sector include the following (MoE, 2021; NEPRA, 2022; GoKP, 2021; GoKP, 2016):

- Emphasis on financial self-sustainability of power sector along with reduced environmental impact
- Ensuring compliance with international commitments to reduce carbon footprint for all activities in the power sector
- Reduction in transmission and distribution losses, and demand-side management to reduce load on national grid
- Reduction in gas subsidies for captive power plants to promote shift to efficient electricity consumption
- Introduction of energy efficiency building codes for new construction and retrofitting of existing buildings
- Increased efforts to promote small and micro hydro power projects though incentives and partnerships with the private sector.

Needs assessment: energy

The following ESTs have been identified and prioritised for the power sector (MoCC, 2016b; MoCC, 2021a; NEPRA, 2021; NEPRA, 2022; GoS, 2023):

- Widespread adoption of solar technology, especially for public buildings
- Energy management technologies such as smart meters and load management software
- Solar powered water pumps and lighting systems, particularly in disaster prone areas
- Smart energy storage and backup devices, such as pumped storage hydel (PSH), to support grid stability on account of alternate and renewable energy deployment
- Quality control mechanisms for micro hydel plants and allied equipment
- Regulatory framework for off grid renewable energy systems in remote areas.

6.1.2 Transport

The government formulated its first ever Electric Vehicle Policy (2019) to cut GHG emissions and reduce the sector's dependence on conventional fuel. The policy aims to transform the auto industry by providing subsidies to popularise the use of electric vehicles (EVs). Charging stations are to be installed, initially in Islamabad and Lahore. Power distribution companies will be responsible for identifying charging locations, based on feeder conditions, and for supply to charging stations (MoCC, 2019b). The National Transport Policy (2018) provides recommendations to improve performance of the sector, including the

development of bus rapid transit (BRT) systems and the promotion of sustainable fuels (MoPDSI, 2018).

The government has also approved the National Freight and Logistics Policy (2021) which contains measures to improve the sector as a whole, and freight and logistics in particular. The National Transport Research Centre is responsible for coordination and development of implementation plans related to transport sector policy (MoC, 2020).

The Engineering Development board has prepared the Auto Industry Development and Export Policy (2021) which outlines strategies to promote environmentally friendly transport options and reduce the sector's carbon footprint (EDB, 2021).

Future directions: transport

Plans for the transport sector include the following measures (MoCC, 2019b; EDB, 2021; GoPb, 2017; WB, 2022; MoPDSI, 2018):

- Development of business plan and feasibility for EVs at the national level
- Conversion of existing vehicle production facilities to EVs
- Provision of charging infrastructure and test data for EVs
- Training, standards and regulations for EVs
- Adoption of Euro-II emission standards for vehicles
- Vehicle inspections and installation of pollution control technologies
- Promotion of non-motorised traffic in new housing developments
- Financial incentives for hybrid and hydrogen fuel cell vehicles.

Needs assessment: transport

The following ESTs have been identified for the transport sector (MoCC, 2019b; EDB, 2021; GoPb, 2017; MoCC, 2021a; MoPDSI, 2018):

- Clean energy vehicles and clean energy bikes
- Smart charging stations for EVs
- Vehicle emission standards and capacity for proper inspections
- Fuel efficient public transport system.

6.1.3 Agriculture, forestry and other land use

Agriculture. Many initiatives are underway to boost agricultural production, improve soil fertility and combat erosion (MoCC, 2021a). The government is investing in building resilience in the sector, focusing on the use of climate-smart technologies and the introduction of drought-tolerant crop varieties (MoCC, 2017). Efforts are being made to improve farmer knowledge about new technologies. In the livestock sector, government research departments are working on genetic improvement to increase productivity.

Forestry. Pakistan has launched a number of afforestation programmes in recent years, including the Ten Billion Tree Tsunami Programme and mangrove plantation initiatives. Another recent effort is the implementation of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme. The National Forest Policy aims to mainstream REDD+ as a preventive tool for deforestation, and to enhance forest cover and carbon stocks (MoCC, 2019a). Green Pakistan is another programme for conservation and regeneration of forests (MoCC, 2019a).

Other land use. The government has launched sustainable land management projects through public sector development funds. MoCC has initiated a geomatic project to develop predictive tools for environmental planning and management. This will also strengthen disaster management through risk mapping (MoCC, 2019c). Data collection is an essential requirement for effective land use modelling, planning and management. The Pakistan EPA is taking steps to improve image capturing and processing for environmental monitoring and modelling, and for glacier monitoring.

Future directions: AFOLU

Agriculture. Plans for the agriculture sector include the following initiatives (MoCC, 2016a; GoKP, 2018; MoCC, 2017):

- Introduction of agricultural practices requiring less mechanisation to reduce reliance on fossil fuels
- Development of crop varieties with improved stress tolerance (salt, drought) and disease resistance through technology like tissue culture, mutation induction and genetic modification
- Focus on commercial biogas plants for waste reduction and production of green manure
- Development of cattle feed mixes to reduce methane production from enteric fermentation
- Technical training of farmers for processing real-time data on climate related threats
- Energy-efficient farm equipment and machinery
- Precision agriculture technologies for efficient fertiliser application, minimal environmental impact and improved crop yields.

Forestry and other land use. Plans include the following initiatives (MoCC, 2019a):

- Improved land management and soil monitoring
- Strict regulations and effective mechanisms for forest protection
- Environmental assessments
- Capacity building of public organisations for real-time demographic assessments.

Needs assessment: AFOLU

Agriculture. The following ESTs are required for the agriculture sector (MoCC, 2021a; MoCC, 2017; GoKP, 2018; GoS, 2023):

- Climate resilient, drought-, pest- and salt-tolerant crop varieties
- Eco-friendly disease prevention and treatment methods (e.g., biological control, improved vaccination)
- Smart agriculture practices (e.g., drip irrigation, hydroponics, laser land levelling, carbon sequestration, tunnel farming, direct seeding, advance mechanisation for sowing and harvesting)
- Water recirculation systems, salinity-tolerant fish and shrimp species for aquaculture and fish farming in waterlogged areas
- Advanced GIS and GPS models
- Feed conservation techniques and fodder banks
- Feasibility studies for different crop varieties (e.g., warmer crop varieties for high altitudes, low input and low delta oil seeds)
- Cloud seeding for drought-prone areas.

Forests and other land use. Key ESTs required are as follows (MoCC, 2019a; MoCC, 2021a; MoCC, 2018; MoCC, 2017):

- High resolution images from light detection and ranging drones for soil monitoring and accurate modelling of forest cover
- Data collection and management to estimate forest degradation, especially for timber and fuelwood harvesting and disturbance
- Facilitation of data generation, processing, map generation and publication
- Technologies, tools, training and data for risk assessment and vulnerability mapping.

6.1.4 Water

The National Water Policy (2018) covers all aspects of water resource development and management, with 33 policy objectives related to agriculture, industry, urban development, environmental concerns, conservation and the use of technology (MoWR, 2018). These objectives are to be achieved through key targets that include the construction of large dams, watercourse lining, increasing water efficiency and real-time monitoring of flows.

The government intends to increase water storage capacity from the current 30 days to 90 days by 2025 (MoCC, 2017). Efforts are underway to boost groundwater recharge through various projects. The Pakistan Council of Research in Water Resources (PCRWR) has piloted models for groundwater recharge, including rainwater harvesting to improve groundwater storage and quality in saline and water scarce environments, and developing recharge well sites. It has also arranged training on integrated rainwater harvesting techniques to manage urban flooding. Land is being provided for water storage ponds on project sites (MoCC, 2016a). The Punjab government is offering generous subsidies for high efficiency irrigation systems.

Future directions: water

Plans and priorities for the water sector include the following (NDMA, 2017; MoPDSI, 2022; GoPb, 2018a; MoWR, 2018; NDMA, 2018):

- Integrated flood management and nature-based solutions to enhance flood resilience
- Regulatory reforms for sustainable water management, including for ESTs in the water sector
- Data collection for water sources across the country to provide real-time data on flows
- Rainwater harvesting technologies to improve water supply, particularly in water-scarce regions
- Sustainable water use in agriculture, horticulture and forestry through advanced irrigation techniques and drainage water management
- Protection of ponds and construction of new ponds for water storage
- Installation of reverse osmosis and desalination plants.

Needs assessment: water

The following EST needs have been identified for the water sector (MoCC, 2017; MoCC, 2021a; NDMA, 2017; MoPDSI, 2022; GoPb, 2018a):

- Regulatory framework for water sector technology
- Glacier monitoring for temporal changes through GIS monitoring
- Water efficient techniques (e.g., furrow, drip and sprinkle irrigation)
- Promotion of solar water desalination for irrigation and drinking
- Rain and flood water harvesting, and spate irrigation systems

- Green infrastructure (e.g., permeable pavements, green roofs) to manage storm water runoff
- Water storage and groundwater recharge technologies (e.g., delay action dams, check dams, percolation ponds, recharge wells, shafts and trenches).

6.1.5 Waste

Many waste management initiatives are being implemented across the country but information on these activities is fragmented and difficult to access.

Future directions: waste

Plans and priorities for the waste sector include the following (MoCC, 2021a; GoPb, 2015; GoPb, 2018b):

- Regulatory framework to ensure replacement of plastic with biodegradable materials
- Outsourcing of waste management services
- Replacing open drains with sewerage systems
- Strict enforcement of hazardous substances rules
- Zero waste approach (reuse, recycling, composting) and waste reduction at source
- Integrated waste management from collection until disposal, especially for solid waste
- Wastewater treatment plants to be made mandatory for new urban schemes
- Solid waste accumulation prevention at high altitudes
- Recycling and reuse of municipal and industrial wastewater after proper treatment.

Needs assessment: waste

The following ESTs have been identified for the waste sector (MoCC, 2021a; MoCC, 2017; GoPb, 2015):

- Advanced effluent treatment plants for wastewater
- Efficient water recycling and reuse techniques
- Mechanical and biological wastewater treatment (e.g. anaerobic digestion)
- Waste-to-energy technology (e.g., incineration, gasification, pyrolysis, bio gasification)
- Liner systems in landfills to restrict leaching and gas migration
- Cost effective wastewater treatment solutions (e.g., constructed wetlands, anaerobic bioreactors)
- Small scale sewage treatment systems using improved technologies (e.g., trickling filters, membrane processes).

6.1.6 Industrial processes and product use

In the industrial sector, the focus has been on energy efficiency and clean energy. Coal-based power projects in the private sector follow World Bank and IFC environmental guidelines, using state-of-the-art technology and monitoring systems. The sector has also been in the forefront of adopting renewable energy technologies. Four R-LNG based projects with a combined capacity of 4,896 MW are being developed using state-of-the-art gas turbines with the world's highest efficiency (over 61%), enabling affordable power generation and with low emissions. The textile industry is adopting energy management systems. Major exporters have already implemented this system and have been continuously improving efficiency.

The National Energy Efficiency and Conservation Authority (NEECA) is currently conducting a pre-qualification process for energy service companies to carry out energy audits in the industrial sector. This is expected to increase the effectiveness of energy efficiency measures.

The Punjab Industries Sector Plan (2018) includes measures for the implementation of combined effluent treatment plants to manage industrial waste efficiently (GoPb, 2018b).

Future directions: IPPU

Plans for the IPPU sector include the following (MoCC, 2016c):

- Carbon tax as a means to support mitigation measures
- Emission monitoring equipment in the industrial sector
- Green fiscal reforms and energy audits in the industrial sector
- Adaptation benefits of forests against climate change to be included in corporate social responsibility mandate of large corporations.

Needs assessment: IPPU

The following ESTs are required for the IPPU sector (NEPRA, 2021; NEPRA, 2022; GoPb, 2018b):

- Periodic tuning of burners in boilers for fuel use efficiency
- Automated system for regulation of oxygen levels at burner to guarantee optimal performance and safety
- Reuse of treated waste water for industrial processes like cooling systems, manufacturing, food processing and other high-rate processing units
- Water-efficient wet processing and alternatives that require less or no water such as dry dyeing
- Regular monitoring for water leakages
- Waste heat recovery systems to improve energy efficiency in industrial operations.

6.2 Barriers and recommendations

Barriers to the transfer and adoption of ESTs and recommendations are provided in Table 6.1. The information in this section is based on stakeholder surveys and desk review of government policies and reports (MoCC, 2015; MoCC, 2019b; MoCC, 2021a; EDB, 2021; GoPb, 2017; GoS, 2016; MoCC, 2016c; MoCC, 2017; NDMA, 2017; NESPAK, 2017; GoP, 2021b).

6.3 Financial resources for development and transfer of ESTs

A number of international agencies are supporting climate-related projects in Pakistan. These are summarised in Table 6.2. Details of ongoing and completed projects, implementing agencies and funding are provided in Annex D.

Table 6.1: Barriers and recommendations

Sector	Barriers	Recommendations
Technical barriers		
Common	• Lack of skilled manpower • Lack of country-specific literature, data and information about climate change modelling • Absence of GHG inventories at provincial level • Absence of quality control mechanism for indigenous technologies	• Provide training within sectors through NGOs and local governments • Prioritise quality control mechanisms within country • Develop of GHG inventory preparation mechanism
Energy	• Energy inefficient equipment • Technical and regulatory challenges in deployment of solar technology • Difficult to access remote areas for Implementation of renewable energy projects • Complexities of operating in high-altitude or seismically active regions • Time consuming legal process for approvals and permits for energy projects	• Improve access to energy efficient machinery • Develop sector-specific policies to generate demand for ESTs • Develop country-specific standards for renewable energy technologies • Improve reliability of and access to power grid • Introduce testing facilities to improve quality control
AFOLU	• Absence of national forest monitoring mechanism • Lack of regulation mechanism for inter-provincial movement and trade of timber • Insufficient seed testing facilities • Lack of seed storage facilities • Heavy reliance on fertiliser and land preparation material	• Analyse environmental impact of projects on forests • Establish new protected areas and connect existing protected areas • Ensure coherence in forest management system across the country, based on international standards • Strengthen legislation and regulatory framework for seed market
Water	• Lack of water management system • Saltation of water storage reservoirs • Lack of regional cooperation on cross-basin water management • Inadequate inspection and maintenance of flood protection structures • Limited availability of real-time hydro-meteorological data • Inconsistent design standards for embankments and barrages	• Introduce alternatives for water-intensive crops • Improve water treatment facilities • Conduct marine spatial planning with measures for acidification mitigation • Address critical gaps in flood protection infrastructure • Strengthen inter-agency coordination and data sharing mechanisms • Develop comprehensive flood risk zoning and land use planning regulations
Waste	• Lack of R&D on advanced wastewater and sludge treatment • Inefficient waste collection and transportation methods	• Enhance role of academic and research institutions for wastewater and sludge treatment • Develop dumping sites in remote areas • Provide latest incinerators and equipment for gasification
Financial barriers		
Common	• Lack of R&D funds in public sector • High capital costs for imported raw material • Expensive feasibility studies	• Provide financial assistance to facilitate local production of ESTs and to finance green projects • Provide financial support to disaster risk management authorities

Sector	Barriers	Recommendations
Energy	• Improper regulatory requirements such as caps on solar net metering hinder growth of renewables • Upgradation of transmission network needed to avoid losses requires substantial funding	• Relax import duties for renewable energy technologies • Pursue public private partnerships to provide low-interest loans and leasing programmes for renewable energy adoption
Transport	• Capital intensive projects • Poor maintenance of transportation assets • High capital cost of BRT limits expansion • High costs of computerised tune-up facilities for EVs • Cost of EV higher than conventional vehicles	• Provide subsidies, incentives and tax exemptions for EVs • Expand State Bank green banking initiative to include financing for EVs • Convert local production facilities of two- and three-wheelers to e-bikes and e-rickshaws
AFOLU	• Limited funds available to upgrade R&D laboratories • Financial constraint at farmer level to adopt advanced technologies • Lack of financial incentives for researchers in the agriculture sector • Lack of funds at organisational level to assess disaster prone agricultural lands	• Introduce competitive market-based salaries for researchers • Provide production subsidies to ensure farmer profits while maintaining market-driven prices • Allocate budget for organisations to approach crop damage areas • Require financial compensation for carbon footprint-intensive projects • Provide incentives for forest dependent communities
Water	• Limited financial capacity of SMEs for sustainable water management • High capital cost for water efficient irrigation systems • Subsidies on solar water pumping can further reduce groundwater levels • Chronic underfunding of flood protection projects	• Pursue international funding for ESTs in the water sector • Provide subsidies for efficient irrigation systems
Social barriers		
Common	• Security issues for installed technologies (e.g., theft, vandalism) • Lack of ownership of technological solutions • Loss of trained manpower due to termination of project staff after completion of project • Conflict between federal and provincial legislation • Environmental considerations neglected while formulating national plans and policies • Insufficient dedicated academic programmes for climate change • Lack of public awareness	• Avoid policy changes for ongoing schemes • Conduct integrated planning and decision making • Realign all existing and new policies with climate change needs considerations • Provide scholarships for climate change related studies • Develop national curriculum focused on climate change studies, adaptation, mitigation, risk assessment and vulnerability assessment • Build institutional capacity for risk assessment at district level
Energy	• Lack of awareness about potential cost and benefits of renewable energy technologies • Disruption to local ecosystems from hydropower projects, particularly aquatic habitats • Displacement of communities that rely on the affected rivers and lands for their livelihoods	• Solarise government offices to raise awareness • Ensure robust environmental impact analysis of hydropower projects
Transport	• Administrative fragmentation • Lack of mechanism for coordination between government and private sector stakeholders • National Trucking Policy required	• Establish coordination mechanism for public and private sector • Develop specific policies for each type of transport

Sector	Barriers	Recommendations
AFOLU	• Lack of comprehensive legal framework to support new interventions • Difficult to commercialise newer seed and crop varieties • Cultural resistance and lack of interest in adopting new methods • Authorisation from landowner for installation of technology on leases land makes promotion of ESTs difficult • Damage to forest lands due to encroachments, non-forest use and other inter-sectoral conflicts	• Restructure seed variety approval system to speed up commercialisation efforts • Build awareness regarding R&D activities • Develop trustworthy systems to work in collaboration with private sector and farmers • Amend legal framework to address authorisation issues
Water	• Absence of unified national guidelines for water management • Absence of national focal point for management of groundwater • Lack of awareness regarding newer techniques for rainwater harvesting and groundwater recharge	• Develop unified national guidelines for sustainable water management • Establish national regulatory body to monitor water management and conservation • Conduct awareness campaign on water conservation • Promote rainwater harvesting for residential, industrial and government buildings
Waste	• Poor law enforcement for waste management • Public opposition to wastewater treatment	• Develop supportive policies and regulations • Conduct public education and awareness raising regarding waste management techniques

Table 6.2: Donor supported projects with EST components

Donor	Number of projects	Cost (million USD)
Asian Development Bank	6	952.31
Clean Development Mechanism	19	0.378
Global Environment Facility	3	18.862
Green Climate Fund	4	722.7
United Nations Environment Programme	2	37.965
World Bank	8	1,989.7

7

Research and systematic observation

7.
Research and systematic observation

For mitigation and adaptation strategies to be effective, they must be based on data and research. This includes systematic observation, real-time data collection and scientific analysis, allowing for evidence based decision making. This chapter provides an overview of current research and systematic observation activities related to climate change in Pakistan.

7.1 Policy on and funding for research and systematic observation

Pakistan has several policies and frameworks that call for research and systematic observation on climate change. These policies focus on improving data collection, climate modeling and monitoring of environmental changes, while ensuring integration with global research efforts.

7.1.1 Policies related to research and systematic observation

The key policies that provide for climate research and systematic observation include:

- National Climate Change Policy: emphasises research on adaptation, mitigation and systematic observation, in line with Paris Agreement obligations.
- National Climate Finance Strategy: allocates funding for research, data management and innovation in climate resilience.
- National Adaptation Plan: identifies research priorities for climate vulnerability assessments and adaptation strategies.
- Framework for Implementation of Climate Change Policy: highlights importance of research in evidence based decision making for climate action.
- National Water Policy: includes directives on hydrological and meteorological research for sustainable water resource management.

7.1.2 Institutions involved in research and systematic observation

Several national institutions contribute to climate research and systematic observation:

- Global Climate-Change Impact Studies Centre: conducts climate modeling, impact assessments and GHG inventory studies.
- Pakistan Meteorological Department: leads meteorological data collection, early warning systems and hydrological modeling.
- National Disaster Management Authority: conducts climate risk assessments and integrates research into disaster preparedness planning.
- Pakistan Space and Upper Atmosphere Research Commission: uses satellite technology for environmental monitoring, including for land use changes and coastal erosion.
- Pakistan Council of Research in Water Resources: conducts hydrological studies, water quality monitoring and research on climate-adaptive water resource management.
- National Institute of Oceanography: monitors sea level rise, marine biodiversity and coastal dynamics.

7.1.3 Funding for research and systematic observation

Research and systematic observation activities are funded through:

- Government allocations: the Ministry of Climate Change and the Planning Commission allocate funds for climate research projects.
- International climate funds: contributions from the Green Climate Fund, Global Environment Facility and World Bank support research initiatives.
- Bilateral and multilateral grants: funding from organisations like GIZ, UNEP and USAID have provided support for climate modeling and data collection projects.
- Public-private partnerships: collaborative research initiatives have been carried out with private sector entities and academic institutions.

7.1.4 International collaboration and memberships

Pakistan collaborates with international research platforms and organisations on a number of activities, including:

- Intergovernmental Panel on Climate Change: climate assessments and adaptation strategies.
- United Nations Framework Convention on Climate Change: research discussions under global climate agreements.
- International Centre for Integrated Mountain Development: glacier and mountain ecosystem research.
- World Meteorological Organisation: strengthening weather and climate prediction models.
- United Nations Development Programme: vulnerability assessments and climate resilience research.
- Asian Development Bank and World Bank: technical assistance for climate risk assessments and systematic observation upgrades.

7.2 Research

Pakistan's climate strategy prioritises research to develop evidence-based solutions for mitigation and adaptation. This section discusses key organisations involved in climate research and ongoing projects with research components, categorised by thematic area.

7.2.1 Research priorities, focus areas and ongoing initiatives

Table 7.1 provides a summary of ongoing climate research activities, organisations involved, projects or programmes with research components, and funding sources.

7.2.2 Climate modeling and scenario development

The following institutions are involved in climate modelling and scenario development:

- Global Climate-Change Impact Studies Centre: leads climate modeling and scenario development
- Pakistan Meteorological Department: develops and maintains climate forecasting models
- COMSATS University Islamabad: conducts interdisciplinary climate research
- Water Informatics and Technology, LUMS: develops AI-driven climate prediction tools
- National University of Sciences and

Table 7.1: Climate research activities

Focus area	Organisations	Programmes/projects	Funding
Climate modeling and scenario development	GCISC, PMD, COMSATS, LUMS-WIT, NUST	• Regional Climate Models for South Asia (GCISC) • Downscaled Climate Projections for Pakistan (PMD) • Climate Risk Profiles for KP and Punjab (GIZ)	USAID, GIZ, Government of Pakistan
Vulnerability, impact assessments and adaptation	PMD, NDMA, WAPDA, SUPARCO, PCRWR	• National Multi-Hazard Vulnerability Assessment (NDMA) • Sindh Resilience Project (Coastal Risk Assessment) (WB) • National Adaptation Plan Implementation (UNDP)	UNDP, WB, Government of Pakistan
Glacial and mountain areas research	GMRC-WAPDA, GCISC, PMD, ICIMOD, SUPARCO	• Glacier Monitoring and Risk Assessment in HKH Region (ICIMOD) • Glacial Lake Outburst Flood (GLOF) Risk Reduction (GCF) • Biafo Glacier Ice Core Study (SUPARCO)	UNDP, ICIMOD, Government of China, GCF
Coastal studies and sea level rise	NIO, PMD, SUPARCO, IUCN	• Sea Water Intrusion and Coastal Erosion Monitoring (NIO) • Mangrove Restoration and Protection Study (IUCN) • Karachi Coastal Development Plan (Government of Pakistan)	Government of Pakistan, UNEP, World Bank
Climate-resilient agriculture	PARC, CIMMYT, SUPARCO, IWMI	• Climate-Smart Agriculture Research Programme (PARC) • Precision Agriculture through Satellite Monitoring (SUPARCO) • Agro-Ecological Zoning for Food Security (IWMI)	FAO, CIAT, World Bank, Government of Pakistan
GHG estimation and monitoring	GCISC, MoCC, Pak-EPA, SUPARCO	• National GHG Inventory Development (GCISC) • Carbon Stock Assessments in Forests and Wetlands (Pak-EPA)	GEF, UNEP, Government of Pakistan

Technology: studies climate resilience and adaptation strategies.

Key research projects include:

- High-Resolution Regional Climate Models for South Asia (GCISC, PMD) supported by USAID, GIZ
- Climate Risk Profiles for KP and Punjab (GCISC, GIZ) funded by GIZ
- Kabul River Basin Water-Climate Assessment (USAID, PMD, GCISC) funded by USAID.

7.2.3 Vulnerability, impact assessments and adaptation

The following institutions are involved in impact assessment and research on vulnerability and adaptation:

- Pakistan Meteorological Department
- National Disaster Management Authority
- Water and Power Development Authority
- Pakistan Space and Upper Atmosphere Research Commission.

Key research projects include:

- National Multi-Hazard Vulnerability Assessment (NDMA, SUPARCO) funded by UNDP
- Sindh Resilience Project, Coastal Risk Assessment (NDMA, PMD) funded by WB
- Implementation of National Adaptation Plan (MoCC, PMD, UNDP) funded by UNDP.

7.2.4 Glacial and mountain areas research

Institutions involved in research on glaciers and mountain areas include:

- Glacier Monitoring Research Centre, WAPDA
- Global Climate-Change Impact Studies Centre
- Pakistan Meteorological Department
- International Centre for Integrated Mountain Development.

Key research projects include:

- Glacier Monitoring and Risk Assessment in HKH Region (GMRC, ICIMOD) funded by ICIMOD, UNDP
- Glacial Lake Outburst Flood Risk Reduction (MoCC, PMD, UNDP) funded by GCF, UNDP
- Biafo Glacier Ice Core Study (SUPARCO, ITPCAS) funded by Chinese Academy of Sciences.

7.2.5 Coastal studies and sea level rise

The following institutions are involved in coastal studies:

- National Institute of Oceanography
- Pakistan Meteorological Department
- Pakistan Space and Upper Atmosphere Research Commission.

Key research projects:

- Sea Water Intrusion and Coastal Erosion Monitoring (NIO, SUPARCO) funded by UNEP
- Mangrove Restoration and Protection Study (IUCN, PMD, SUPARCO) funded by WB
- Karachi Coastal Development Plan (GoP) funded by GoP.

7.2.6 Climate-resilient agriculture

The following institutions are involved in research on climate-resilient agriculture:

- Pakistan Agricultural Research Council
- International Maize and Wheat Improvement Center
- Pakistan Space and Upper Atmosphere Research Commission.

Key research projects:

- Climate-Smart Agriculture Research Programme (PARC, CIMMYT) funded by FAO, WB
- Precision Agriculture through Satellite Monitoring (SUPARCO, PARC) funded by GoP
- Agro-Ecological Zoning for Food Security (IWMI, SUPARCO) funded by FAO.

7.3 Systematic observation

Pakistan has an extensive meteorological and hydrological data collection network, managed by multiple national organisations. Their activities include weather forecasting, early warning systems, climate monitoring and hydrological assessments. Collectively, these government agencies, non-government organisations and international partners form a robust network for systematic observation and research.

7.3.1 Meteorological and hydrological data network and services

This section provides an overview of key organisations involved in meteorological and hydrological data collection (Table 7.2), Pakistan's meteorological and hydrological data collection network (Table 7.3, Figure 7.1) and the types of services provided (Table 7.4).

7.3.2 Technological advancements

Pakistan's river catchments, located in transboundary mountainous regions, lack ground-based observations due to limited data sharing. To

Table 7.2: Organisations involved in meteorological and hydrological data collection

Organisation	Role in data collection
Pakistan Meteorological Department (PMD)	Manages weather monitoring, climate modeling, early warning systems and seasonal forecasting
Water and Power Development Authority (WAPDA)	Monitors river flows, glacial melt and hydrological cycles, providing data for water management and flood forecasting
Pakistan Space and Upper Atmosphere Research Commission (SUPARCO)	Uses satellite remote sensing for weather pattern monitoring, water resource assessment and agricultural climate predictions
Pakistan Council of Research in Water Resources (PCRWR)	Conducts hydrological research, groundwater monitoring and water quality assessments
National Disaster Management Authority (NDMA)	Uses meteorological and hydrological data for disaster preparedness, early warnings and response planning

Table 7.3: Meteorological and hydrological data collection network (also shown in Figure1)

Network type	Number of locations	Coverage	Managing organisation
Manual weather observatories	99 stations	Nationwide	PMD
Automatic weather stations (AWS)	262 AWS (expanding to 300)	Nationwide	PMD (with support from ADB)
Weather radars	4 (Islamabad, Karachi, Mardan, Sialkot)	Partial coverage (expanding to 8 radars)	PMD (funded by World Bank)
Flood telemetry stations	707 stations (planned under NFPP-IV)	River basins	PMD, WAPDA
Satellite-based climate monitoring	SUPARCO remote sensing system	Nationwide	SUPARCO
Hydrological monitoring stations	85 major river monitoring points	Major river basins	WAPDA, PCRWR

Table 7.4: Types of services provided

Service type	Description	Managing organisation(s)
Weather forecasting	Provides daily, weekly and seasonal forecasts for agriculture, aviation and the public	PMD
Early warning systems (EWS)	Monitors extreme weather events like heatwaves, floods and cyclones	PMD, NDMA
Flood forecasting and river flow monitoring	Tracks river flows and issues flood warnings	WAPDA, PMD
Drought monitoring	Assesses soil moisture and long-term rainfall deficits	PMD, PCRWR
Cyclone and coastal hazard warnings	Monitors tropical storms and storm surges	PMD, NIO
Satellite-based climate data	Uses remote sensing for climate modeling and environmental monitoring	SUPARCO
Climate resilience advisory	Provides climate data for policymakers and disaster management	PMD, NDMA

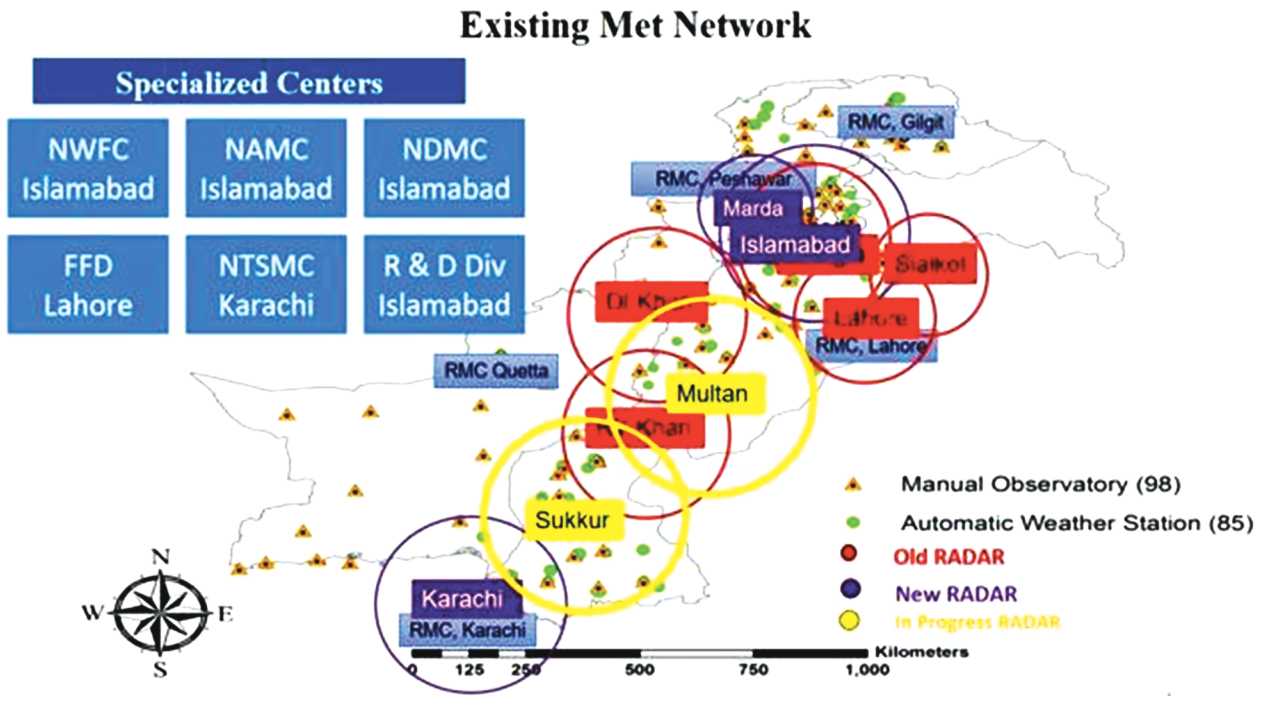
Table 7.5: Donor-supported projects and activities

Project name	Focus area	Funding agency	Implementing organisation
Hydromet and Disaster Risk Management Services Project	Modernisation of PMD forecasting capabilities, new AWS, radars	WB	PMD
Flood Telemetry Master Plan 2023	Expansion of flood forecasting infrastructure	ADB	PMD, WAPDA
Climate Adaptation and Resilience for South Asia (CARE)	Regional climate monitoring and adaptation planning	WB, ADPC	PMD, WAPDA, SUPARCO, Planning Commission
Glacial Monitoring and Early Warning Systems (GLOF-II)	Real-time glacier monitoring and flood prediction	GCF, UNDP	PMD, NDMA
Expansion of Satellite-Based Climate Monitoring	Development of remote sensing applications for meteorology	SUPARCO, APSCO	SUPARCO

Table 7.6: International partnerships in meteorological and hydrological research

International partner	Nature of collaboration
World Meteorological Organisation (WMO)	Supports meteorological data sharing, training and forecasting enhancements
United Nations Development Programme (UNDP)	Assists in climate resilience and early warning system development
International Centre for Integrated Mountain Development (ICIMOD)	Collaborates on glacier and hydrology research in the Hindu Kush Himalaya region
World Bank (WB) and Asian Development Bank (ADB)	Fund projects related to hydrometeorology and disaster preparedness
Asia-Pacific Space Cooperation Organisation (APSCO)	Collaborates with SUPARCO on remote sensing applications for meteorology

Figure 7.1: PMD network of manual observatories, weather stations and radars

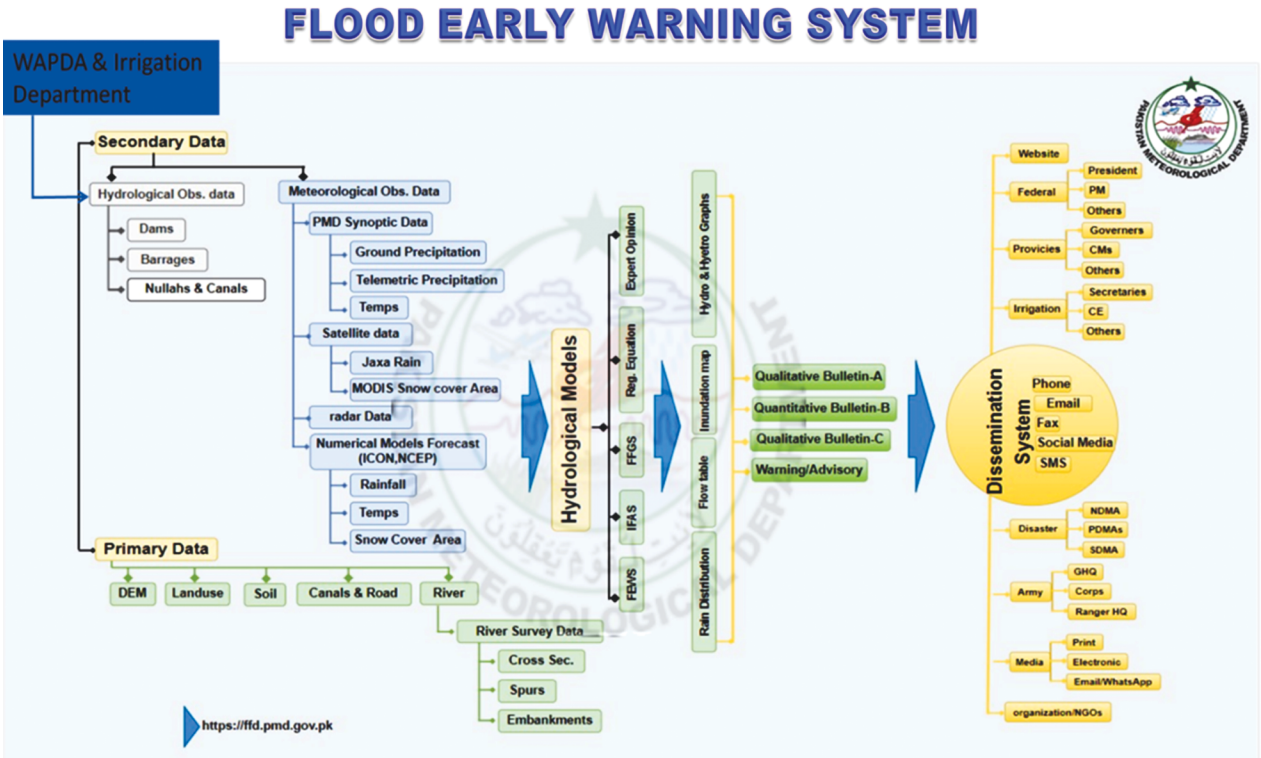


address this issue, the PMD relies on satellite and radar technology for real-time monitoring. PMD operates four quantitative precipitation measuring (QPM) radars, one each in Mardan, Karachi, Islamabad and Sialkot, with the latter two crucial for monitoring transboundary weather systems. Satellite data (NOAA and JAXA) is used to supplement this information because high mountains block radar coverage in some areas. All meteorological and hydrological data received from national and international sources are input into hydrological models (FEWS, Indus-IFAS and FFGS) to forecast flash and riverine floods (Figure 7.2). New S-band radars in Islamabad and Karachi, along with planned installations in Multan and Sukkur, will improve coverage. PMD also uses lightning detectors nationwide for improved forecasting.

PMD is implementing the **Hydromet and Disaster Risk Management Services Project**, which aims to enhance PMD's capacity, and supports the adoption of advanced technology for timely and reliable hydro-meteorological and disaster risk management services. The project will improve community resilience against climate risks, including health emergencies, food security challenges and natural disasters. Key interventions include the installation of weather radars (Cherat, Gwadar, Sialkot and Quetta), high-frequency radars for tidal monitoring, 300 automatic weather stations (AWS) nationwide, and a high-performance computing (HPC) system for weather prediction and flood inundation modelling. The project will also develop impact-based agriculture and climate advisory services.

Under the updated **National Flood Protection Plan IV**, work is underway on the installation of 8 new weather radars, 707 flood telemetry stations, 6 new regional flood forecasting centres, 262 new AWSs for remote areas and the upgradation of WAPDA's surface water hydrology stations.

Figure 7.2: Flood early warning system used by PMD



SUPARCO plays a crucial role in systematic observation through **satellite technology and remote sensing**. Pakistan's earth observation satellites provide data on land use, deforestation, sea surface temperatures and water bodies. SUPARCO's satellite imagery has been key in monitoring deforestation in the northern regions and assessing land-use impacts on climate and ecosystems. National organisations like WAPDA, PMD, GCISC and NDMA, along with academic institutions, use these satellite images for hydrology, water management, agriculture, forestry and coastal assessments. The National Emergency Operations Centre (NEOC) uses satellite data for analysis to support disaster preparedness and response.

7.3.3 Disaster preparedness and management

PMD's **Flood Forecasting System** works closely with organisations like WAPDA and NDMA to integrate data and improve disaster preparedness. The Flood Forecasting Division (FFD) collects weather, climate and hydrological data from various sources, which is used by civil society organisations for disaster mitigation. NDMA plays a key role in coordinating and disseminating information to the public, media and relief agencies, while NEOC utilises technology for impact-based forecasting and early warnings.

The **Federal Flood Commission** (FFC) coordinates flood protection planning at the national level, ensuring collaboration between federal and provincial organisations. The FCC also plays a role in systematic monitoring through the following activities:

- Flood data collection and analysis: monitoring river flows, flood-prone areas and water levels using hydrological data from WAPDA and PMD
- Coordination of flood early warning systems: integrating meteorological forecasts from PMD and hydrological data from WAPDA to issue national flood advisories
- Monitoring of flood control infrastructure: overseeing the performance of embankments, barrages and dams through collaboration with NHA and provincial irrigation departments
- National flood risk assessments: compiling flood vulnerability reports and maps to support preparedness and planning
- Evaluation of flood management strategies: conducting post-flood impact assessments to refine flood routing protocols and mitigation measures.

Flood management, including routing floodwater, is primarily handled by provincial bodies and federal agencies like WAPDA, PMD and NHA. PMD's early warning systems for GLOFs and other hydro-meteorological disasters have been highly effective, preventing casualties and enabling proactive disaster management.

7.3.4 Water resource management and glacier monitoring

WAPDA's **Glacier Monitoring Research Centre** (GMRC), established in 2012, monitors glaciers in the Karakoram region and collects data from 20 AWSs in the Upper Indus Basin (Figure 7.3). GMRC, in collaboration with national and international partners like PMD, GCISC, NARC, ICIMOD, UNDP, USAID and FAO, assesses climate change impacts, generates river flow forecasts and conducts risk assessments for glacial lakes and landslides to inform water resource management and early warning systems. Key activities include ablation studies on glaciers, snout surveys, glacial lake monitoring, isotope analysis and permafrost monitoring. This also enables forecasting of water

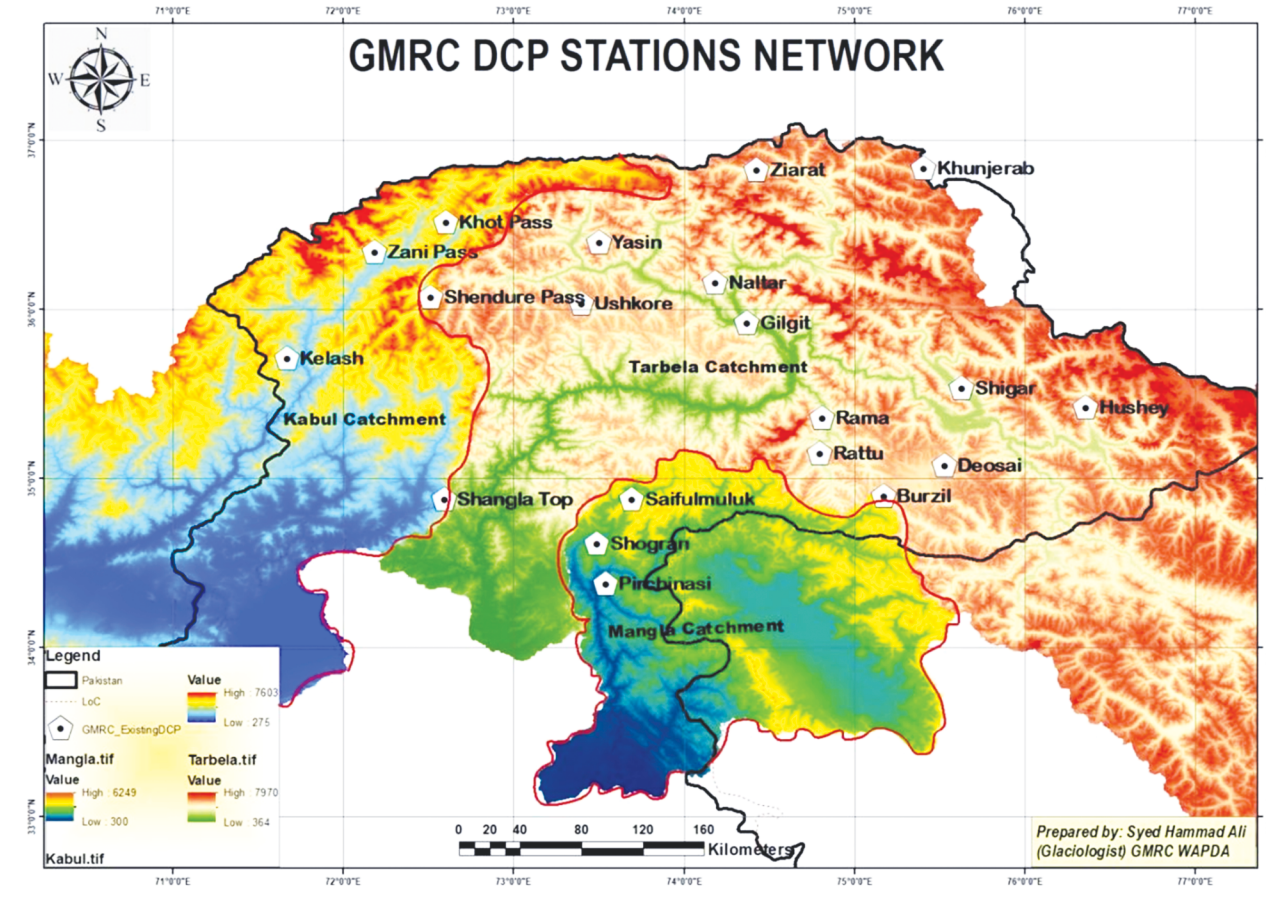
availability for the Indus River, crucial for hydropower development. In collaboration with SUPARCO, GMRC conducted a study on the hydro-meteorological impacts of climate change on river flows in the Hunza and Astore basins. SUPARCO also developed the Google Earth Engine Glacier Velocity (GEEG-Vel) method to monitor glacier dynamics, providing accurate insights into the effects of climate change on glaciers.

While primarily engaged in research, the **Pakistan Council of Research in Water Resources** (PCRWR) contributes to systematic observation by deploying hydrological monitoring instruments as part of its research studies and projects. These instruments collect data on groundwater levels, surface water availability and water quality, supporting early warning systems and national water management strategies.

Similarly, **Water Informatics and Technology** (WIT) at LUMS enhances systematic observation through IoT-based sensor networks that monitor stream flows, groundwater levels and climate variables in real time. These data streams improve the accuracy of hydrological assessments and water resource planning.

The **International Water Management Institute** (IWMI) runs the **Water Resource Accountability in Pakistan** (WRAP) programme, which integrates systematic observation by using remote sensing, satellite-based monitoring and field data collection to track water distribution, flood risks and groundwater trends. This integrated approach supports data-driven water management and planning. The **International Centre for Integrated Mountain Development** (ICIMOD) contributes to glacier monitoring and water resource

Figure 7.3: Network of data collection stations in Upper Indus Basin



management in the Hindukush-Karakoram-Himalaya region, using remote sensing and field research to track glacier melt and assess GLOF risks.

7.3.5 Coastal and sea level monitoring

The **National Institute of Oceanography** (NIO) systematically monitors coastal areas, focusing on sea-level changes, coastal erosion and ocean currents. NIO data is crucial for understanding the impacts of rising sea levels to inform climate-resilient coastal projects. NIO's scope includes the study of coastal erosion, deposition, sedimentation and anthropogenic changes resulting from urbanisation. Its biological research includes investigation of spatial and temporal variations in the distribution and breeding patterns of marine organisms in both coastal and deep waters, primary productivity in coastal waters, food web dynamics, and mangrove ecosystem studies in nearshore environments. NIO also studies ecological problems caused by industrial and recreational activities.

The PMD's **Marine Meteorology Office** in Gwadar and **Tropical Cyclone Early Warning Centre** (TCWC) in Karachi play a vital role in forecasting tropical cyclones and marine weather conditions. Specialising in early warnings, TCWC protects maritime activities and coastal communities, making a significant contribution to disaster preparedness and resilience in the maritime domain.

7.3.6 Ecosystem and biodiversity monitoring

Various national and provincial organisations are engaged in ecosystem and biodiversity monitoring. At the federal level, the **Ministry of Climate Change** (MoCC) oversees biodiversity conservation policies and international commitments, while the **Zoological Survey of Pakistan** conducts systematic monitoring of wildlife populations, migratory species and habitat conditions across the country. The jurisdiction of the **Pakistan Environmental Protection Agency** (Pak-EPA) is limited to the Islamabad Capital Territory (ICT).

Biodiversity and environmental monitoring at the provincial level falls under the respective **provincial and regional environmental protection agencies** (EPAs) and **forest and wildlife departments**. These provincial agencies manage protected areas, conduct biodiversity assessments and implement conservation initiatives. The Sindh forest department also contributes to ecosystem monitoring through mangrove conservation and wetland management programmes along the coastal belt.

Pak-EPA is responsible for **water and air quality monitoring** within ICT. In the provinces and regions, this role is carried out by the respective provincial EPAs. These agencies conduct ambient air quality assessments, industrial emissions monitoring and water pollution control within their jurisdictions. Air quality monitoring is also performed by universities, research institutions and private sector initiatives through low-cost sensor networks and automated monitoring stations in major urban centres.

Other organisations and entities involved in environmental monitoring include Clean Air Asia and ICIMOD (air quality), GCISC (climate change impacts), and UNICEF and SDPI (health impacts of pollution).

7.4 Research and observation to tackle climate challenges

Table 7.7 provides a summary of major climate-related challenges, the research and observation efforts addressing them, and the organisations responsible.

Table 7.7: Research and systematic observation on climate challenges

Challenge	Type of research/systematic observation	Organisation responsible
Glacial melt and water availability	Glacier monitoring, hydrological modeling and GLOF risk assessments	GMRC-WAPDA, PMD, SUPARCO, ICIMOD, UNDP
Flooding and extreme weather events	River flow monitoring, flood forecasting, early warning systems	PMD, NDMA, WAPDA, SUPARCO
Drought and water scarcity	Groundwater and surface water monitoring, drought impact studies	PCRWR, WAPDA, PMD, provincial EPAs
Air quality and urban pollution	Ambient air quality monitoring, emissions assessments, satellite-based pollution tracking	Pak-EPA (ICT), provincial EPAs, SUPARCO, universities, private sector
Coastal erosion and sea level rise	Remote sensing of coastal changes, sea-level monitoring, coastal ecosystem studies	NIO, PMD, SUPARCO, IUCN
Agricultural vulnerability to climate change	Climate-smart agriculture research, crop modeling, soil moisture monitoring	PARC, SUPARCO, IWMI, FAO
Biodiversity and ecosystem changes	Wildlife and habitat monitoring, mangrove conservation, species population assessments	MoCC, Zoological Survey, provincial wildlife and forest departments, IUCN
Heatwaves and rising temperatures	Temperature pattern analysis, urban heat island effect studies, climate projections	PMD, GCISC, SUPARCO, universities

8

Other relevant information

8.
Other relevant information

This chapter discusses cross-cutting themes and activities that are relevant for effective climate action. These include public awareness, education and training; networks for knowledge sharing; and the role of women in climate action.

Findings in this chapter are based on a series of surveys conducted to obtain stakeholder feedback on each theme, supplemented by desk research. Five surveys were carried out:

- Assessment of Public Awareness Level of Climate Change in Pakistan (2,000+ respondents)
- Assessing Implementation of Education, Training and Public Awareness Activities on Climate Change in Pakistan (175+ organisations)
- Climate Change-Related Capacity Building Activities in Pakistan (70+ organisations)
- Knowledge and Information Sharing, and Networking on Climate Change (70 organisations and/or networks)
- Gender Equality and Women's Empowerment on Climate Change Issues (300 households).

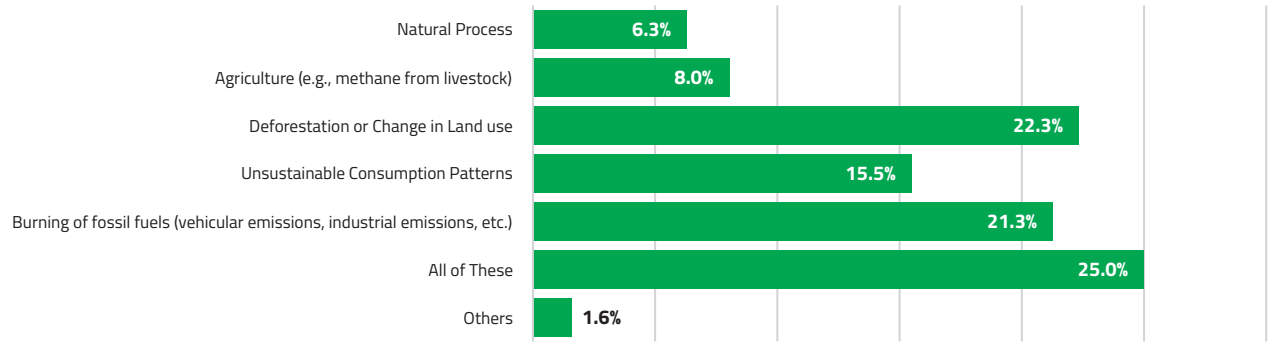
Survey methodologies and key findings are discussed in the sections that follow.

8.1 Public awareness of climate change

A national survey was conducted, reaching more than 2,000 respondents. To ensure geographic coverage and diversity of respondents, a hybrid method was used involving in-person interviews as well as digital platforms (email, social media). The questionnaire was also made available in Urdu, for ease of comprehension. The highest number of responses (61.6%) came from Punjab, followed by the Islamabad Capital Territory (15.2%), Sindh (9.6%), KP (5.7%), Balochistan (3.1%), GB (2.6%) and AJK (2.2%).

The overwhelming majority (99%) of respondents believe that climate change is taking place, with 22.3% identifying deforestation and land use changes as the primary cause, 21.3% identifying the burning of fossil fuels and 15.5% naming unsustainable consumption patterns (Figure 8.1). Only 6.3% attribute climate change to natural processes.

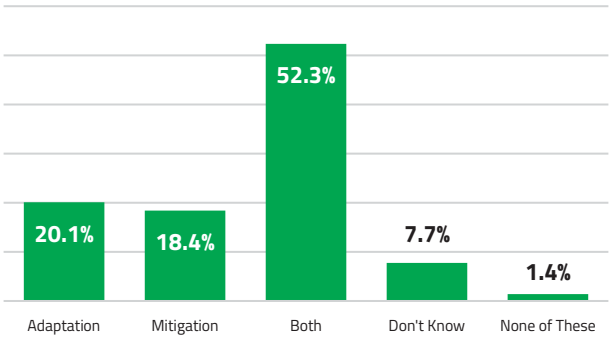
Figure 8.1: Causes of climate change



With regard to climate-related changes observed over the last five years, 17.3% note a rise in temperatures and 16.0% report a change in rainfall, followed by flash floods (11.6%) and water scarcity (13.2%) (Figure 8.2). Other observed changes are region-specific and include forest fires (8.7%), droughts (8.0%), GLOFs (6.6%) and epidemics (6.3%).

Respondents were asked to rate their knowledge on various environmental and climate-related issues. Based in their own assessment, the largest number are aware of pollution (water, air, land), while awareness of carbon footprints, disaster risk management and sustainable development is poor. With respect to climate action, 75% of respondents report knowledge about the concept of adaptation and 67% about mitigation. In terms of national priorities, 20.1% believe Pakistan should prioritise adaptation, 18.4% believe mitigation should be the priority and 52.3% think both are equally important (Figure 8.3). The vast majority believe that all stakeholders are equally responsible for climate action, followed by the government, the public and business/industry.

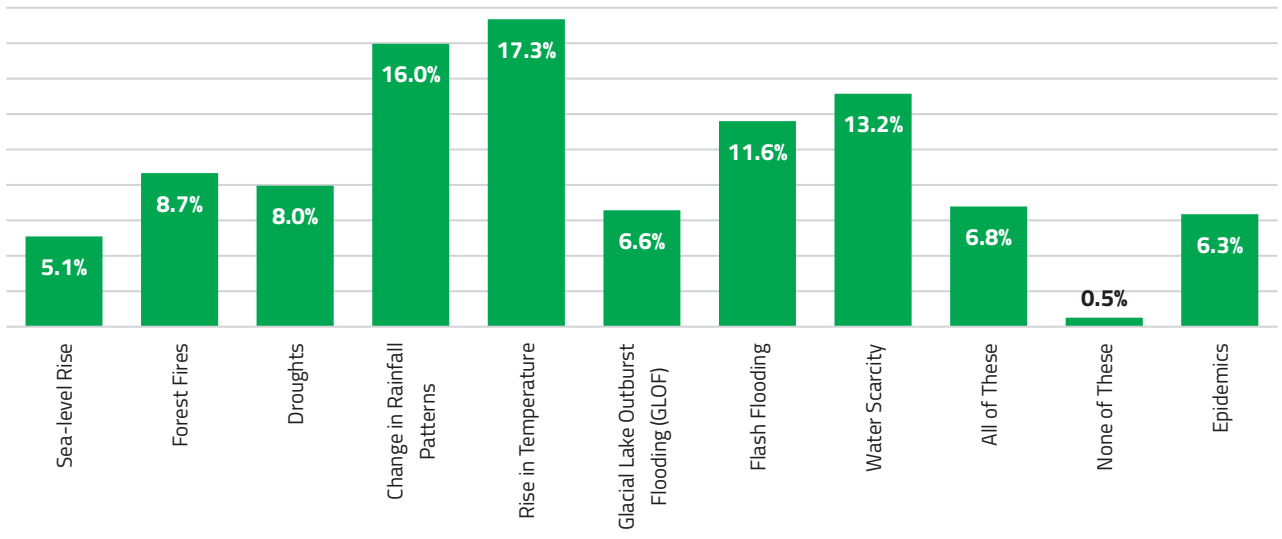
Figure 8.3: Prioritisation of climate action



Awareness of climate change campaigns in Pakistan is divided, with 59% of respondents answering in the affirmative and 41% in the negative. Awareness of climate change-related activities, policies and international commitments is low, with just 14.3% aware of the National Climate Change Policy and 14.5% reporting they are not aware of any relevant policy documents.

With respect to information on climate change, digital platforms (internet, social media) are the primary source (27%), followed by television (12%), academic literature (12%), newspapers (10%) and seminars/workshops (10%) (Figure 8.4). This confirms that the internet and social media are

Figure 8.2: Observed climate-related changes in the last five years



critical tools for effective climate change communication campaigns.

8.2 Education, training and public awareness initiatives

A number of initiatives on climate change education, training and public awareness have been implemented across the country (see Annex E). To assess their implementation and effectiveness, more than 175 key stakeholder organisations from across Pakistan were surveyed. The largest number of responses came from government organisations (44%), followed by academia (19%), civil society (19%), the corporate/private sector and other sectors (18%). Survey findings were supplemented with desk research on policies and interventions.

8.2.1 Policies on climate change education

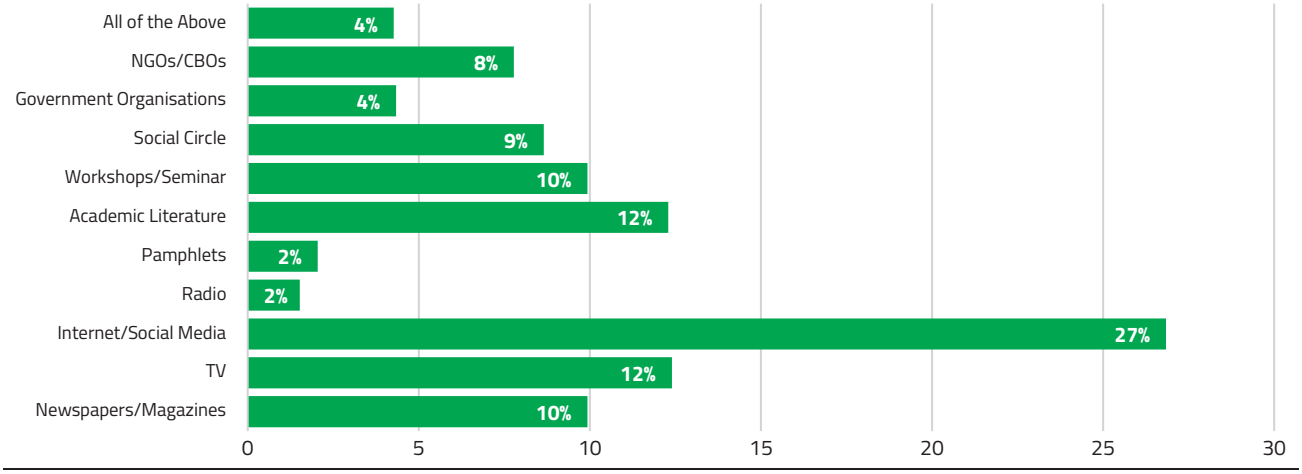
National and provincial climate policies emphasise the importance of integrating climate change education into all levels of the system, from primary school to university. The National Environment Policy calls for environmental education at all levels, while the National Climate Change Policy underscores the importance of raising awareness and building institutional capacity. The Nationally Determined Contributions recommends the inclusion of climate change in secondary school curricula and specialised courses at higher education institutions. Provincial policies also highlight the importance of climate change awareness and capacity building, with initiatives to promote gender-responsive measures and enhance public and stakeholder knowledge.

Survey findings suggest that while national and provincial policies emphasise the importance of integrating climate change into education, interventions like the Single National Curriculum have limited focus on climate change. A significant percentage of stakeholders believe current climate change education policies are insufficient. There is a recognised need for deeper integration and consistent implementation of climate change education and capacity building at all levels.

8.2.2 Policy implementation

Despite efforts to integrate climate change into learning activities and materials, meaningful integration is limited and remains superficial. Respondents point to a number of constraints when it comes to implementation of policies on climate change education. These include poor coordination between stakeholders (73%), lack of

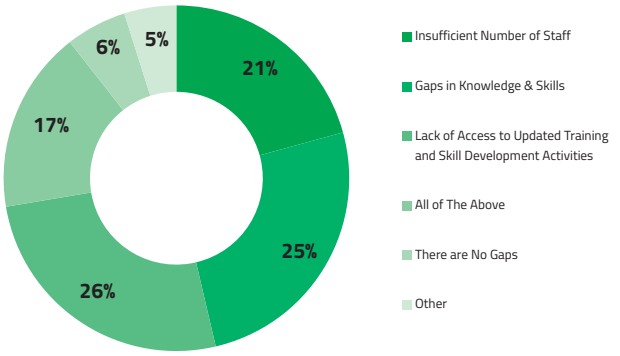
Figure 8.4: Sources of information on climate change



financial resources (70%) and lack of government willingness (68%). Other issues include inadequate monitoring (65%), lack of human resources (64%) and lack of infrastructure (53%). Only 37% of respondents believe lack of technical resources is an issue (Figure 8.5).

The most common human resource capacity issues identified are lack of access to updated training (26%), and gaps in knowledge and skills (25%), followed by insufficient staff (21%) (Figure 8.6).

Figure 8.6: Human resource capacity gaps



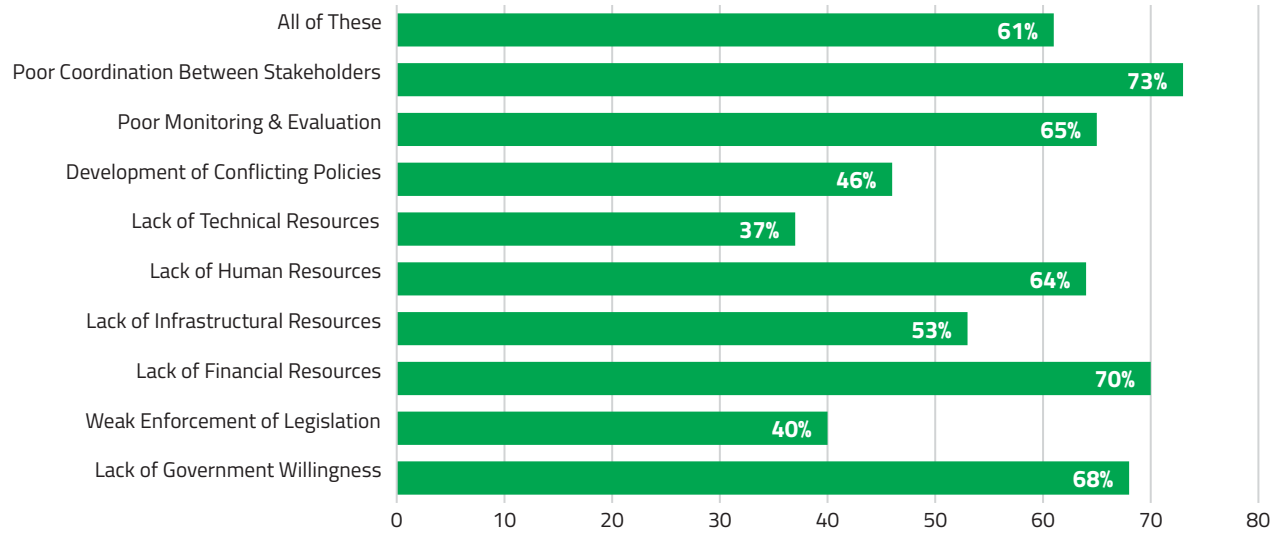
With respect to technical and infrastructure capacity requirements, most organisation indicate a lack of funding (30%), followed by a lack of physical resources (e.g., space, equipment), the need for technological support (e.g., ICT, Internet), and the absence of a monitoring and evaluation system.

It is pertinent to note that addressing gaps in climate change training, education and awareness is crucial for effective action. Bridging these gaps requires resources and targeted interventions. Implementation hurdles include limited government willingness and organisational deficiencies. Improved data collection and monitoring, and better coordination are also critical.

There is a need to prioritise the integration of climate change as an underlying theme in all policies, plans and programmes related to education, training and public awareness. This includes restructuring the curriculum to include climate-related themes, and developing pathways of non-formal education that can cater to vulnerable populations. Programmes need to be more hands-on and context-specific, in local languages, and aligned with cultural norms.

It is also important to develop an effective plan for implementation. This would include training teachers and community members (leaders,

Figure 8.5: Constraints in implementation of policies on climate education



women, young people, religious leaders) to be able to transfer knowledge and skills, along with the development of relevant learning materials.

To address the need for financial resources, government allocations should be supplemented with donor-funded grants and investment from the private sector. Public-private partnerships can also be useful to mobilise technical and infrastructure resources. To assess the impact of interventions and ensure transparency in spending, robust monitoring and evaluation systems should be developed. This is only viable if all key stakeholders work collaboratively, instead of in silos as is observed currently.

8.2.3 Status of climate change education

Of the organisations surveyed, 81% offer climate change learning activities primarily targeting youth (30%), followed by business/industry (23%). Key objectives are sensitisation and awareness raising (87%), and knowledge dissemination (65%) (Figure 8.7).

The majority of organisations develop climate-related publications, including guides and manuals, and offer e-learning courses. Most address multiple climate-related themes (Figure 8.8). Many organisations have plans to enhance expand coverage and increase offerings.

Figure 8.7: Type of activities or courses offered

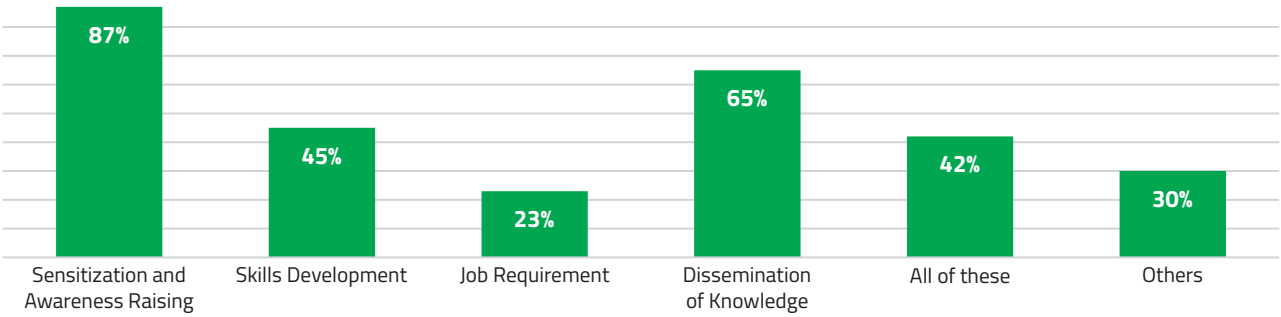
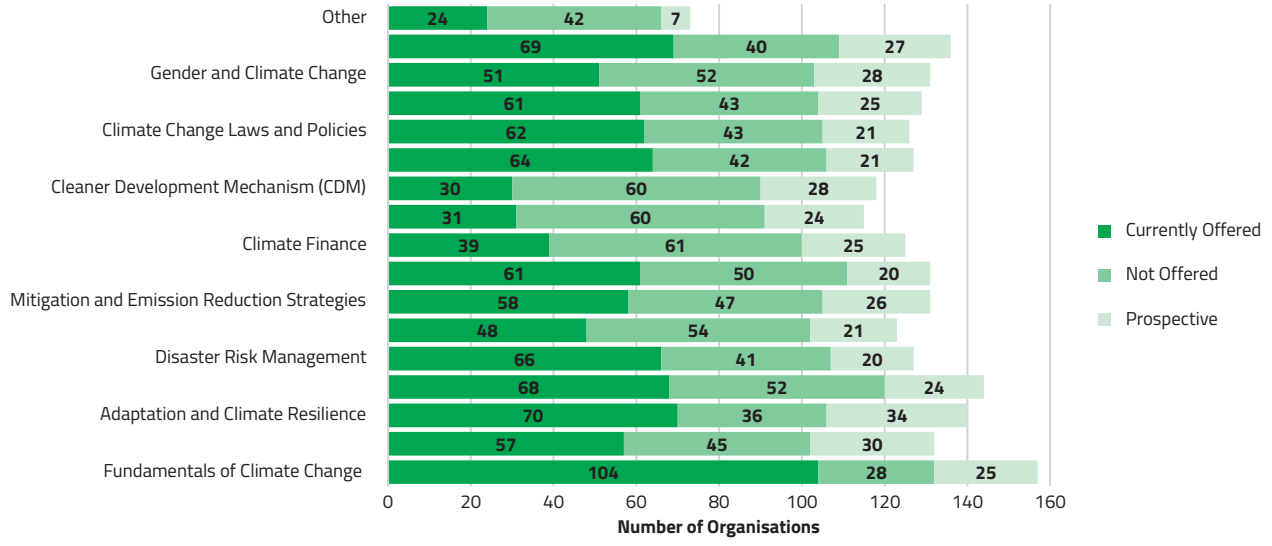


Figure 8.8: Thematic areas of learning materials



8.3 Capacity building

A national survey of more than 70 organisations from relevant sectors was conducted to assess current capacities and needs. Respondents belonged to key sectors related to climate adaptation and mitigation, including agriculture, energy, industry, transport, water, forestry and waste management. Questions were related to ongoing and planned capacity-building activities, gaps, and sector-specific needs.

8.3.1 Policies on capacity building for climate action

The National Climate Change Policy notes the scarcity of national climate change experts and the lack of institutional capacity to address climate issues. It calls for capacity enhancement through training, networking and regional knowledge sharing. The Framework for Implementation of Climate Change Policy emphasises the importance of capacity development for key sectors like water, agriculture, disaster preparedness and energy. The NDCs also acknowledge Pakistan's need for capacity building in order to fulfil its climate commitments.

8.3.2 Planned and on-going capacity building initiatives

The majority of organisations surveyed provide some type of climate-related capacity building for their workforce and well as externally. These activities cover the following themes, as identified by respondents:

- Agriculture: sustainable practices to mitigate GHG emissions while ensuring food security and resilience of farming systems
- Water: management, distribution, conservation and purification of water resources, addressing challenges such as access to clean water, sustainable use, infrastructure, availability and quality
- Energy: generation, distribution and utilisation of diverse energy sources, with emphasis on sustainability and the transition to renewable sources (household, industry, transport)
- Health, safety and environment: safeguarding human well-being, ensuring workplace safety and preserving the natural environment by implementing regulations, protocols and measures to minimise risks and promote sustainable practices across various industries
- Sustainability and plastics: reducing plastic pollution, promoting recycling, innovation for biodegradable alternatives, adopting circular economy principles to minimise environmental impact
- Disaster management: proactive planning, response and recovery efforts to minimise impact of disasters on communities, preparedness to build resilience of infrastructure, coordinated emergency response strategies
- Climate change and finance: mobilisation and management of funds to addressing climate-related challenges, supporting mitigation efforts, facilitating adaptation measures, promoting sustainable development
- Emissions: systematic measurement, monitoring and reporting of GHG emissions from human activities to understand and manage their impact.

8.3.3 Capacity building needs

While both the government and non-government organisations implement capacity development initiatives, frequency and effectiveness of these activities limited, as reported by respondents.

There is a significant absence of needs assessments at the organisational level, with 75% of organisations admitting to not having conducted capacity needs assessments related to climate change. Not surprisingly, 81% of organisations find existing capacity-building activities inadequate, with only 19% reporting being satisfied. These findings emphasise the urgency of prioritising capacity development based on comprehensive needs assessments across sectors.

Key challenges in capacity development include insufficient funding (25%), lack of skilled human resources (16%), limited access to technology and physical resources (16%), and lack of information about capacity building opportunities (14%) (Figure 8.9). To overcome these challenges, priority should be given to enhancing funding, building technical expertise and improving data systems.

8.3.4 Support required for capacity building

Respondents identify a number of areas where capacity development support is required (Table 8.1). Besides sector-specific needs, capacity development is also required for essential non-technical skills such as communications, negotiation and fundraising.

8.3.5 Priorities for capacity building activities

Respondents recommend enhancing capacity-building efforts across sectors, with a focus on training of trainers (18%), alignment with organisational needs (17%) and creating platforms for coordination (17%) (Figure 8.10). Other recommendations include institutionalising climate change across public and private institutions, appointing permanent climate change focal persons and increasing awareness within institutes.

Figure 8.9: Challenges in Capacity Development

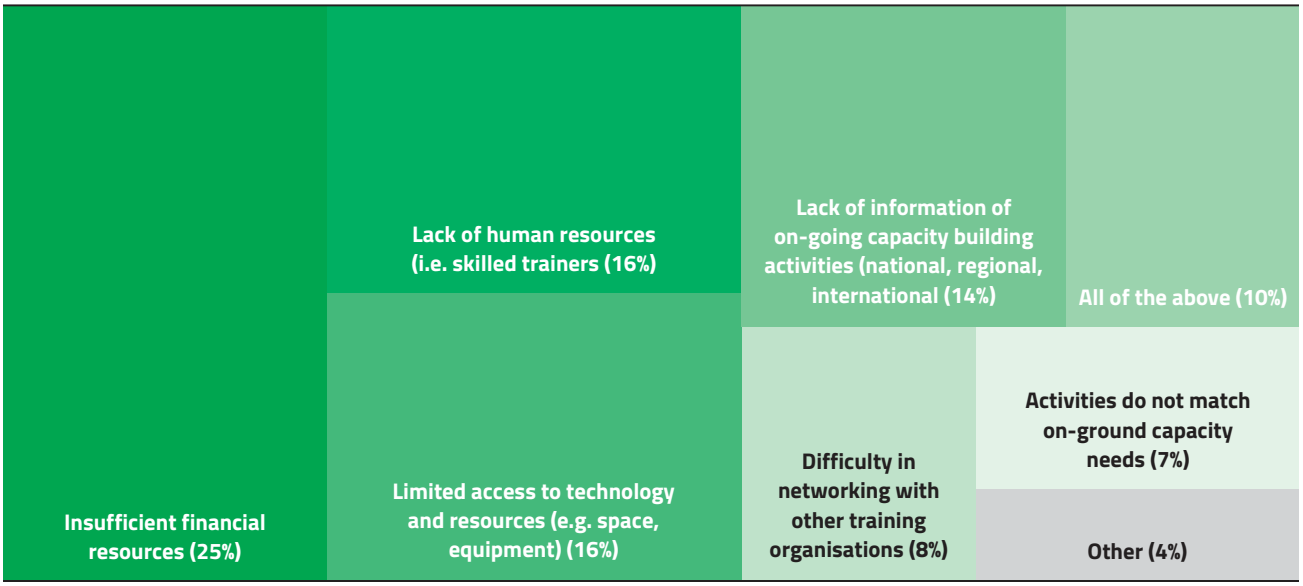
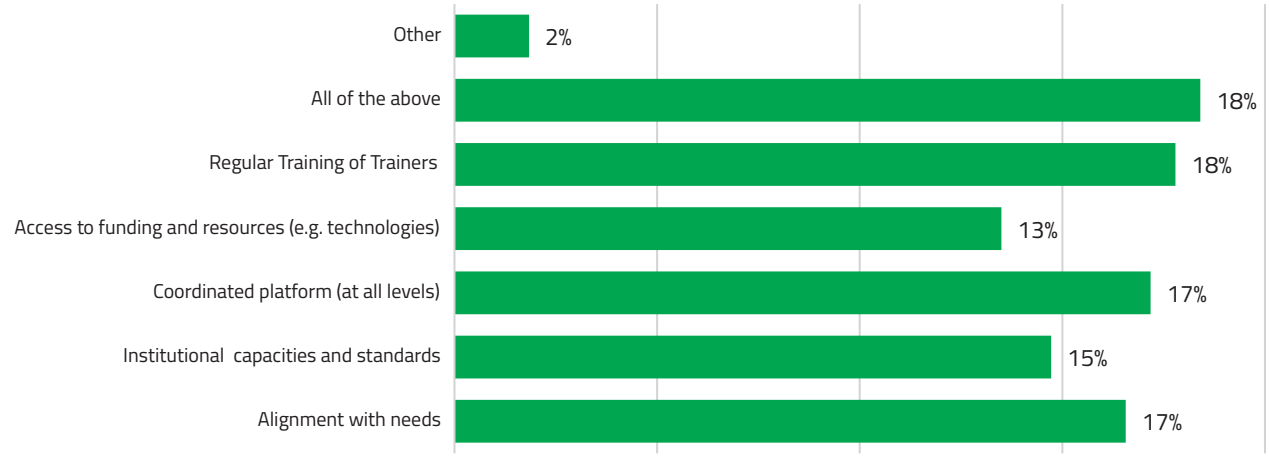


Table 8.1: Capacity development needs

Mitigation	Adaptation
Water management	
• Groundwater management • Efficient water usage and storage	• Mapping of water resources • Wetland rehabilitation • Water-sensitive forest management
Disaster risk resilience	
• Flood mitigation models • Infrastructure resilience	• Mass awareness • Early warning systems • Weather forecasting for agriculture • Community-based skill development • Plans for minimising loss and damage
Waste management	
• 3Rs (reduce, reuse, recycle) • Circular economy • Sustainable fleet management	• Resilient waste infrastructure and management systems
Industry	
• Environmental, social and governance (ESG) • Training in clean development mechanisms • Governmental capacity building for regulation • Proposal writing for securing funds for projects	• Updated curriculums and trainings for climate-resilient industries • Proposal writing for securing funds for projects • Localising technology
Energy	
• Awareness of green energy transitions • Carbon/renewable energy credits • Renewable energy procurement plans • Renewable financing models • Energy efficiency • Energy management • Energy audits • Zig-zag brick kilns	• Resilient energy infrastructure • Diversification of usage of energy resources • Renewable infrastructure
Agriculture and forestry	
• Solar water pumping • Climate-smart agriculture • Forest inventory and biomass calculation • Sustainable management practices	• Aerobic rice production • Crop monitoring • Community-based range improvement interventions. • Direct seeded rice technology • Mixed crop livestock in a rangeland-based system. • Pest and disease management • New plant varieties • Indigenous conservation

Figure 8.10: Recommendations to improve capacity building



8.4 Knowledge, information sharing and networking

Pakistan participates in a number of national, regional and international knowledge-sharing networks and climate initiatives (see Annex F). To gain a better understanding of Pakistan's involvement in these platforms and networks, a country-level online survey was conducted, inviting members and representatives of 70 organisations to participate. The survey aimed to gather insights into the role, contribution and networking practices of Pakistani organisations within the climate change domain.

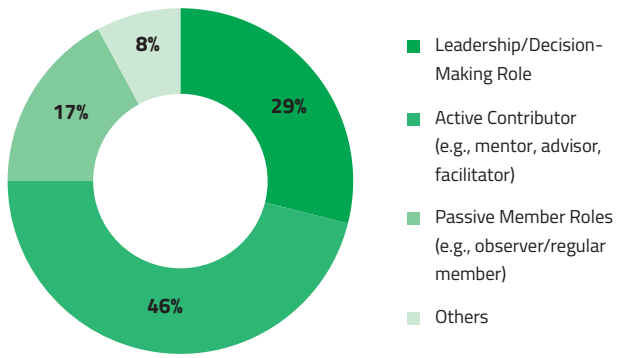
8.4.1 International and regional cooperation

Through the **National Plastic Action Partnership Pakistan**, in collaboration with the World Economic Forum, efforts are underway to combat plastic pollution. Pakistan's commitment to the **Global Methane Pledge** involves ambitious targets to reduce methane emissions. Pakistan also played an important role in the creation of the **Loss and Damage Fund** at the 27th Conference of Parties (COP 27). The **Indus Basin Initiative Pakistan** aims to understand climate change impacts and build community resilience through research and regional cooperation. As a member of the **Climate and Clean Air Coalition**, Pakistan has committed to reducing emissions by at least 30% by 2030.

8.4.2 National and international information networks

Survey results show that more than 60% of organisations are members of national and/or international climate change networks. Additionally, 33% participate in regional and 32% in local networks, while others engage through social media and academic institutions. Of those surveyed, 29% of organisations take the lead in engagement, 46% describe their role as active contributors and 17% participate as observers or regular members (Figure 8.11).

Figure 8.11: Engagement in climate-related networks



The most common subject areas for information and knowledge exchange networks are water management, nature-based solutions and waste management, followed by energy, agriculture, disaster preparedness, industry and resilient infrastructure. Most organisations are involved in multiple areas, indicating broad engagement across climate-related networks.

A significant percentage of these networks focus on facilitating knowledge exchange (74%) and coordinating climate action initiatives (70%) (Figure 8.12). Other areas of work include collaboration on adaptation and mitigation strategies (61%), capacity building (53%) and region-specific issues (50%).

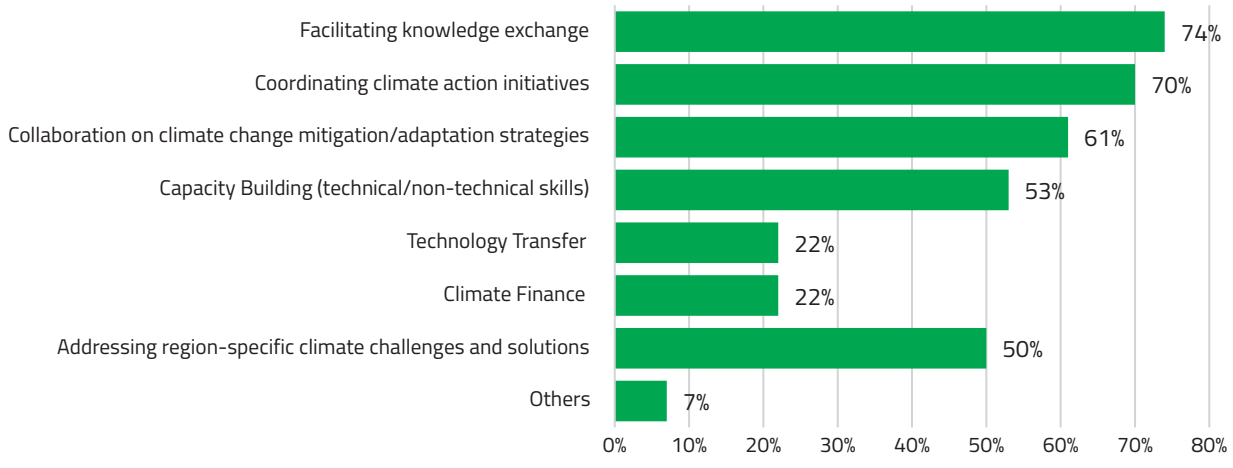
8.5 Gender equality and women's empowerment on climate change issues

This section discusses gender equality in the context of climate change in Pakistan. The analysis was developed through a combination of desk review and field surveys.

For the desk review, national climate and gender policies and plans were studied to assess gender responsiveness at the country level, and to identify gaps and challenges.

The purpose of the survey was to gain a better understanding of gendered aspects of climate-related issues and interventions at the community level. The survey was conducted in 300 households belonging to climate-vulnerable communities. A representative sample of 30 to 45 women per village/district was developed, based on convenience sampling. Local organisations and WWF-Pakistan's network of field offices provided support in reaching hard-to-access areas. The study was conducted in climate-vulnerable communities across Pakistan, including Lasbela (Balochistan); Bagnotar and Chatarnath in Abbottabad district, and Madyan in the Swat valley (KP); Taunsa and Lahore (Punjab); Karachi, Keti Bunder, Nagarparkar and Babo Dablo (Sindh); and multiple locations in GB. Survey areas were chosen based on high exposure to climate risks such as floods, heatwaves, droughts, water scarcity, GLOFs and extreme weather events. The classification took into account socio-economic vulnerabilities, with a focus on women and marginalised groups who are disproportionately affected by climate change impacts.

Figure 8.12: Objectives of networks and platforms



8.5.1 Impacts of climate change on women and marginalised groups

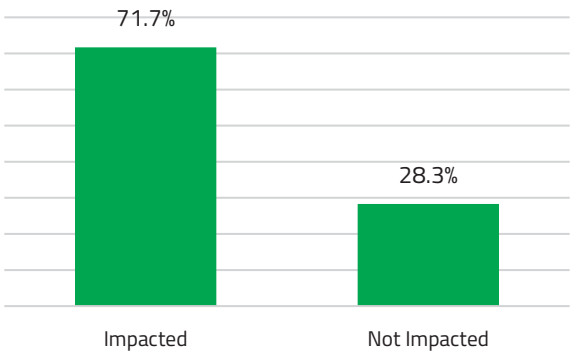
Climate change reduces crop yields and livestock productivity, exacerbating food insecurity and poverty. Women, who play a crucial role in agriculture, face resource access challenges and an increased burden of work due to water management and other climate-related challenges (IFAD, 2020; Kakar, 2019). Women and children also face increased health risks in the aftermath of extreme weather events, such as from waterborne diseases (SRSP, 2022). Gender-based violence is known to escalate in situations of precarity, including as a result of climate change impacts, displacement and migration (UN Women, 2022).

Survey results show that 37.3% of respondents identify as climate migrants, either currently or in the past. A substantial percentage are aware of climate change, with first-hand experience witnessing climate change impacts within their communities. Respondents report diverse impacts of climate change, with water scarcity, excessive rain and flooding being prominent concerns. Region-specific concerns include storms and rainfall in Sindh, GLOFs in GB and wildfires in KP. Additional climate change impacts observed include temperature fluctuations, altered snowfall patterns, effects on agriculture, health and livelihoods, and increased frequency of extreme weather events. The majority of respondents (77.8%) perceive a disproportionate impact on women, citing increased household responsibilities and challenges in accessing water and sanitation. Only 22.2% believe women and men are equally affected, noting men's work-related challenges and women's dual household and agriculture responsibilities.

8.5.2 Impact of climate change on women's livelihoods

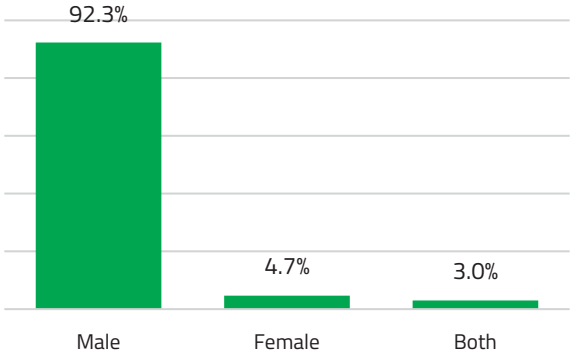
The majority of surveyed households (71.7%) report that their household income and livelihoods are affected by climate change (Figure 8.13). Reported impacts include restricted access to food and water, and limited earning opportunities due to climate-induced events.

Figure 8.13: Climate change impact on livelihoods



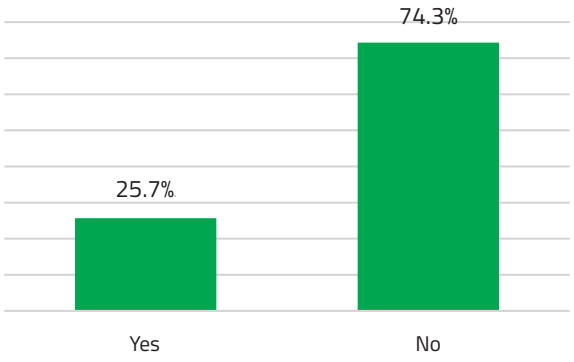
Climate-vulnerable communities are typically in an income bracket far below the national average. Within surveyed households, 92.3% of primary income earners are men (Figure 8.14), with 73% reporting household income between USD 50-110 per month. Only 6.8% report income exceeding USD 175 per month, while 7.5% earn less than USD 50 per month.

Figure 8.14: Primary income earner



Around half (51.9%) of the women surveyed report no additional contribution to the household besides caregiving, while 45.5% report having additional duties such as supporting work in the fields and livestock rearing. The remainder are engaged in community work, mainly unpaid. The majority of respondents (60%) state that women in their households do not receive a monthly stipend from the head of the household, mainly due to poverty, debt or insufficient household income. Rather, it is women who typically contribute to household income. Livelihoods are precarious, with 74.3% of respondents reporting a lack of alternate livelihood opportunities, insufficient savings, no funds to cope with emergencies, or ongoing loan repayments (Figure 8.15). Of the 25.7% with access to emergency funds or alternate income, community or neighbourhood committees are the main source, followed by seasonal activities or temporary labour in cities during times of hardship.

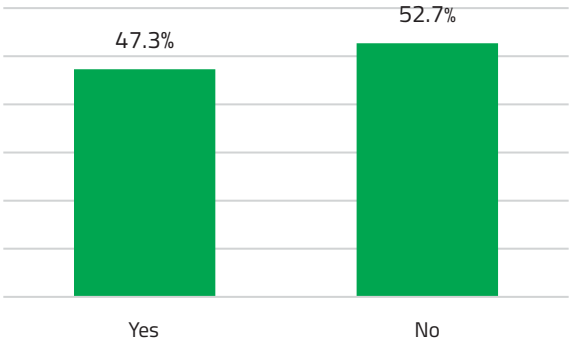
Figure 8.15: Alternate livelihoods and access to emergency funds



8.5.3 Women's access to basic services

With respect to basic services such as clean water and sanitation facilities, 47.3% of respondents report having access, while 52.7% lack access, highlighting the need for targeted interventions (Figure 8.16).

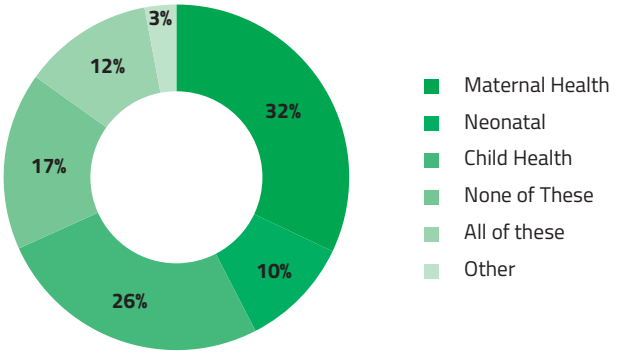
Figure 8.16: Access to resources and basic services



The vast majority (81.2%) report that climate change affects access to basic services. Significant disruptions include access to firewood and other energy sources (74.1%), and access to education as a result of school closures or displacement (27.1%), while 17.3% report slight disruption and 29.5% cite other impacts.

Of the women surveyed, 32% lack access to maternal health facilities as a result of climate-induced disasters, 25.8% face challenges in accessing child health services and 10.4% lack access to neo-natal health services (Figure 8.17).

Figure 8.17: Access to health services

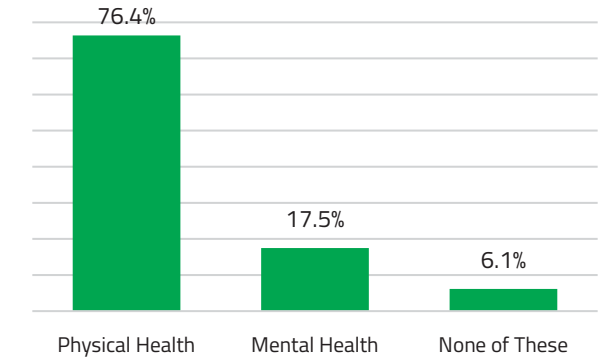


8.5.4 Impact of climate change on women's health

The majority (76.4%) of respondents report health issues due to climate change, including

waterborne disease and heat-related illness, and 17.5% report mental health issues such as emotional trauma and post-traumatic stress in the wake of extreme weather events. Just 6.1% report no mental or physical health impacts (Figure 8.18).

Figure 8.18: Impact of climate change on health



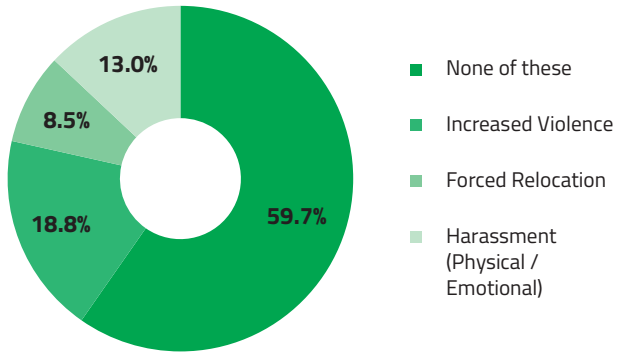
Interestingly, 60.7% of respondents report no loss of life as a result of extreme weather events, while 39.3% report the death of a close or distant relative. Losses are described as being either the direct result of a disaster or indirectly through the increased spread of disease.

8.5.5 Gender-specific challenges related to climate change

The majority (65.3%) of respondents face gender-specific challenges related to climate change, such as increased caregiving responsibilities and difficulty accessing resources. This underscores the need for targeted interventions to address gender disparities in climate resilience.

As many as 18.8% of women report increased violence post-disaster, while 13% report experiencing harassment in non-permanent settlements. Concerns about forced relocation are expressed by 8.5% of respondents, highlighting the need for improved safety measures for vulnerable populations during extreme weather events (Figure 8.19).

Figure 8.19: Safety concerns during extreme weather events



8.5.6 Gender roles in climate change mitigation and adaptation activities

Gender responsive strategies for community-level resilience are critically important. This is supported by survey results, with 46.6% of respondents reporting no strategies in place to cope with climate change effects in their communities. Just 13.1% report that early warning systems are in place in their community. Other community disaster preparedness measures reported include water conservation (12.8%), emergency funds (8%) and dedicated community teams (7%), underscoring the need for resources and training to bolster resilience.

Little support is available either from the government or from NGOs for mitigation or adaptation activities. The vast majority (78.2%) of respondents report no support, while just 21.8% have received some type of assistance. Types of support received include solar-powered water pumps, emergency kits, first-aid training, climate-smart agriculture and cash support for post-disaster rehabilitation. The main areas of support required, as identified by survey respondents, are listed in Table 8.2.

8.5.7 Women's role in decision-making and leadership for climate action

According to the survey, 54% of respondents report that women are included in climate-related decision making, while 46% report that women are not included (Figure 8.20). Meanwhile, the vast majority (84.6%) of respondents confirm their willingness to take leadership roles within their communities for climate action.

Figure 8.20: Inclusion in decision making

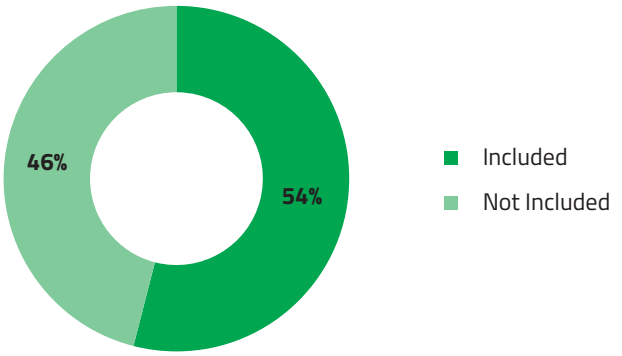


Table 8.2: Support required to build climate resilience

Sector/activity	Type of support required
Agriculture	Resources to enhance crop production
	Climate-resilient agriculture techniques
Cooking	Clean fuel sources to avoid deforestation
Disaster preparedness	Flood protection mechanisms or interventions
Education	Reconstruction of damaged and non-functional schools
Financial support	Purchasing equipment for tailoring and embroidery
	Establishing emergency funds for women
	Construction/reconstruction of homes
Health	Provision and enhancement of basic medical facilities
Infrastructure	Metalled roads to newly elevated houses and
	Water, sanitation and hygiene facilities
Livelihoods	Alternative livelihood options for diversification of income
	Skills centre and training for women (handicrafts, tailoring, embroidery)
Water	Water conservation techniques
	Resources for installation of water pumps
	Measures to address water scarcity
	Clean water supply
Awareness and training	Awareness of climate change impacts
	Training on climate change adaptation and mitigation
	Women- and youth-focused capacity building

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Annexes

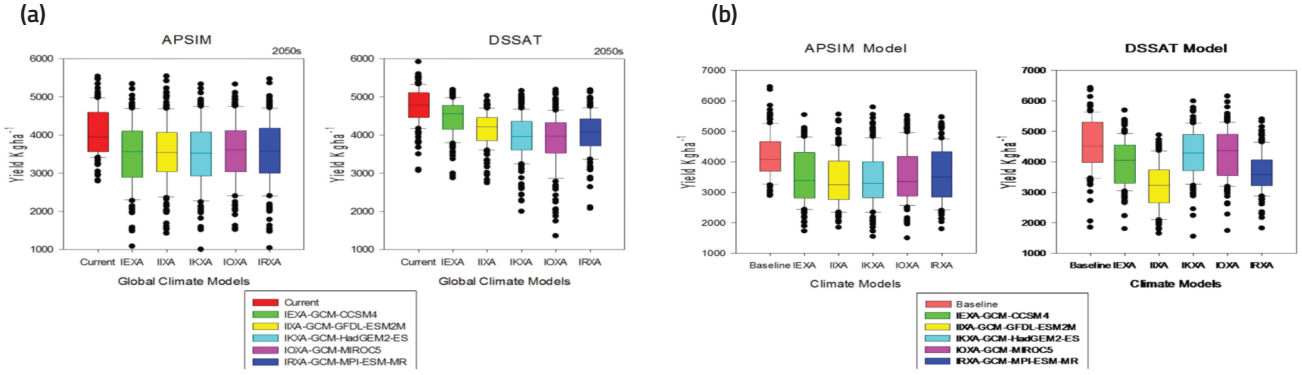
Annexes

Annex A: Climate change impacts on crops

Studies on the impact of climate change on Pakistan's agriculture highlight significant challenges for the country's major crops, including wheat, maize, cotton, rice and sugarcane. Researchers predict a 3°C rise in temperature by 2040, with an additional 5-6°C increase by the end of the century, leading to severe consequences for crop productivity, particularly wheat (Ghanem, 2010). Climate related changes in precipitation and temperature patterns will continue to disrupt the growth stages of crops like cotton, which is expected to be among the hardest hit (Davidson, 2018). Declines of 14.7% in wheat production and 20.5% in rice have already been observed (Haq et al., 2021).

Temperature increases and erratic rainfall have become key issues in Pakistan's agriculture sector, which is divided into 10 agro-ecological zones. Many of these zones, including the Indus delta and northern dry mountains, are highly susceptible to climatic variations that impact crop yields (Khan et al., 2021). Studies using models such as Decision Support System for Agrotechnology Transfer (DSSAT) and The Agricultural Production Systems Simulator (APSIM) predict further reductions in rice and wheat yields, by as much as 15.2% for rice and 14.1% for wheat (Figure A-1) under current climate scenarios (Habib-ur-Rahman et al., 2022).

Figure A-1: Reduction in (a) wheat (b) rice yields simulated by APSIM and DSSAT models, Punjab

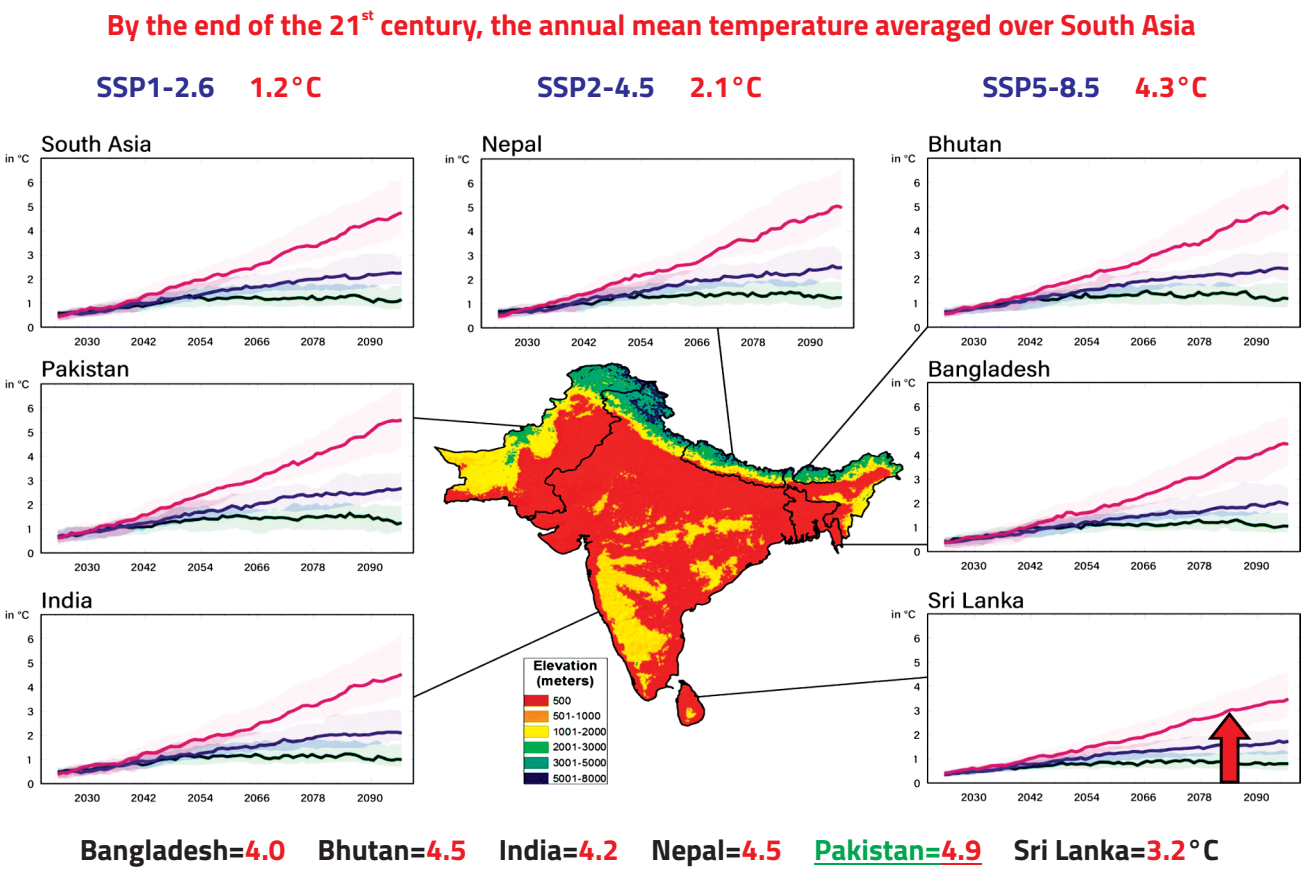


Reduction in wheat yield of APSIM and DSSAT models for 155 farms; variation with 5-GCMs in rice-wheat cropping system of Punjab-Pakistan.

Reduction in rice yield of APSIM and DSSAT models for 155 farms; variation with 5-GCMs in rice-wheat cropping system of Punjab-Pakistan.

Projections from CMIP6 climate models suggest that Pakistan could experience a temperature increase of 4.9°C (Figure A-2), alongside a 26.4% rise in precipitation, leading to more frequent extreme weather events such as floods and droughts (Almazroui et al., 2020). These weather anomalies are already causing crop failures, reducing wheat yields by as much as 14.7% (Haq et al., 2021). Rising temperatures also affect key growth stages like booting and anthesis for crops such as rice, resulting in further yield reductions (Zafar et al., 2018).

Figure A-2: Average mean temperature changes over South Asia



M. Almazroui et al., 2020

Crop-specific vulnerabilities

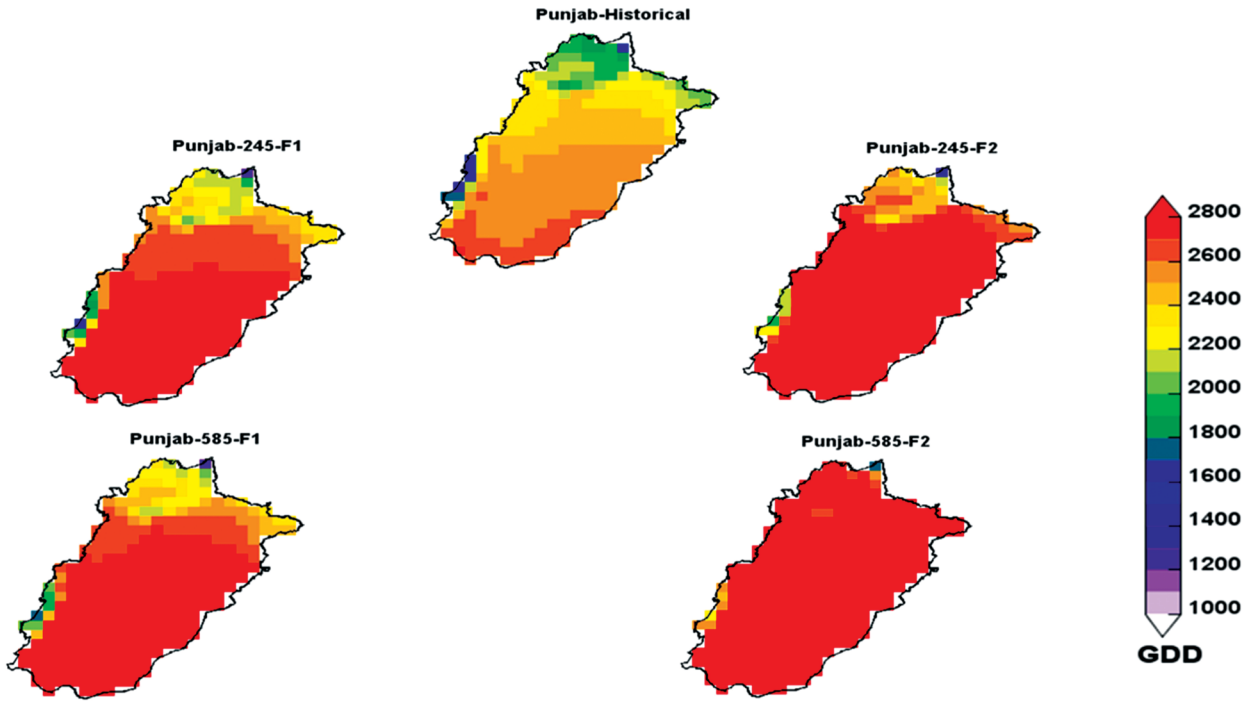
Wheat, rice, maize, sugarcane and cotton are the focus of climate change concerns because of their economic importance and sensitivity to climate stressors (Table A-1). For instance, cotton in southern Punjab and Sindh has seen reduced yields due to early heatwaves. Similarly, sugarcane in Sindh is vulnerable to both waterlogging and drought conditions, depending on the year.

Table A-1: Impact of climate change on crop production

Crop	Growing Area	Projected Yield Changes (%)
Wheat	Semi-arid areas: Faisalabad, Sheikhupura	-3.4 to -12.5
	Arid areas: Badin, Bahawalpur, Hyderabad, Multan	-3.9 to -13.4
Rice	Rice tract: Gujranwala, Hafizabad, Narowal, Sialkot	-10.4 to -21.6
Cotton	Bahawalpur, Multan, Rahim Yar Khan	-31.2 to -38.9
Maize	Okara, Sahiwal	-26 to -34
Crop water requirements: Projected to increase from 5.49% to 10.1% for wheat crop in different agro-ecological zones.		

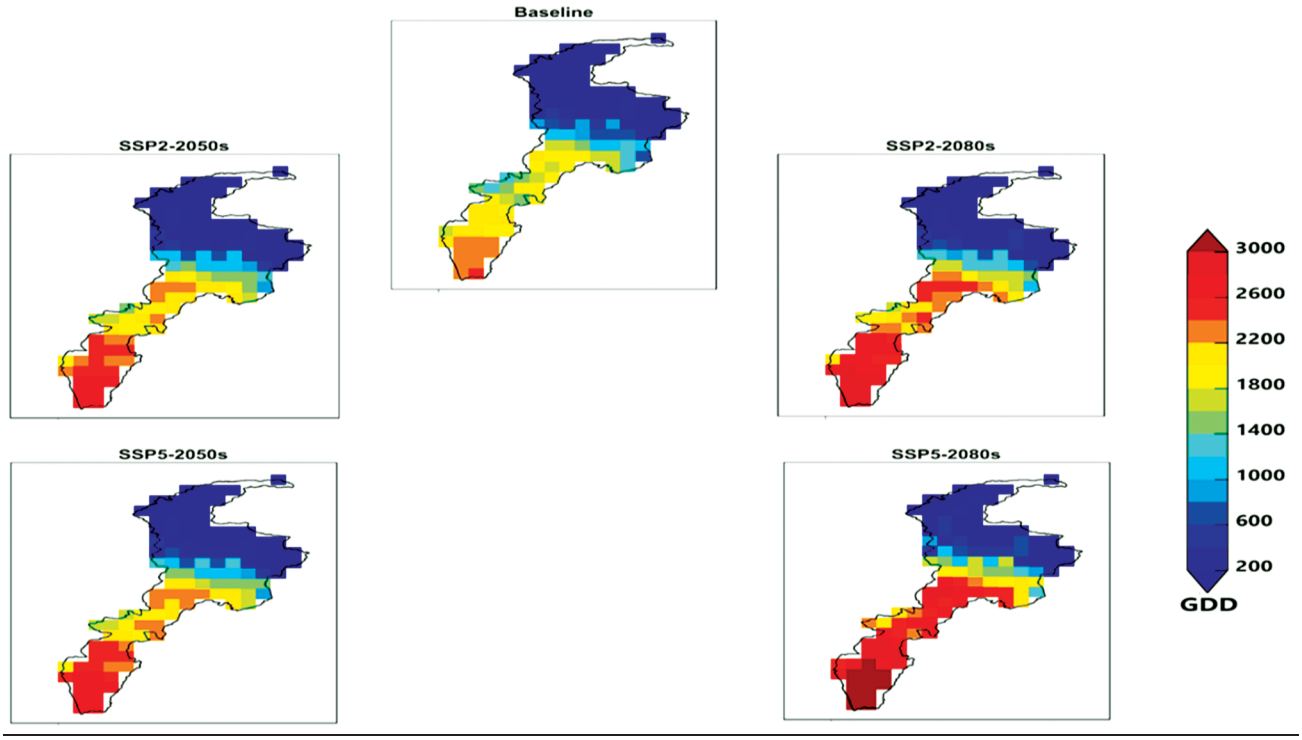
Wheat, a staple crop grown predominantly in Punjab and Sindh, is highly susceptible to rising temperatures, especially during the critical flowering and grain-filling stages. Temperature increases of 1.5°-2.5°C could lead to a significant reduction in wheat yields, particularly in southern Punjab. An analysis of growing degree days (GDD) shows an increase in accumulated growing degree days for both scenarios (RCP 4.5 and RCP 8.5) and time periods (F1 and F2) in all major wheat producing zones of Punjab including the Potohar region, Central and Southern Punjab (Figure A-3).

Figure A-3: Impact of growing degree days (GDD) on wheat crop in Punjab



Maize and **sugarcane** are also affected by erratic rainfall and changing seasonal patterns, particularly in KP and Punjab, where water availability is critical to maintaining productivity.

Figure A-4: Impact of growing degree days (GDD) on wheat crop in KP



Annex B: Questionnaire on constraints, gaps and financial, technical and capacity needs

1. Name of Organisation: _____

2. Identify the sector your organisation is operating in:

   - ☐ Power
   - ☐ Water
   - ☐ Transport
   - ☐ Agriculture
   - ☐ Waste Management
   - ☐ Forestry
   - ☐ Other, please specify _____

3. Identify the role(s) your organisation plays or can play in climate change scenario w.r.t sector mentioned above

   - ☐ GHG Inventory Preparation
   - ☐ Vulnerability Assessment
   - ☐ Mitigation Actions / Projects
   - ☐ Adaptation Actions / Projects

4. Identify the constraints, gaps and bottlenecks in the four categories (preparation of GHG inventory, vulnerability assessment, mitigation actions and adaptation actions) which are most suited to your organisation.

	Constraints and Gaps	**Proposed Solutions**
GHG Inventory Preparation		
Vulnerability Assessment		
Mitigation Actions		
Adaptation Actions		

5. Identify the technical, financial and capacity building need in the four categories (preparation of GHG inventory, vulnerability assessment, mitigation actions and adaptation actions) which are most suited to your organisation.

TECHNICAL SUPPORT			
	Support Needed	**Support Received**	**Additional Support Required**
GHG Inventory Preparation			
Vulnerability Assessment			
Mitigation Actions			
Adaptation Actions			

FINANCIAL SUPPORT			
	Support Needed	**Support Received**	**Additional Support Required**
GHG Inventory Preparation			
Vulnerability Assessment			
Mitigation Actions			
Adaptation Actions			

CAPACITY BUILDING SUPPORT			
	Support Needed	**Support Received**	**Additional Support Required**
GHG Inventory Preparation			
Vulnerability Assessment			
Mitigation Actions			
Adaptation Actions			

Annex C: Questionnaire for development and transfer of ESTs

1. Name of Organisation: _____

2. Identify the sector your organisation is operating in:

   - ☐ Power
   - ☐ Water
   - ☐ Transport
   - ☐ Agriculture
   - ☐ Waste Management
   - ☐ Forestry
   - ☐ Other, please specify _____

3. What steps are being taken by organisation for development and deployment of ESTs?

   - ☐ ESTs are part of organisation's current policy and operations
   - ☐ ESTs are considered in future planning
   - ☐ ESTs are neither part of current operations nor part of future policy and planning

4. The table given below includes brief of information collected for Second National Communication (SNC) in 2018. Kindly provide the updated information required for Third National Communication (TNC) regarding the sector in which organisation is working.

Sector	ESTs Identified in SNC	Updated ESTs	Barriers Identified in SNC	Recommendations Proposed in SNC	Barriers	Recommendations
Power	• Optimal use of boilers and furnace • Energy management • Renewable energy technologies and products • Energy audits in Industrial sector		• Lack of technological skills Government policies, strategy and regulations without incentives for the promotion of renewable energy • Less coordination between Govt. departments and NGOs	• Need to increase certified technicians trained by accredited institutions • Encouraging private sector to introduce leasing and installation of renewable energy technologies. • Improvement of coordination between stakeholders		

Sector	ESTs Identified in SNC	Updated ESTs	Barriers Identified in SNC	Recommendations Proposed in SNC	Barriers	Recommendations
Transport	• Mass transit system • Up- gradation of • road and railway networks. • Cost reduction for hybrid vehicles • Introduction of engine emission standards		• Absence of national transport policy • Employment Loss for people working in existing transport system • Lack of long- term plans and strategies	• Development of National Transport Policy supporting BRT • Create alternative jobs • Adoption of energy efficient measures • Local manufacturing of efficient buses to reduce cost • Domestic manufacturing and installation of the computerised tune up equipment and machinery to reduce cost		
Agriculture	• High efficiency irrigation systems for irrigated and rain-fed areas • Drought and salt tolerant crop varieties • Climate monitoring and forecasting early warning system • Improved livestock breeding • Off field crop residue management		• Limited communication among technology developer, supplier, and users • Limited R&D capacity • Limited human skills and training in designing and installation of systems • Small underdeveloped market • Weak supply chain and distribution mechanism	• Need to improve coordination and collaboration among national, regional and international organisations and R&D agencies for data and products sharing • Training of farmers and other users, including agriculture extension staff • Need to increase number of testing facilities and skilled staff Need to increase allocation of financial resources for the modernisation, expansion, and up gradation of climate monitoring, forecasting, and early warning systems		

Sector	ESTs Identified in SNC	Updated ESTs	Barriers Identified in SNC	Recommendations Proposed in SNC	Barriers	Recommendations
Water	• Groundwater recharge (managed aquifer recharge) • Urban storm water management • Flood Early Warning System • Furrow irrigation • Construction of big dams and reservoirs such as Bhasha Dam		• Limited financial allocation for local governments • Lack of sound comprehensive cross sectoral policies for resource protection, development and management • Limited institutional capacities especially at local level in integrating climate change risks in development planning • Limited human skills and maintenance especially at local level	• Ensure the availability of sufficient local development funding • Approval of water policy with special focus on water conservation and sustainable groundwater management • Define administrative boundary of groundwater aquifers and authorise a single ground water management body in each province • Recognise the role and authority of water user organisation and/or other indigenous administrative set up in formal decision-making processes. • Resolve ownership right to water and land and property rights through improved policy coordination • Invest in technical capacity building of R&D and local government institutions • Ensure local training and availability of construction and maintenance staff • Need to launch awareness campaigns for the conservation of water		

Sector	ESTs Identified in SNC	Updated ESTs	Barriers Identified in SNC	Recommendations Proposed in SNC	Barriers	Recommendations
Forestry	• Social/ Farm forestry as carbon sink • Reducing deforestation and forest degradation using biofuels and solar thermal products • Sustainable forest management • Rehabilitation of mangroves • Fire management in forests		• No economic incentive mechanism in place for SFM • Policy and regulatory measures not supportive to SFM • Low capacity of staff for development of SFM plans • Limited participation of community in decision making • Alternate strategies in case of disasters and forest fires not defined • Lack of R&D in identifying and cultivating local species of the forest • Return from forestry require a long period of time • Unavailability of land resources for forestry and Illegal wood- cutting	• Creation of economic incentives • Promotion of SFM • Strong Legal regulatory body • Increasing awareness about innovative and precision agriculture methods		
Waste	• Wastewater treatment and reuse • Fuel production from kitchen waste and cattle dung (biogas/biomass) • Usage of black bags for residual waste and ban on the usage of plastic bags		• Lack of enforcement of waste management standards by relevant government agencies • Lack of long term plans and strategies for waste management • Lack of energy efficient machinery	• Inclusion of long term plans in government policies for waste management • Inclusion of waste management standards • Creation of economic incentives i.e. carbon credit • Optimal utilisation of machinery • Implementation of energy conservation measures		

Sector	ESTs Identified in SNC	Updated ESTs	Barriers Identified in SNC	Recommendations Proposed in SNC	Barriers	Recommendations
All sectors (common barriers and their solutions)	N/A	N/A	**Economic Factors** • High Capital Costs • Risk of investment • Scale of investment by developed countries is less • Lesser financial incentives **Social Factors** • Lack of awareness • Technology push vs market pull • Lack of transfer experience **Technical Factors** • Lack of skilled manpower • Limited institutional capacity • Insufficient locally manufactured technologies	Economic Factors • Financial assistance in the form of subsidy, low taxes, and soft loans • Need to exploit alternative revenue generation sources • Level of investment by developed countries needs to be scaled up Social Factors • Wide dissemination of knowledge and information to raise awareness level • Provision of test and demonstration facilities to end users • Proper training programmes Technical Factors • Capacity building of institutes • Increased technical training		

5. The table below includes international donor agencies providing funding for clean energy technologies through various programmes. Provide information on any project underway, completed or being planned to be included in the database prepared under TNC.

Funding Source	Name of Project	Cost	Duration	Status (Completed/ Ongoing/Submitted)
Adaptation Fund				
Asian Development Bank				
Clean Development Mechanism				
Global Climate Fund				
Global Environment Facility				
Government of Finland				
International Finance Cooperation				
International Monetary Fund				
Islamic Development Bank				

Funding Source	Name of Project	Cost	Duration	Status (Completed/ Ongoing/Submitted)
Japan International Cooperation Agency				
Least Developed Countries Fund				
Multilateral Fund for the implementation of the Montreal Protocol				
Nordic Investment Bank				
Private Financing Advisory Network				
Special Climate Change Fund				
United Nations Development Programme				
United Nations Environment Programme				
United Nations Industrial Development Organisation				
United States Assistance for International Development				
World Bank				
World Resource Institute				

6. Mention any additional information or queries below.

Annex D: Donor supported programmes with EST components

Donor	Project	Implementing agency	Cost (USD million)	Duration
Asian Development Bank	Balakot Hydropower Development Project	Energy and Power Department, Government of Khyber Pakhtunkhwa	475	2021-27
	Karachi Bus Rapid Transit Project Design Advance (previously Karachi Mass Transit Project Design Advance)	Planning and Development Department, Government of Sindh	11.98	2016-20
	Peshawar Sustainable Bus Rapid Transit Corridor Project	Khyber Pakhtunkhwa Urban Mobility Authority Trans-Peshawar (The Urban Mobility Company)	437	2017-22
	Peshawar Sustainable Bus Rapid Transit Corridor Project Design Advance	Planning and Development Department, Government of Khyber Pakhtunkhwa	12.35	2016-19
	Peshawar Sustainable Bus Rapid Transit Corridor Project Design Advance	Planning and Development Department, Government of Khyber Pakhtunkhwa	12.35	2016-19
	Preparing Climate-Resilient Agriculture and Natural Resources Development Projects	Planning and Development Department, Government of Khyber Pakhtunkhwa Planning and Development Board, Government of Punjab	3.63	2021-24
Clean Development Mechanism	Almoiz Bagasse Cogeneration Project	Almoiz Industries Limited	0.003	2010-17
	Biogas-based cogeneration project, Shakarganj Mills, Jhang	Shakarganj Mills Ltd	0.002	2010-20
	Biomass fuel switch project, Sapphire Finishing Mills	Sapphire Finishing Mills Ltd	0.002	2012-23
	Biomass-based cogeneration in Engro Foods Supply Chain, Muridke	Engro Foods Supply Chain (Pvt) Ltd	0.006	2013-22
	Community-based renewable energy development in the Northern Areas and Chitral	Aga Khan Rural Support Programme (AKRSP)	0.015	2009-16
	Composting of organic content of municipal solid waste, Lahore	Lahore Compost (Pvt) Limited	0.020	2010-17
	Foundation Wind Energy-I project (50 MW)	Foundation Wind Energy Ltd	0.016	2015-25
	Foundation Wind Energy-II project (50 MW)	Foundation Wind Energy-II (Private) Limited	0.016	2014-24
	Grid connected combined cycle power plant project utilising permeate gas, Qadirpur	Engro Corporation Ltd	0.091	2013-22
	Gulpur hydropower project (102 MW)	Mira Power Ltd	0.046	2021-28
	Low head hydropower development project, Punjab	Punjab Power Development Company Ltd	0.012	2021-28
	Patrind hydropower project	Star Hydro Power Ltd	0.052	2017-24

Donor	Project	Implementing agency	Cost (USD million)	Duration
	Power Generation through wind energy, Gul Ahmed Wind Power	Gul Ahmed Wind Power Ltd	0.017	2014-23
	Power generation through wind energy, Metro Power Company	Metro Power Company Ltd	0.017	2014-23
	Reduction of heavy fuel oil usage for power generation, Lucky Cement, Pezu	Lucky Cement Ltd Carbon Services (Pvt) Ltd	0.002	2013-22
	Sachal wind power project (49.5 MW), Jhampir	Sachal Energy Development (Pvt) Ltd	0.015	2017-27
	Sapphire wind farm Project (49.5 MW)	Sapphire Wind Power Company Ltd	0.013	2015-25
	Yunus Energy wind farm project (50 MW)	Yunus Energy Ltd	0.015	2016-26
	Zorlu Enerji wind project	Zorlu Enerji Pakistan Ltd	0.018	2014-25
Global Environment Facility	Delivering the Transition to Energy Efficient Lighting in Residential, Commercial, Industrial and Outdoor Sectors	National Energy Efficiency and Conservation Authority	7.561	2017-22
	Development and application of decision-support tools to conserve and sustainably use genetic diversity in indigenous livestock and wild relatives	Pakistan Agricultural Research Council	10.754	2009-20
	Development of National Action Plan for Artisanal and Small-Scale Gold Mining in the Islamic Republic of Pakistan	Ministry of Climate Change, Government of Pakistan	0.547	2022-25
Green Climate Fund	Green BRT Karachi	Asian Development Bank	583.5	2018-25
	Pakistan Distributed Solar Project	JS Bank Ltd	54.0	2022-33
	Scaling-up of Glacial Lake Outburst Flood (GLOF) risk reduction in Northern Pakistan	United Nations Development Programme	37.5	2016-24
	Transforming the Indus Basin with Climate Resilient Agriculture and Water Management	Food and Agriculture Organization of the United Nations	47.7	2019-26
United Nations Environment Programme	Environmental Education and Youth Project	University of Agriculture, Faisalabad	8.322	2018-23
	Operationalization of the Special Programme to support institutional strengthening at the national level to enhance the implementation of the Basel, Rotterdam and Stockholm conventions, the Minamata Convention on Mercury and the Strategic Approach to International Chemicals Management	Ministry of Climate Change of Pakistan and other international partners	29.643	2016-25

Donor	Project	Implementing agency	Cost (USD million)	Duration
World Bank	Balochistan Integrated Water Resources Management and Development Project	Irrigation Department, Government of Balochistan	209.7	2016-25
	Khyber Pakhtunkhwa Hydropower and Renewable Energy Development	Pakhtunkhwa Energy Development Organization, Energy and Power Department, Government of Khyber Pakhtunkhwa	727	2020-27
	Pakistan Hydromet and Climate Services Project	National Disaster and Risk Management Fund, Ministry of Climate Change	188	2017-24
	Punjab Green Development Programme	Transport Department, Energy Department, Finance Department, Environmental Protection Department, Industries, Commerce, Investment and Skills Development Department, Planning and Development Board	273	2017-25
	Punjab Resilient and Inclusive Agriculture Transformation	Agriculture Department, Government of Punjab	262	2022-27
	Sindh Resilience Project	Sindh Irrigation Department, Provincial Disaster Management Authority, Sindh	120	2016-24
	Sindh Solar Energy Project	Energy Department, Government of Sindh	105	2018-25
	Solid Waste Emergency and Efficiency Project	Local Government Department, Government of Sindh	105	2020-25

Annex E: Initiatives on climate change education, training and public awareness

Organisation	Name of programme or activity
Government	
Environmental Protection Agency (EPA)	Awareness strikes
Ministry of Climate Change	Youth 4 Climate Pakistan Clean and Green Pakistan
Ministry of Planning, Development and Special Initiatives (MoPD)	National Conference on Sustainable Development Goals
National Disaster Management Authority (NDMA)	Climate Action Leadership Activity Book Climate Action Children's Activity Book
National Energy Efficiency and Conservation Authority (NEECA)	Energy efficiency and conservation seminar series
National Highway Authority (NHA)	Plastic Bags Se Azadi awareness campaign
National University of Sciences and Technology (NUST)	Youth conference
Pakistan Council of Research in Water Resources (PCRWR)	Pakistan Water Week 2021, 2022
Pakistan Meteorological Department (PMD)	Climate Change Impact and Integration Cell
South Punjab Education Department	Children's Green Book
Private/NGO/research	
Centre for Climate Research and Development	Dissemination material
Idara-e-Taleem-o-Aagahi	Mahol Saheliyan books on climate justice
Sharmeen Obaid Chinoy Films/Canada Fund for Local Initiatives	Pakistan's Climate Change Heroes
Sustainable Development Policy Institute (SDPI)	Sustainable development conferences Network for Clean Energy Transition
INGO/donor	
British Council Pakistan	Active Citizens Programme Response on Climate Change
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Pakistan	Pakistan German Climate and Energy Initiative Youth For Climate Action
Food and Agriculture Organisation (FAO)	FAO FFS Training of Facilitators
Friedrich Naumann Foundation	Booklets on climate change information
International Union for Conservation of Nature (IUCN) Pakistan	Gender and Climate Awards
Oxfam Pakistan	Climate Project
Pakistan Red Crescent Society	Climathon Y Accelerator Challenge Climate Change Adaptation for Resilient Action training
Save The Children	My Forest Child

Organisation	Name of programme or activity
United Nations Children's Fund (UNICEF) Pakistan	World's Largest Lesson (Making Climate Education Accessible for Every Child)
United Nations Development Programme (UNDP) Pakistan/ Citi Foundation	Mover's Programme
World Wide Fund for Nature (WWF) Pakistan	Eco internship programme Outdoor education programme Student ambassador programme Citizen journalism for environmental advocacy Green schools Climate march Environmental education modules
WWF-Pakistan/Pakistan US Alumni Network (PUAN)/US Mission in Pakistan	Climate Change Emergency: Pakistan in the 21st Century and the Road to COP 28
Civil society	
Civil Society Coalition for Climate Change	Pakistan Climate Change Portal
Code For Pakistan	Hackathon
Fridays for the Future	Digital and on-ground climate strikes
Hashoo Foundation	Climate Action Programme
Stimulus/CleanTech Republik	Climate launchpad
Corporate	
Engro Pakistan	Awareness campaign on wetlands
JS BANK	Green Innovation Challenge
Nestle Pakistan	Core Alliance Ecotourism initiatives
Pepsi Co	Reverse vending machine

Annex F: National, regional and international climate change networks

National networks		
Name	**Member types**	**Website**
Climate Action (Pakistan)	All	https://twitter.com/ClimateActionPk
Pakistan-German Renewable Energy Forum (PGREF)	Business, academia, policymakers	https://pgref.org
Water Environment Forum (WEF)	NGO	http://waterenvironmentforum.pk
Pakistan Environment Trust (PET)	NGO	https://pakenvironment.org
Strengthening Participatory Organisation (SPO)	NGO	https://spopk.org
Pakistan Fisherfolk Forum (PFF)	Private	https://pff.org.pk
Climate Transparency Forum	All	https://climate-transparency-platform.org
Civil Society Coalition for Climate Change (CSCCC)	NGO	https://www.csccc.org.pk
Pakistan Youth Climate Network (PYCN)	NGO	https://x.com/PycnOfficial
Fridays for Future Pakistan	Youth	https://fridaysforfuture.pk
Climate Action Pakistan	NGO	https://twitter.com/climateactionpk
Sustainable Development Solutions Network	NGO	https://www.unsdsn.org
Pakistan Sustainable Development Forum (PSDF)	NGO	https://www.facebook.com/psdf.pk1
Pakistan Leadership Forum- Environmental Conservation Organisation (ELF)	NGO	https://twitter.com/pakistanelf

Regional networks			
Name	**Member type**	**Website**	**Pakistan membership**
Global Center of Adaptation (South Asia)	NGO	https://gca.org	Yes
South Asian Network for Development and Environmental Economics (SANDEE)	Network	https://www.sandeeonline.org	Yes
East Asia Forum	Government	https://www.eastasiaforum.org	No
The Asia Pacific Adaptation Network	Government	http://www.asiapacificadapt.net	Yes
Regional Gateway for Technology Transfer and Climate Action in Latin America and the Caribbean (REGATTA)	Government	https://cambioclimatico-regatta.org	No
Ecosystem-based Adaptation for Food Security in Africa Assembly (EBAFOSA)	Government	https://ebafosa.org	No
The West Asia Regional Network on Climate Change (WARN-CC)	Government	Not Available	No
Network Nature Nordic Hub	Government	https://networknature.eu	No
Asia Environmental Youth Network	NGO	https://www.aeyn.org	Yes
Regional Sustainability Network (RSN)	NGO	http://rsnet.africa	No
Learning for a Sustainable Future Forum (LSF)	NGO	https://lsf-lst.ca	No
Climate Action Network South Asia (CANSA)	Civil society	https://cansouthasia.net	Yes

International networks

Name	Member type	URL	Pakistan membership
Climate Vulnerable Forum & V20	Government	https://thecvf.org	Upcoming
Climate Action Network	Civil society	https://climatenetwork.org	Yes
Earthjustice	NGO	https://earthjustice.org	No
The Global Green Growth Institute (GGGI)	Government	https://gggi.org	Yes
YOUNGO	Youth	https://youngoclimate.org	Yes
Organisation for Economic Co-operation and Development (OECD)	Government	https://www.oecd.org	No
LCOY	NGO	https://www.lcoy.earth	Yes
UN Climate Technology Centre and Network (CTCN)	UN-based Network	https://www.ctc-n.org	Yes
Knowledge for Climate	Network	https://knowledgeforclimate.net	Yes
Commonwealth Youth Climate Change Network (CYCN)	Youth Network	https://yourcommonwealth.org	Yes
Global Adaptation Network	UN-based Network	https://www.unep.org	Open
Young Reporters for the Environment	NGO	https://www.yre.global	No
The Earth Charter	Network	https://earthcharter.org	Yes
Sustainable Development Solutions Network (SDSN)	NGO	https://www.unsdsn.org	Yes
Climate Action Network (CAN)	NGO	https://climatenetwork.org	No
International Forum for Environment, Sustainability and Technology (IFOREST)	NGO	https://iforest.global	No
Climate and Development Knowledge Network	NGO	https://cdkn.org	Yes
United Nations Forum for Sustainability Standards (UNFSS)	NGO	https://unfss.org	No
One Planet Network	NGO	https://www.oneplanetnetwork.org	Yes
Climate Change: Impacts & Responses Research Network	NGO	https://on-climate.com	No
Natural Biodiversity Strategies and Action Plans (NBSAP)	Government	https://www.cbd.int	Yes
Earth Journalism Network (EJN)	NGO	https://earthjournalism.net	Yes

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Contributing partners

- Global Climate-Change Impact Studies Centre (GCISC), Ministry of Climate Change and Environmental Coordination
- National Energy Efficiency and Conservation Authority (NEECA), Ministry of Energy, Power Division
- Pakistan Council of Renewable Energy Technologies (PCRET), Ministry of Science and Technology
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