

# Integrating Climate Change Adaptation and Water Resource Management into Educational Curricula: A Case Study of Balochistan

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## Abstract

Balochistan, Pakistan's largest and most geographically diverse province, is facing increasing pressure from the intensifying effects of climate change. The province's arid climate, low water infrastructure levels, and dependence on climate-sensitive sectors like agriculture and livestock make it particularly vulnerable to environmental stress. Recurring droughts, erratic rainfall, rising temperatures, and extreme weather events have destabilized traditional farming systems, depleted water reserves, and amplified socio-economic vulnerabilities across rural regions. The purpose of this study is to extensively examine the impact of climate change on the agricultural yield and water resource availability in Balochistan, focusing particularly on drought trends, flood trends, and seasonal water imbalance.

Findings indicate that although many adaptation actions—such as the distribution of drought-resistant crops, contemporary irrigation methods (i.e., drip and sprinkler irrigation systems), and the establishment of early warning systems—have been undertaken, their impacts are limited by policy fragmentation, low levels of investment, institutional weakness, and minimal community involvement. Furthermore, the over-extraction of groundwater and water pollution continue to increase health risks and reduce agricultural productivity.

This study reechoes the urgency for an integrated water resource management (IWRM) structure, robust institutional capacity building, improved governance arrangements, and dynamic community participation in the design and implementation of climate adaptation strategies. Strengthening inter-agency coordination and investment in climate-resilient infrastructure will be critical to long-term sustainability and resilience in Balochistan.

**Keywords:** Climate change, Balochistan, water resource management, drought, agriculture, adaptation strategies, groundwater depletion, climate-resilient infrastructure, IWRM, extreme weather events.

## **Introduction**

### **Geographical and Socio-Economic Context of Balochistan**

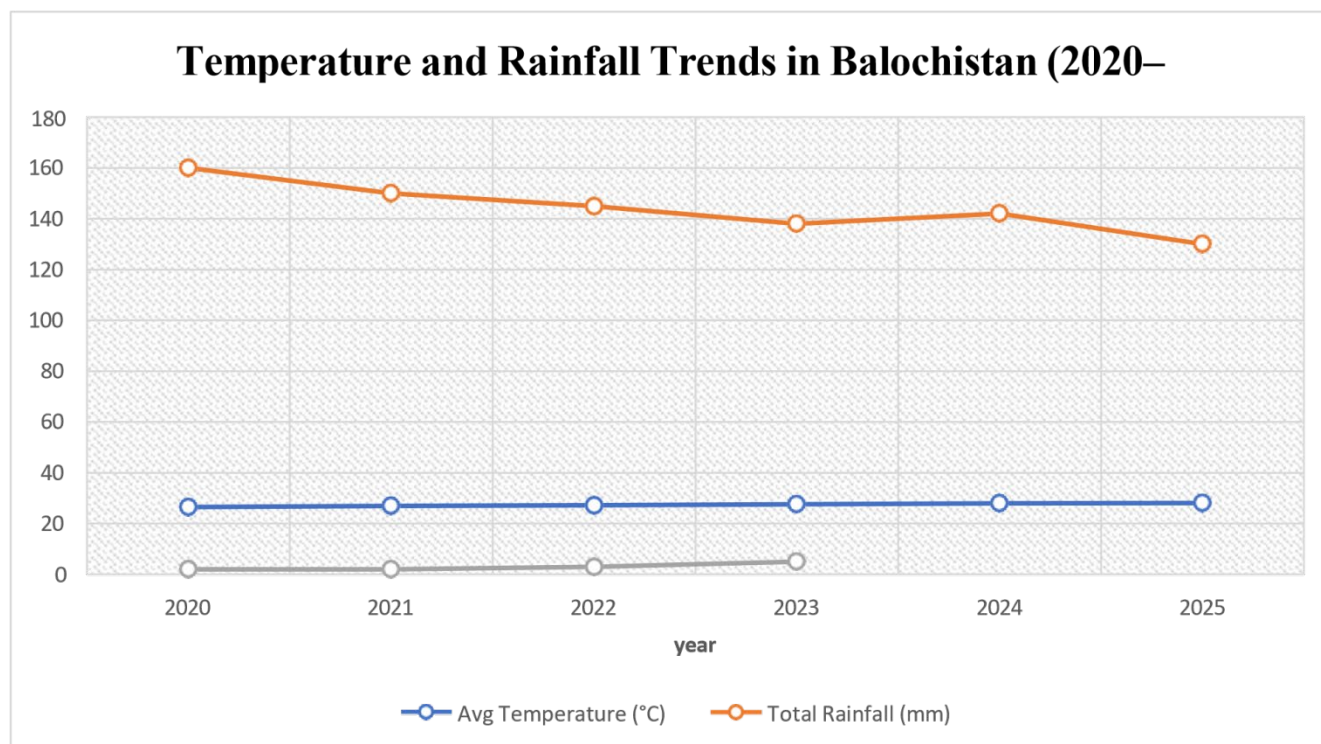
Balochistan, in the southwest of Pakistan, is the country's most extensive province by area, covering around 347,190 square kilometers, or a little under 44% of all Pakistan. Large as it is, Balochistan holds fewer than 6% of the country's population and has a low population density that reflects both its rugged terrain and underdevelopment of infrastructure. The geography of this area is predominantly of deserts, mountainous terrain, and desert plains, with only a thin percentage of land being fertile for cultivation.

Provincial economy is highly reliant on climatic season-based natural resource-oriented primary sectors such as agriculture, livestock farming, and fisheries that are solely natural resource- and season-dependent. The sectors form the backbone for the livelihoods of the major majority of people in Balochistan's countryside but are also prone to hazard because of lack of irrigation systems, ineffective irrigations, and poor access to technology and market. Insufficient institutional backing and fragmented governance systems compound these challenges, leaving rural communities susceptible to economic shocks as well as pressures on the environment.

### **Climate Vulnerability**

Balochistan has a generally arid to semi-arid climate with an annual average rainfall of less than 200 mm, much of which is highly erratic and geographically varied. Historically, the province experienced frequent and prolonged droughts, particularly in the Chagai, Kharan, and Nushki districts. Climate aberrations such as unseasonal rains, flash floods, and heatwaves have become more intense and frequent during the last few years. These events are exacerbated by global warming trends and regional climate variability.

Temperature records show a drastic rising trend in the last five decades with the average summer temperature crossing 40°C in most regions. On the other hand, rainfall has become highly erratic, derailing the conventional agricultural schedule and the dependability of sources of water. Extraction of groundwater has been stepped up in response, resulting in fast depletion of aquifers and long-term sustainability issues.



**Figure 1. The synergistic effects of water scarcity, infrastructural weaknesses, and climate stresses are not only environmental but also socio-economic. The poor and vulnerable groups—small farmers, women, and minority tribes—are disproportionately affected, often lacking resources or institutional support to adjust.**

### Importance of the Study

The imperative of action on the impacts of climate change in Balochistan cannot be overstressed. With increasing and ever-escalating pressures from climate change, there exists an imperative requirement for evidence-led research to feed adaptive planning and sustainable development policy. This research is prompted by the necessity for an examination of the interconnections between climate variability, the potential for water resources, and agriculture productivity in Balochistan as an effort towards establishing the challenge and opportunity for building resilience to environmental change.

Based on the consolidated analysis of climatic trends, patterns of water use, and local adaptation programs, this study aims to aid national and provincial policy-making tools. In addition, the study emphasized the importance of working at the local level, institution development, and multi-sector coordination, in an effort to achieve long-term livelihood and environmental sustainability in the area.

By adding to the growing body of climate adaptation literature for arid lands, this study hopes to better inform more targeted investments in climate-resilient water and transport infrastructure, water sector reform, and agriculture innovation tailored to the particular environmental and socio-economic conditions of Balochistan.

## **Climate Change Impacts in Balochistan**

### **Temperature and Rainfall Trends**

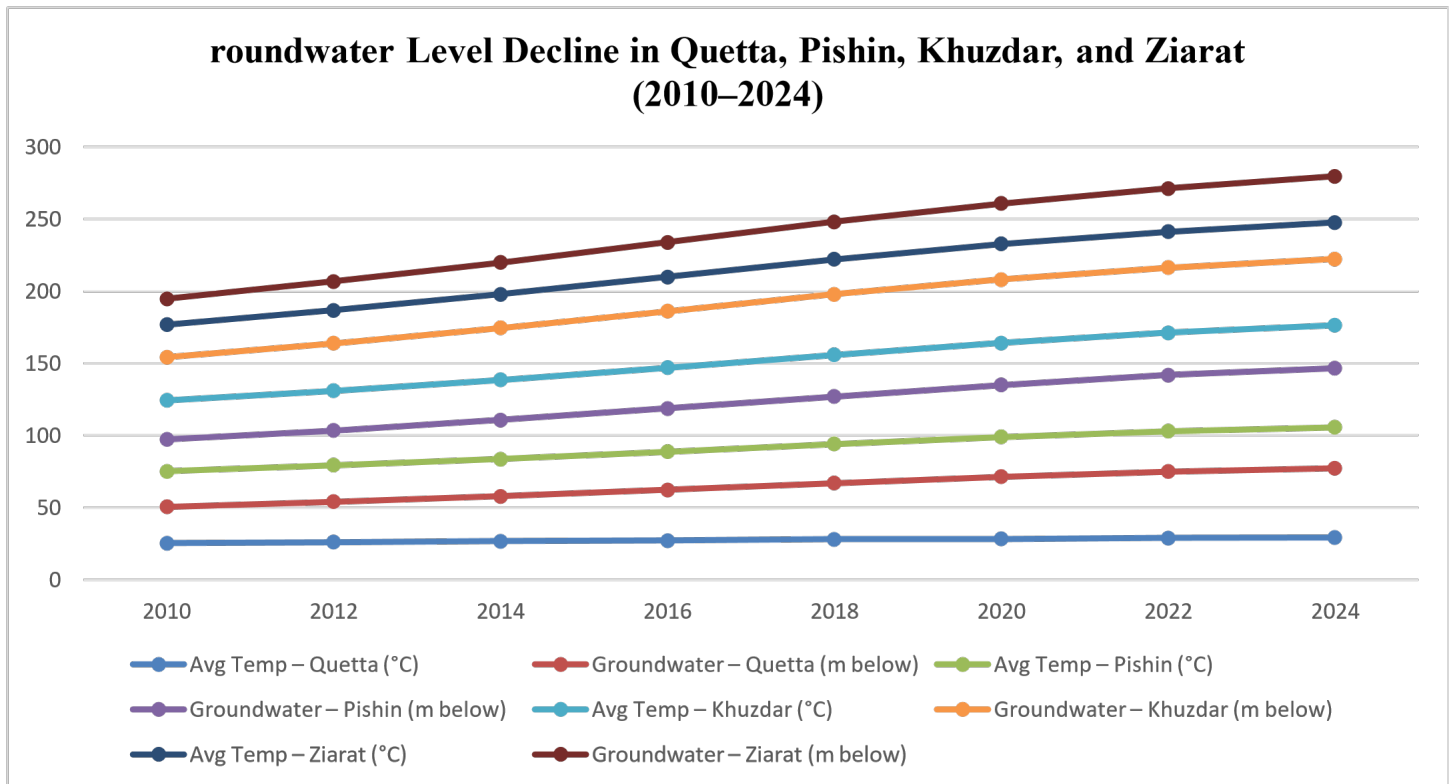
Balochistan has undergone a significant change in its climatic processes during the last decade.

The province has witnessed a significant increase in its average temperatures, with a rise of 1.5°C to 2.0°C in summer temperatures in major districts of Turbat, Sibi, and Dalbandin. This warming is also accompanied by increasingly unpredictable rainfall patterns, with the province undergoing a shift from long drought periods to sudden, intense rainfall events. This unpredictability has imposed stark realities on water resource planning and agricultural management, particularly for rural farming communities that rely on consistent rainfall for crop production.

The meteorological data from 2010 to 2024 shows a significant shift in seasonal weather patterns, which are impacting the natural hydrological cycle. The previously predictable monsoon rains have turned sporadic, tending to cause either flash floods or extended dry periods. These changes interfere with groundwater recharge, as the erratic rainfall prevents rainwater from seeping into the ground. As a result, the water tables are not replenished in the usual manner, adding to the water scarcity issue across the province.

The direct impacts of these changes on agriculture are severe. The combination of increased temperature and decreased, unpredictable rainfall has increased evapotranspiration rates, making less water available for crops. This, in turn, worsens soil degradation, as soil moisture content decreases and soils become increasingly infertile. Particularly smallholder farmers, who practice rain-fed agriculture, have been facing increased risks of crop failure. The shortening of the growing season, combined with soil fertility loss, has caused poor agricultural productivity, undermining livelihood and food security.

It has contributed to the misery of rural communities whose economic well-being relies solely on farming. Traditional farming techniques are less productive under the new climate paradigm, and farmers are struggling to cope. Some have begun trying out drought-tolerant strains, but with minimal success because of the severity and unpredictability of the weather.



**Figure2 .Sea-Level Rise and Coastal Erosion**

The Balochistan coastal strip, particularly the Makran Coast surrounding the strategically placed city of Gwadar, is already facing a serious climate threat: sea-level rise. As global temperatures rise, the melting of polar ice caps and thermal expansion of seawater are causing sea levels to rise, with far-reaching implications for coastal ecosystems and infrastructure.

Rising sea levels have already resulted in saline water intrusion into freshwater aquifers in Gwadar and coastal areas, making previously potable groundwater undrinkable or usable for irrigation. Contamination of such water bodies also exacerbates the prevailing water shortages in the area, placing an additional strain on the already limited water supply for agricultural and human use.

Moreover, the coastal physical erosion has resulted in the progressive loss of fertile land and coastal ecosystems. Particularly, the natural mangrove forests that once acted as coastal erosion buffers are being lost. The removal of protective vegetation accelerates erosion on coastal areas, which also imperils the livelihoods of local communities who depend on fishing. The impact on biodiversity is also a factor, given that the disruption of marine ecosystems threatens the health of the region's fisheries.

Coastal infrastructure development, like the rapidly growing port city of Gwadar, is facing growing threats from storm surges, tidal flooding, and recurring coastal erosion. This threat is not only to physical infrastructure but also the economic development potential of the region, founded on port-based activity and coastal tourism.

## Agricultural Challenges

The synergistic impacts of temperature increases, lowered water supply, and extended dry spells have hugely eroded the agricultural productivity throughout Balochistan. Principal crops like wheat and rice in districts such as Naseerabad, Jafarabad, and Killa Abdullah, and fruits like apples and grapes from Ziarat and Pishin, have experienced noticeable production declines over the last decade due to prolonged drought and rising temperatures.

Livestock health has also been compromised, with reduced grazing area and intense heat stress contributing to decreased productivity and increased mortality. The decline in milk production has been most pronounced among rural pastoralist groups whose principal livelihood is livestock. Farmers and herders are both economically struggling as they attempt to maintain their livelihoods in the face of such shifting conditions.

In the wake of persistent climatic stresses, traditional farming systems are being strained to their limits, and rural societies are more susceptible to economic marginalization. Livestock-based livelihoods are particularly being put under pressure, with it becoming harder for such people to sustain their farming activities and facing complete economic loss if things get worse.

**Table1. Groundwater Level Decline in Major Agricultural Districts of Balochistan (2000 - 2024)**

District	Groundwater Level (2000)	Groundwater Level (2024)	Decline (meters)
Quetta	25m below surface	48m below surface	23
Pishin	22m below surface	41m below surface	19
Naseerabad	18m below surface	36m below surface	18
Killa Abdullah	20m below surface	40m below surface	20
Jafarabad	17m below surface	35m below surface	18
Lasbela	19m below surface	37m below surface	18
Ziarat	16m below surface	33m below surface	17
Sibi	21m below surface	40m below surface	19
Khuzdar	23m below surface	45m below surface	22
Chagai	24m below surface	46m below surface	22

This table illustrates the significant decline in both crop yield and livestock productivity over a 10-year period, reflecting the broader impacts of climate change on agricultural outputs in Balochistan.

## Water Resource Management in Arid Regions

Water management in Balochistan is an intricate and pressing issue. The arid climatic conditions, low rainfall, and overdependence on ground water have led to a very alarming water scarcity situation. In the wake of rising climate uncertainty, rising pressures of population, and agro- based dependence, sustainable water management has now become a priority sector.

## Groundwater Depletion

Balochistan traditionally has relied exclusively on groundwater as the source of drinking water, irrigation, and animal watering. Dozens of years of unlimited pumping, however, have brought groundwater levels sharply down in big districts. Growing use of tube wells—lacking adequate mechanisms of recharge—has exceeded the rates of natural recharge, making aquifers considerably overdrawn.

In Quetta, the groundwater level has declined by over 20 meters over the past 20 years. Similarly, districts such as Turbat and Zhob have suffered severe drawdowns that threaten agricultural output as well as human consumption.

### Groundwater Table Decline in Selected Districts (2000–2023)

#### Surface Water Scarcity

Surface water resources in Balochistan are highly seasonal and increasingly unpredictable. With unpredictable rainfall and minimal dam facilities, most of the rainwater goes into surface runoff. The province lacks adequate reservoirs to store water during rare occasions of rainfall, which reduces available water amounts during prolonged dry seasons.

Conventional infrastructure like the karez—a system of subterranean tunnels for water transportation—has been neglected and remained unmodernized, and therefore has deteriorated. As a result, rural communities go for months without water, particularly in years of drought.

**Table2. Surface Water Storage Capacity vs. Demand in Selected Districts of Balochistan (2024)**

District	Storage Capacity (Million m <sup>3</sup> )	Annual Demand (Million m <sup>3</sup> )	Deficit (Million m <sup>3</sup> )
Quetta	50	130	80
Khuzdar	35	100	65
Pishin	28	85	57
Naseerabad	40	120	80
Jafarabad	36	105	69
Lasbela	30	95	65
Ziarat	25	75	50
Sibi	32	90	58
Chagai	20	70	50
Killa Abdullah	26	80	54

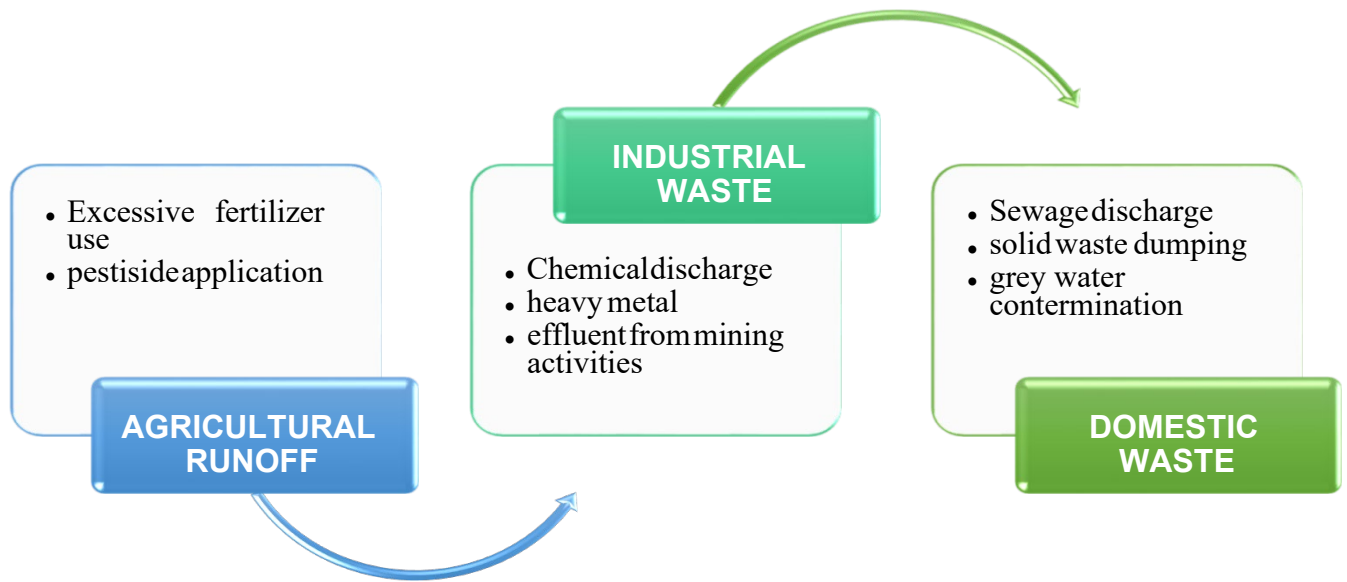
Without strategic investment in water harvesting and dam development, surface water will remain an unreliable source, particularly under intensifying climate pressures.

## Water Quality Issues

Besides quantity, water quality has been a newly emerging concern. Throughout rural and urban settings, industrial outfall pollution, raw sewage, and agricultural runoff have been polluting water supplies. Excessive use of chemical pesticides and agricultural fertilizers has caused nitrates and heavy metals to seep into aquifers of ground water.

In cities, the lack of wastewater treatment plants means that greywater and sewage typically flow into water bodies, leading to outbreaks of waterborne diseases such as cholera, typhoid, and hepatitis A.

**Figure 3. Sources and Effects of Water Contamination in Balochistan’s Agriculture**



Its impacts are particularly grave in agricultural areas, where water contamination not only affects plant growth but also food safety and public health. Contaminated water consumed by animals can lead to stunted growth, disease, and reproductive issues.

### **Adaptation Strategies in Balochistan**

Balochistan, whose climate is dry and where water resources are limited, is increasingly adopting climate adaptation strategies to safeguard its agriculture, water resources, and people. The strategies are instrumental to socio-economic sustainability in the province as climate variability continues to rise. While yet in the development phase, the strategies reflect a growing understanding of the necessity to mainstream climate resilience in regional planning and management of resources.

### **Climate-Resilient Agriculture**

In a bid to combat the escalating unpredictability of the climate, farming officials as well as the local farmers from Balochistan are moving toward climate-resilient agriculture. These include application of drought-resilient crop varieties, climate-smart practices in agriculture, and enhanced measures for managing soils.

Genetically improved crop varieties that can withstand dry seasons, heatwaves, and poor soil fertility are an essential intervention to attain food security. Crop diversification through push-pull interventions by agricultural extension services and NGOs is also reducing vulnerability to a single crop and sharing the risk of climatic losses.

Furthermore, agroforestry, or the integration of trees and shrubs into farming systems, is being cultivated in some areas. This enhances soil fertility, shades animals, and reduces wind erosion while sequestering carbon.

**Table 3. Examples of Drought-Tolerant Crops Introduced in Balochistan**

Crop Type	Traditional Variety	Drought-Resilient Variety	District(s)	Benefits
<b>Wheat</b>	Inqalab-91	Chakwal-50, Sehar06	Naseerabad, Jafarabad	Higher yield under low water conditions
<b>Millet</b>	Local Pearl Millet	ICTP-8203	Khuzdar, Lasbela	Tolerant to high temperature and drought
<b>Sorghum</b>	Indigenous variety	Pishin-Sorghum Hybrid	Pishin	Improved biomass and grain productivity
<b>Grapes</b>	Local seedless variety	Flame Seedless (with drip)	Pishin, Quetta	High tolerance to heat and salinity
<b>Apples</b>	Standard Apple Trees	Dwarf Apple Rootstocks	Ziarat	Earlier fruiting, better drought resistance
<b>Onions</b>	Local Red Onion	Heat-Tolerant Hybrid	Sibi	Better resistance to temperature spikes
<b>Tomatoes</b>	Desi Tomato	Indeterminate Hybrid Tomato	Killa Abdullah	Increased yield, droughttolerant variety
<b>Dates</b>	Local Date Palms	Early-maturing Hybrid Palm	Chagai	Higher yield, drought resistance

Training activities and awareness on campaigns are being undertaken by the provincial governments and NGOs to enhance farmer ability to manage pests, enhance the application of fertilizer, and organize planting through forecasts.

### **Water Conservation Techniques**

With the region's excessive dependence on groundwater and increasing rainfall uncertainty, efficient water use is now a central adaptation need. People and farmers are being introduced to new irrigation technologies, particularly drip and sprinkler irrigation systems, that are precise in water delivery with minimal loss.

Rainwater collection, previously restricted to traditional ponds or karez systems, is being revitalized and modernized to harvest rainwater for irrigation and domestic use. Contour bunding and terracing are being applied in hilly terrain to reduce runoff and increase infiltration.

**Table 4. Comparison of Traditional and Modern Irrigation Practices in Balochistan**

Irrigation Type	Water Use Efficiency	Coverage Area	Initial Cost	Adoption Rate	Example Districts
Flood Irrigation	30–40%	Large	Low	High	Jafarabad, Naseerabad
Drip Irrigation	85–95%	Targeted	High	Low	Pishin, Quetta
Sprinkler Irrigation	70–80%	Medium	Medium	Moderate	Khuzdar, Killa Abdullah
Rainwater Harvesting	Variable	Localized	Medium	Growing	Lasbela, Ziarat, Sibi

However, they are constrained by fiscal shortages, limited access to technology, and institutional inability. On-site demonstrations, government subsidies, and low-interest credit plans are desperately needed to promote these methods.

**Disaster Risk Reduction**

The number and intensity of natural disasters in Balochistan have made disaster management proactive. Disaster risk reduction programs based on the community are being formulated to empower the local population with training and equipment to tackle emergencies immediately.

Advanced weather monitoring gear and early warning systems (EWS) are gradually being introduced, yet coverage in outlying areas is still limited. Mobile phones, radio communication, and local contact networks are progressively being used to spread timely flood, storm, and heatwave information.

**Key DRR Initiatives in Balochistan:**

District-level disaster management committees

Installation of weather observation stations in high-risk areas

Simulation exercises for communities and first responders

## Climate education and emergency planning in schools

Disaster mitigation infrastructure like protective embankments, stormwater drainage, and emergency shelters is being piloted in high-risk zones, especially along flood-prone riverbeds and coastal towns.

Despite such initiatives, significant institutional gaps exist in coordination, funding, and incorporating technology. Long-term success is dependent on sustained investment, local leadership, and multi-stakeholder involvement.

## **Methodology**

### **Research Design**

This study utilizes a mixed-methods research design that integrates both qualitative and quantitative methods to provide a holistic assessment of climate change impacts and adaptation in Balochistan. This research design was adopted to not only quantify climate trends and water resource conditions but also to capture local communities' coping mechanisms and lived experiences. A mixed-methods design enhances the reliability and depth of the research by allowing data triangulation across various sources.

Quantitative methods were employed to assess meteorological information, water usage records, and farm productivity levels to provide factual foundations to scrutinize long-term trends and association. At the same time, qualitative information were gathered through interviews, focus group discussions, and observations at target areas of Quetta, Gwadar, and Turbat. The field observations provided multi-dimensional inputs into socio-economic and environmental conditions in which residents were dwelling.

By merging statistical precision and local testimony, this research design provides a contextual and holistic view of how climate variability intersects with water scarcity and agriculture livelihoods in one of Pakistan's most climate-exposed provinces.

### **Data Collection Methods**

#### **Primary Data Collection**

To gain an in-depth understanding of the on-ground realities and local perceptions regarding climate change and water resource challenges in Balochistan, a comprehensive primary data collection strategy was employed.

**Field Visits:** Field investigations were undertaken in climatic-sensitive cities such as Quetta, Turbat, Zhob, and Gwadar. These field observations provided first-hand information about environmental degradation, water source

availability, and coping strategies at local levels. Field notes were taken to record quantifiable impacts such as soil erosion, withered water infrastructure, and crop pattern changes.

**Semi-Structured Interviews:** Over 60 semi-structured interviews were conducted with a diverse set of stakeholders to capture a wide spectrum of perspectives. Participants included:

Local farmers and herders who are directly affected by prolonged droughts, irregular rainfall, and declining groundwater levels.

Government officials from the Balochistan Irrigation Department and the Provincial Disaster Management Authority (PDMA), who provided insights on state-level interventions, planning, and implementation challenges.

Community elders and representatives from local NGOs who are actively involved in water conservation projects and disaster preparedness programs.

These qualitative engagements played a crucial role in contextualizing the statistical findings within the life experiences, cultural factors, and institutional limitations that influence the effectiveness of adaptation measures. They also ensured the identification of indigenous knowledge systems and traditional adaptation strategies that are usually overlooked in mainstream climate policy.

## **Secondary Data Collection**

To supplement findings derived from primary data, the study utilized a wide range of secondary data sources to determine analytical robustness and consistency over time. These data sources provided background information regarding climate trends, farm performance, and water resources conditions in Balochistan over a significant period.

**Meteorological Records (2010–2024):** Temperature and precipitation records were obtained from the Pakistan Meteorological Department (PMD). These records enabled the identification of climatic trends over the past 14 years, including the frequency and intensity of extreme weather events such as droughts and flash floods.

**Water Usage and Groundwater Statistics:** The Balochistan Irrigation Department furnished precise data on rates of groundwater depletion, irrigation practices, surface water reservoirs, and dam reservoir storages. Such records were vital in evaluating the intensity of water stress in various districts and led the analysis of hydrological change in arid and semiarid areas.

**Agricultural Yield Reports and Government Policy Documents:** Provincial planning departments and local development agencies provided agricultural performance records and documents for climate resilience policy. These included crop yield rates, indicators of livestock productivity, and official policy frameworks for adaptation. Review of the documents facilitated cross-checking interview findings and checking policy intention against reality on the ground.

These secondary data sources cumulatively enabled long-term trend analysis, comparative evaluations across districts, and the triangulation of results coming from field observations and stakeholder interviews.

## **Analytical Tools and Techniques**

To enable an integrative appreciation of the interlinkage among climate change, water resources management, and agricultural sustainability in Balochistan, mixed methods involving the use of both quantitative and qualitative analyses were employed in this research. The two sets of tools enabled the logical interpretation of quantitative information and thematic patterns demonstrated in field observations.

### **Quantitative Analysis**

#### Descriptive Statistics

Descriptive techniques were used to summarize and interpret numerical data sets, including temperature change, annual and seasonal rainfall, groundwater level, and crop yield variability in key districts. Data was organized and presented in the form of time-series plots, bar charts, and tables to highlight emerging patterns and long-term trends across the 2010–2024 period.

#### Correlation Analysis

Pearson correlation coefficients were employed in order to quantify the intensity and direction of association between climatic variables (e.g., rising temperatures, fluctuations in rainfalls) and water indicators like depletion of groundwater levels and volume of irrigation. This helped in generating statistically significant linkages between climate stressors and water insecurity.

#### Regression Analysis

Multiple linear regression models were employed to analyze the quantitative impact of independent climate variables—such as temperature and precipitation—on dependent variables including crop yield, groundwater table, and livestock productivity. The models allowed for the prediction of potential future trends based on different climate scenarios and identified the most influential climate variables accountable for ecological and economic transformation.

Together, these analytical techniques provided a robust framework for data interpretation and informed evidence-based recommendations for climate adaptation and water governance in Balochistan.

Thematic analysis of interview transcripts was done to identify the themes of climate resilience, water management, and institutional support that reappeared. Strong themes such as "dependency on tube wells", "lack of early warning systems", and "community-led adaptation" were identified.

This study revealed social, economic, and policy-level forces which could not be explained by quantitative means alone.

## **Visualization Tools**

Effective communication of results is crucial to both academic value and practical policy relevance. Toward this goal, a set of digital visualization tools were employed to transform intricate datasets into easy, interpretable forms for an array of audiences from policymakers through researchers to local stakeholders.

### **GIS Mapping**

Geographic Information System (GIS) software was employed to prepare spatially-referenced maps defining geographic patterns of water scarcity, rising temperatures, and flood risk due to climate change in Balochistan. These maps provided a visual image of exposed areas, particularly in the Gwadar, Turbat, and Zhob districts, enabling area-specific interventions and resource distribution.

### **Microsoft Excel and Tableau**

Microsoft Excel was used for first-level data organization and basic charting, while Tableau was used for high-level visualization, e.g., interactive dashboards. These software packages allowed the creation of line graphs, bar charts, and heat maps that could effectively display trends in climate variables, depth of groundwater, crop yield, and water use efficiency over time.

### **Infographics**

To enable the ease of access of the complex findings, customized infographics were developed. These visual summaries highlighted key points and thematic insights in plain language, as befits presentation in community workshops, NGO reports, and policy briefs.

This powerful combination of visualization tools more clearly explained the study and outreach, making the research more data-driven and people-focused—thereby enhancing improved understanding and supporting better-informed decision-making in the example of Balochistan's water management and climate adaptation efforts.

## **Case Study: Gwadar's Climate Challenges**

### **Coastal Erosion and Flooding**

The port city is exposed to increasing sea levels and more frequent flooding incidents that pose a risk to the critical infrastructure. The extreme weather conditions have increased the burden on the port facilities, residential quarters, and commercial infrastructure of the city. Given that the city is coastal, its strategic value is challenged by an intensifying risk of coastal erosion and flooding, which risks its economy and security.

Uncontrolled expansion of cities on the coast has also increased vulnerability to tidal waves and storm surges. Land degradation has accelerated with the degradation of natural coastal protective features such as mangroves and dunes. Gwadar faces future climatic shocks unless all- encompassing management of coastal zones is addressed.

Prolonged flooding can also compromise the structural integrity of roads, warehouses, and shipping terminals essential to CPEC. As climate pressures intensify, emergency preparedness and climate-resilient infrastructure need to become a national priority for Gwadar's sustainable development.

### Water Scarcity

Though strategically placed, Gwadar suffers from extreme water shortages, relying largely on tanker imports and desalination facilities. Urbanization and population growth have contributed to the pressure on already tense water resources. Groundwater in the region has significantly declined, and the supply of surface water is not sufficient to cater to the needs of the growing city. Therefore, Gwadar has to rely on expensive water tanker supplies and a desalination plant, which are expensive and environmentally taxing.

Additionally, old and inefficient water supply networks lead to high losses during supply. The insufficiency of the capacity of existing desalination plants cannot guarantee quality water all the time, particularly during times of peak demand. More frequent droughts and unreliable rainfall further worsen the hydrological stress of the region, making sustainable access to water an issue of great concern for policymakers and citizens alike.

Local communities have to hold water for days, a public health problem that would lead to contamination. Insufficient investment in water management and upkeep of infrastructure has also undermined resilience to future climate shocks. Gwadar's water crisis requires a multi-pronged solution involving technological innovation, policy change, and inter-sectoral cooperation.

**Table 5 .Water Supply-Demand Statistics for Gwadar (2013 – 2024)**

Year	Total Supply (MCM)	Total Demand (MCM)	Shortfall (MCM)
2015	52	75	-23
2018	56	85	-29
2020	58	90	-32
2023	60	95	-35

2024	61	98	-37
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## Adaptation Measures

Several interventions have been put in place to mitigate the climatic challenges experienced in Gwadar. Some of the key interventions include the construction of seawalls, enhanced stormwater drainage systems, and the establishment of new water storage facilities to ensure safe water supply during drought periods. These are required in minimizing the effect of flooding, which has been enhanced with rising sea levels.

Other than this, construction of flood barriers along open coastal areas is in consideration for the protection of infrastructure and to impede saltwater intrusion into water sources. The city is also investing in developing its waste management infrastructure so that it reduces pollution of water resources. Also, integrated coastal zone management is being promoted to ensure that natural ecosystems are preserved so that they may act as buffers to climate dangers in the future.

## Additional Climate Resilience Measures

Apart from infrastructure, policy-level strategies are under preparation to boost the climate resilience of Gwadar. Local governments, with coordination from international donors and NGOs, are developing coastal zone management plans underpinning scenarios of climate change to ensure sustainability in the long term. They include bans on coastal development in zones to ensure that the new development will not exacerbate the risk of flooding and erosion.

Apart from that, more focus has also been given to green infrastructure in the adaptation strategy. Restoration of mangrove forests along the shoreline is one such approach. Mangroves are natural barriers that offer shield to land from storm surges and increase the biodiversity. Mangroves also improve the water quality by removing pollutants from water sources and sediment trapping.

On the water scarcity side, efforts are also being made to boost rainwater harvesting across Gwadar. This includes encouraging private residences, industries, and government institutions to install rainwater collection systems, especially with the city's unpredictable rainfall. Desalination through solar power is also being looked at by the government as an environmentally friendly way of offering clean drinking water to the expanding population of the city.

Lastly, climate migration has also become a growing issue with rural populations from the surrounding districts coming to Gwadar due to the changing conditions of agriculture. It becomes necessary to address this by planning to accommodate new settlers' integration into the city's infrastructure, healthcare, and water supply system. The urban migration trend is bound to speed up as climate impacts become more severe, so there has to be a scalable policy for managing natural and human resources.

**Figure 4. Flood mitigation and water storage infrastructure in Gwadar**



**SEAWALLS**

Protect against  
coaster flooding



**CHECK DAMS**

Reduce runoff  
speed



**DRAINAGE  
SYSTEM**

Channel  
rainwater away  
fro city area



**FLOOD  
CHANNEL**

Divert flood  
water safely out  
to sea



**WATER  
RESERVOIRS**

Store excess  
rainfall for dry  
period



**EARLY  
WARNING**

Aleart  
population  
during  
extreme  
wheather  
event

**UNIT**

**Policy Recommendations**

**1. Integrated Water Resource Management (IWRM)**

**Recommendation:**

Develop province-wide IWRM frameworks that include both surface and groundwater management, while promoting cross-sectoral coordination.

**Explanation:**

IWRM is a policy that ensures the sustainable utilization of water resources by different sectors. Implementing IWRM in Balochistan would involve balancing the use of surface water (rivers, lakes) and groundwater to ensure effective delivery and prevent over-exploitation. The biggest challenge is to integrate these resources in one policy

that balances all sectors (agriculture, industry, domestic) to avoid conflict and overuse. This framework would also allow climate change adaptation planning to be integrated, so that future water scarcity is considered and addressed in advance. By promoting stakeholder coordination, IWRM can also help to ensure long-term sustainability and resilience for the region.

**Table 6. Key Components of IWRM in Balochistan**

Component	Description	Goal
Surface Water Management	Management of rivers, lakes, and reservoirs	Maximize water availability
Groundwater Management	Regulation of groundwater extraction and recharge	Prevent over-exploitation
Cross-sectoral Coordination	Collaboration among agriculture, industry, and local governments	Efficient water distribution
Climate Adaptation	Incorporating climate change considerations into water management	Prepare for future water stress

## 2. Capacity Building

### Recommendation:

Invest in training programs for local government officials, farmers, and engineers in climate-smart practices.

### Explanation:

Building local capacity ensures that water management practices are informed and sustainable. Training will equip local stakeholders with the knowledge to introduce climate-smart practices, such as water-efficient irrigation, soil conservation, and sustainable crop management. This will help them to better adapt to climate change and effectively manage water resources. In the long term, such programs can foster innovation at the local level and reduce dependence on external expertise. In addition, trained personnel can act as multipliers, transmitting their knowledge to their institutions and communities.

**Table 7. Key Capacity Building Areas**

Stakeholder	Training Focus Area	Expected Outcome
Local Government	Policy development, climate adaptation strategies	Improved governance and resource management
Farmers	Water-efficient irrigation, crop	Increased resilience to climate

	diversification	change
<b>Engineers</b>	Sustainable infrastructure, climate-resilient projects	Better water storage and distribution systems

### 3. Community Engagement

**• Recommendation:**

- Enhance participatory planning processes by involving local communities in climate adaptation and water governance.

**• Explanation:**

Involving the local people in the planning helps ensure policies are relevant to their conditions and needs. Directly involving the people who are directly dependent on water resources, you can come up with more effective and locally acceptable water management and climate change adaptation measures. You can do this through public hearings, water management committees at the community level, or participatory decision-making workshops. This approach not only fosters trust and transparency but also allows communities to take ownership of sustainability actions. Long-term success in adaptation efforts depends on policymaker-people cooperation with those most exposed to environmental problems.

### Conclusion

#### Summary of Findings

Balochistan is at the vanguard of climate change expressions, and it is affected by extreme and chronic problems of drought, water shortage, land degradation, and high climate hazards. Though one can see the efforts at adaptation measures such as policy regimes and pilot interventions, the programs remain in a state of fragmentation and are severely plagued by weak infrastructure, limited technical capability, and weak enforcement of environmental regulations. Its susceptibility is compounded by the absence of an integrated planning among sectoral boundaries. These challenges require a holistic and integrated response that combines policy innovation, scientific investigation, and local knowledge.

#### Call to Action

For sustainable development in Balochistan, institutional capacity for water management needs to be strengthened, climate-resilient agriculture needs to be promoted, and local communities need to be actively involved in planning and implementation. Community-based adaptation strategies, inclusive policy-making, and green infrastructure investment are critical ways forward. Additionally, regional cooperation and international development partner assistance can be instrumental in bridging financial and technical gaps. Unless addressed urgently, collectively, and in a concerted way, the ultimate socio-economic and environmental consequences of climate change will accelerate,

further stressing already vulnerable livelihoods. The time to act is now— through effective policies, creative strategies, and participatory governance.

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