PAKISTAN CLIMATE CHANGE IMPACT STORYLINES BASED ON EXISTING VULNERABILITY LITERATURE.

Lead Consultant: Prof. Rosalind Cornforth
Researchers: Dr. Cathie Wells, Dr. Elena Saggioro and Dr. Celia Petty (Walker Institute)
Reviewer: Olga Buto (WSP)
Approvers: Christine Wissink (WSP)
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Summary: As Pakistan faces increasingly severe climate induced challenges and hazards, understanding the country's key vulnerabilities at a local level will be vital in planning for adaptation. This report summarises current and projected climate changes and key vulnerabilities at national and provincial level. It then discusses risk assessment, based on historical disaster records, province-based climate projections and other measures of risk. Key findings at a provincial level in the sectors of water resources, agriculture, health and disaster management are examined. In the context of this quantitative and qualitative data, storylines are created for each province, before current perceived barriers to adaptation are discussed and conclusions drawn. Given the large amount of reports, articles and papers written about the challenges that Pakistan is facing as the climate warms, this document provides a comprehensive synthesis to inform the development of future adaptation planning.

TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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ABBREVIATIONS

ABBREVIATION	DEFINITION
ADB	Asian Development Bank
CDKN	Climate Development and Knowledge Network
CMIP	Coupled Model Intercomparison Project
CPEC	China-Pakistan Economic Corridor
DAPP	Dynamic Adaptive Policy Pathway
DDMA	District Disaster Management Authority
ENSO	El Niño-Southern Oscillation
EWS	Early Warning System
GCF	Green Climate Fund
GCM	Global Climate Model
GDP	Gross Domestic Product
GLOF	Glacial Lake Outburst Flood
IBIS	Indus Basin Irrigation System
IPCC	Intergovernmental Panel on Climate Change
IUCN	World Conservation Union
MOCC	Ministry of Climate Change
NAP	National Adaptation Policy
NCCPIC	National Climate Change Policy Implementation Committee
NDMA	National Disaster Management Authority
NGO	Non-Governmental Organization
PCCPIC	Provincial Climate Change Policy Implementation Committee
PCRWR	Pakistan Council of Research in Water Resources
PDMA	Provincial Disaster Management Authority
PMD	Pakistan Meteorological Department
PWD	People with Disability
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SMS	Short Message Service
SRSP	Sarhad Rural Support Programme
SSP	Shared Socio-Economic Pathway
SUPARCO	Space and Upper Atmosphere Research Commission
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
WAPDA	Water and Power Development Agency
WB	World Bank

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WEF	World Economic Forum
WFP	World Food Programme
WI	Walker Institute
WWA	World Weather Attribution

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EXECUTIVE SUMMARY

The overall aim of this project is to provide a comprehensive synthesis of existing research and stakeholder views on projected climate change and the risks it will entail, given current levels of vulnerability at both national and provincial levels in Pakistan. Impact storylines have been produced by gathering information on historical climate events, data on climate projections and considering how socio-economic factors may increase event impact. Extrapolation of the methods used can help to produce further storylines focused on more localized regions, but here a provincial approach is considered. Four key sectors have been reviewed at provincial level: water resources, agriculture, health and disaster preparedness after consultation with the MoCC and UNEP. This work resulted in the enabling environment diagrams created to allow key barriers to implementation to be analysed from the research into the risks inherent in each of these sectors as the climate changes and from a detailed review of current action plans and policies.

Early dialogue was critical in both providing the focus of this report and ensuring that material used would be current. Where stakeholder involvement was possible, it added real insight into these findings. However, information from local experts was limited and most of the material gathered in creating this study comes from an extensive review of peer-reviewed papers, reports and grey literature (see the List of references). Additional information provided by stakeholders, that was not incorporated into the main conclusions is available in Annex 1.

Pakistan is in a uniquely difficult position, bearing the brunt of climate disasters, whilst also trying to develop in an environmentally sound way. This is an expensive process, for which resources are scarce both in terms of funding and human capacity. Section 1 of the report provides an overview of the current position of the country.

In the report the observed changes in Pakistan's climate and projected future changes are described both at a national and on a local scale. Given the uncertainties involved in precipitation prediction in particular, a range of different futures must be considered. However, the key findings are that Pakistan must prepare for a hotter, drier future, interspersed by periods of intense rain and flooding. The coastal region is already vulnerable to saline intrusion and tropical storms, but these are expected to become more severe in the future. Freshwater reserves are likely to run low, due to glacial shrinkage in the north of the country, reducing riverine water flow in the second half of the next century.

The current level of vulnerability of different sectors of life in Pakistan are considered based on available literature. These show that vulnerabilities tend to be interwoven in a complex web covering health, water availability, food security, gender, education and poverty, which heightens risk alongside geographical exposure.

The study considered the historic climate events over the last three decades and explored the links to the El Niño-Southern Oscillation Climate Pattern. La Niña induced conditions in the north of Pakistan in both 2010 and 2022 caused spring heat which resulted in GLOFs, followed by pre-monsoon thunderstorms, increasing the length of the monsoon period. Records climate disasters were illustrated graphically, including at a provincial level.

Future climate data was taken from the World Bank Climate Data Portal, as more detailed climate projection was outside of the scope of this report. Indicators for potential climate hazards were taken to be the 5-day maximum rainfall compared to a baseline of 1995-2014 data to track changes to the timing and intensity of the monsoon season. The maximum length of dry periods and the number of dangerously hot days were also considered for the heatwave and drought prone provinces of Punjab, Balochistan and Sindh, whilst ice days and percentage rainfall were considered for the far colder province of Khyber Pakhtunkhwa

From here research was more finely focused on water resources, agriculture, health and disaster preparedness on a provincial scale, with conclusions drawn about the key issues facing each of Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh. These showed that water management is critical for building climate resilience of the country. All provinces will need to concentrate on improving irrigation method efficiency in the future, but that over all there is also a need to overhaul the national irrigation

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infrastructure and tighten regulations to ensure tariffs not only encourage reduced use of resources, but also provide much needed funds for ongoing water system maintenance. At the same time, subsidies for groundwater pumping need to be removed and rainwater harvesting encouraged. If Pakistan could improve water storage, then the current cycle of droughts and floods could be broken.

Agriculture faces massive challenges, as the climate changes, but for those able to adapt, also real opportunities. Research into the best use of agricultural land, including better crop choices and new planting patterns could increase productivity despite or in some places due to the warming climate and seasonal changes. However, universal funding is needed to ensure that farmers with small properties are not excluded from this process.

Healthcare across Pakistan was found to be variable depending on the level of investment and amount of training and education available. Better regulation and inter-provincial discussion on the healthcare needs of the country are needed urgently, as the growing population is putting pressure on available resources, even outside of climate disasters.

Preparedness for disasters is also highly variable, with some districts having local action plans and others still struggling to deal reactively with the last impact as the next one arrives. Levels of risk need to be considered at a district level, a method for which has been considered using risk tables within this report. However, if these are then ignored and actions are not taken, then knowing the risks will not mitigate climate change impacts.

Findings from considering CMIP6 data are used in conjunction with information from literature to create provincial climate storylines. In-depth reviews of socio-economically vulnerable sectors and previous climate events are then applied to illustrate how projected climate changes could affect each province. These findings are given as infographics, to make further dissemination of information and gathering of more comprehensive local risk assessments easier.

In all areas of this research, there seems to be a gap between planning and implementation. This is in part due to a lack of resources and in part due to a lack of capacity at the local level needed for adequate climate change preparedness. To break down this barrier, enabling environment diagrams have been produced to show where the shortfalls are in funding, regulation, training, technology, research and resources. These are completed at a national level in the four key sectors of water resources, agriculture, health and disaster preparedness as well as for general climate change preparedness. By using this method at a provincial and district level, key needs can be addressed so that climate change action is no longer impeded.

This report attempts to address a vast array of needs, but the scope of the key conclusions has been constrained by a lack of local data and limited engagement with stakeholders. Whilst the key aims have been addressed, further work would need to be completed at a local level to quantify socio-economic impacts and analyse fully the effect that the suggested adaptation measures would have. It is hoped that this report will be used to support and encourage further engagement in the process of National Adaptation Planning, particularly in the translation of policies into action, so that Pakistan can become less vulnerable and more resilient to future climatic challenges.

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SECTION 1: INTRODUCTION

Pakistan has undergone political and economic instability for a number of decades (1). This in turn has affected development with considerable economic variability and a lack of foreign investment (2). GDP grew from 2012 to 2018, but was reduced in both 2019 and 2020. After another increase in 2021, projections for 2022 show a further fall back to pre-2016 levels (3). The primary sector of Pakistan's economy was responsible for 23% of the country's GDP in 2021, with the nation's industry responsible for 19% (4). The tertiary sector, encompassing intangible goods like tourism and financial services was responsible for 52% of the 2021 GDP, as Pakistan starts to move from an agriculture-based to a knowledge-based economy (4).

FIGURE 1: PAKISTAN (IMAGE: LARA JAMESON WWW.PEXELS.COM)

Against a backdrop of increasing population, areas of extreme poverty, challenging social norms and territorial tensions, Pakistan is making efforts to increase its resilience to climate change, by placing it at the centre of its development agenda, making global climate commitments and pursuing a comprehensive adaptation policy which targets improving the lives of the most vulnerable members of its society (5).

Climate change is being mainstreamed across and within governmental institutions in the country. In 2018, Pakistan's federal government devolved responsibilities for climate change adaptation and mitigation from a centralised system to the provincial governments of Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh (5). The Ministry of Climate Change (MoCC) was set up the following year to co-ordinate efforts to prepare Pakistan for a more climate resilient future (6).

Pakistan is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Climate agreement. Pakistan has also submitted its first Nationally Determined Contributions (NDC) in 2016 and updated this in 2021.

Climate adaptation is a high priority for the government as is highlighted in the Climate Change Act (2017), the National Climate Change Policy (2012 and 2021) and the National Sustainable Development Goals (SDGs) Framework for Pakistan. The development of the National Adaptation Plan is ongoing and aims to set out what the Federal Government will do to support efforts across all levels of government, business and the community to better anticipate, manage and adapt to the impacts of climate change.

1.1: Climate change challenges

In addition to economic challenges, Pakistan's geographical position within precipitation bearing weather systems, increases its exposure to extreme climate events (7). Several regions of Pakistan are considered to be particularly vulnerable to climate change. These are susceptible to varied events and impacts due to differences in geography, land-use and natural climate. The Indus River Valley is a key area of risk, as the majority of Pakistan's population live in this region (2). As many communities are built on the flood plain, this makes them vulnerable to floods caused by increased glacial melting further upstream, as well as changes in rainfall patterns (8; 5). This has been particularly notable in the 2022 floods in which large areas of Balochistan and Sindh were submerged affecting 15% of Pakistan's population (1). Thar, Cholistan, Kharan and Thal are all desert regions, which along with much of the arid and semi-arid areas of Pakistan are at risk of drought events, particularly in places where there is no access to the Indus River irrigation system (2). As all four provinces of Pakistan are dependent on climate sensitive livelihoods, each has its own vulnerabilities associated with particular aspects of climate change (9). In this report an overview of national vulnerabilities will be given, before key aspects of this are revisited with a provincial focus.

1.2: Report aims

This report aims to give an overview of the climate-induced risks faced by the most vulnerable people in Pakistan. Its findings are based on a comprehensive synthesis of both peer-reviewed and grey literature. Previously published projection data is used in producing climate storylines to show potential future risk scenarios for each province - Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh. The aim of this work is to inform the policy makers in Pakistan and provide additional evidence for sound decisions in the field of climate adaptation and risk management.

1.3: Report contents

In Section 2, a brief overview of the current and projected climates in Pakistan is given with reference to the most up-to-date information available. Section 3 gives an in-depth analysis of the drivers of vulnerability across Pakistan, using evidence from a wide range of relevant literature sources. In Section 4 past climate events are reviewed and projections of future climate are

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discussed using the latest generation of Global Climate Models (GCMs). Section 5 focuses on four key areas: Water Resources, Agriculture, Health and Disaster Preparedness, by referring to stakeholder views on provincial needs and recent localized literature. A risk chart is included for each province to highlight the most vulnerable districts. All of this qualitative and quantitative data is then used to create climate storylines for Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh in Section 6. Enabling environment details, aimed at overcoming barriers to adaptation as described in recent literature, are given in Section 7 and final conclusions are summarised in Section 8.

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SECTION 2: CURRENT CLIMATE AND PROJECTED CHANGES

In order to assess the level of risk posed by climate change, it is vital to have a full picture of current climate observations and projected changes for Pakistan. In the absence of newly generated data, the review which follows will be based on recent literature.

Pakistan's climate varies with its topography, but is dominated by the Indian monsoon from the east and the westerlies bringing rain to the northwest (10). Near the coast it is hot and dry, with temperatures falling as one moves further north (6). The winter from December to February is generally cool and dry, followed by a hot, dry spring from March to May. The southwest monsoon period from June to September is the rainy summer season, with monsoons retreating from October to November (6). 60% of Pakistan's annual rainfall is from the summer monsoon, but from December to March there are also the westerlies bringing some precipitation to the northwest of the country (11).

2.1: Observed climatic changes

Temperature:

A key index when assessing climate change is temperature, as this provides primary evidence of global warming. The average temperature of Pakistan has been rising throughout the 20th century, but at a rate slightly below that for South Asia as a whole (6). An overall rise of 0.6°C over the last century meant an average rise of 0.07°C per decade (12). More recent data shows a strengthening to this warming effect, particularly in the post-monsoon and winter months (6). Above average temperature increases have been recorded in Sindh and southwest Balochistan (12). The hot and humid weather in March and June brings temperatures of over 49°C, with winter temperatures currently varying between 4 and 20°C on average, depending on region (11).

> "Such long-term warming is not seen in the natural climate, suggesting it is of anthropogenic origin."
>
> Nikolaos Christidis for the UK Met Office attribution study concerning the 2022 heatwave in Pakistan (299).

Winter warming of between 0.9 and 1.1°C has been recorded in Punjab, Sindh and Balochistan over the last fifty years (6). From 1997 to 2016, minimum temperatures rose by 0.1°C, but no trend was seen in the maximum temperatures (13). Between 1990 and 2011 the number of heatwaves recorded in Sindh increased and across the whole country eleven days has been added to the average duration of heatwaves every decade (12). The heatwave in 2022 was assessed to be thirty times more likely to happen in the current climate than in a pre-industrial world, highlighting the effect that global warming is having on the temperature in Pakistan (7). During the monsoon season temperatures cool in all but the Balochistan plateau (12).

Evapotranspiration:

Evapotranspiration involves the transfer of water from land to the atmosphere, by both evaporation from land surfaces and the transpiration of plants. It is important to monitor this process and any changes that might happen in the future as it has a direct impact on crop growth and irrigation needs and is used in drought risk management (14). From 1995-2014 the average annual evapotranspiration for Pakistan was 1059.7 mm, but higher temperatures are likely to lead to increases in this amount (10; 15). It has been noted that heatwaves in Punjab have led to higher evapotranspiration, requiring extra water resources in growing crops (16). In Sindh the increased level of evapotranspiration is putting pressure on an irrigation system which is already struggling to supply adequate water to the region (17). Heat stress on crops due to these higher rates of evapotranspiration have also been reported in stakeholder discussion about food security (18; 16).

Precipitation and monsoon patterns:

Rain systems are crucial for predominantly agricultural economies such as Pakistan. Currently Pakistan has a summer rainy season that is usually 6 weeks long. Three-quarters of the country has less than 250 mm of rain annually, with the Indus Basin getting 20 mm less than this, but the sub mountain region in the north having an annual rainfall of 760-2000 mm (11). Generally Pakistan has less rainfall than parts of India at the same latitudes (7).

Through the temperature gradient between land and water, heating winds converge over land bringing monsoon rainfall. More intense monsoons, coincide with strong La Niña events, in which air pressure over the western Pacific falls, increasing rainfall (7; 19). In Pakistan winds bring moisture from the Indian Ocean. The timing of the monsoon is critical in dictating planting seasons. Late arriving monsoons reduce the length of the growing season, whereas early monsoons may reduce yield by affecting the early growth of crops. Heavy rainfall is expected in the summer, but there are inter-seasonal and interannual variations (12).

Rain normally occurs at low elevations, so mainly misses the western and northern mountains (20). Monsoon depressions generally track north, but in 2022 all 8 recorded depressions went towards southern regions of Balochistan and Sindh (7). It is

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thought that this may have been due to elevated surface temperatures caused by the earlier heatwave (7). Previously the monsoon was expected to start in June, with mild rainfall in southeast Sindh, increasing in July and August (20). Over the last 50 years the overall duration of the monsoon season has decreased, with a delay in starting of 30 days per decade in the east (12).

FIGURE 2: MOUNTAINS IN NORTH PAKISTAN. (IMAGE: JAHANZAIB KHAN)

Conversely, the north has had a shorter than normal dry season, with an increase in winter rain of 20.8 mm. In 2022 Khyber Pakhtunkhwa and northwest Balochistan received heavy rainfall at the end of August, leading to downstream riverine flooding as late as September. Balochistan and West Sindh previously reported receiving very little rain, in the order of 20 mm per month, whereas Lower Sindh receives up to 100 mm across the season (20). Rainfall is observed to be particularly erratic in upland Balochistan with frequent droughts and occasional torrential floods (15).

A pattern of alternating floods and droughts is brought about by changes in rainfall from one year to the next, with these changes correlating with the El Niño cycle (6). In the last fifty years there has been the highest frequency of extreme precipitation events, which are defined as having more than 50 mm of rainfall in a day (12). Although between 1960 and 2007 there was a 10-15% reduction in rainfall recorded across the coastal regions and the arid plains, increased precipitation over the eastern region counteracted this. Overall, there was a 61 mm increase in average rainfall over the last century (11). Between 1997 and 2016 precipitation has become more intense, with a positive annual increase due to changes in August and September rainfall (13).

The largest threat to livelihoods in Pakistan is seen by some as the fluctuation in intensity and frequency of rainfall, which brings with it the prospect of climate disasters on both a local and provincial scale (21). Unseasonal rains have already destroyed crops and led to climate migration. For example, in the Thar region in 2019, rains falling after 6 dry years, destroyed crops of beans and livestock fodder, causing Tharis to migrate to other districts (22).

Glacier and snow cover:

Pakistan is home to more glaciers than anywhere else outside of the North and South Poles. Increased temperatures and precipitation are hastening snow and ice melt in North Pakistan, which is causing a greater risk of glacial lake outburst floods (GLOFs) (10). Currently the Indus River receives 50-80% of its flow from snow and glacier melt, so increases to volume cause widespread flooding (23; 24). The Government of Pakistan is participating in a project to reduce the risk to northern regions from GLOFs and the landslides that they often cause (24).

Glacier melt is also having an impact on the province of Sindh where inadequate water storage infrastructure has led to riverine overflow on low elevation land on many occasions, such as the floods of 2010 and 2013 (17). In Northeast Punjab, flooding along the Chenab River is also being exacerbated by the acceleration of snow and glacier melting in the north (25). However, the contributions of melted snow and glacier ice to run-off are currently poorly quantified, so there are no accurate records of this effect (25).

Sea level rise:

As the ocean warms in response to changes in the climate, sea water expands, resulting in sea level rise. Despite Pakistan's relatively short coastline, the low elevation of the south of the country, makes it vulnerable to sea level rises and coastal erosion (2). The Karachi coast has seen a sea level rise of 1.1 mm per year over the last century, which is just under the mean global rise of 1.4 mm (11). However, from 2006-2015 the rate was at its highest, at 3.6 mm (11). In Sindh the sea erosion and intrusion caused by these rises has resulted in many local communities migrating to the city of Karachi (17). 3 million acres of land have been removed by sea erosion in the last 40 years and in this time a million people have moved from coastal districts to the city of Karachi, an industrial and commercial hub, which is perceived as less vulnerable to climate change, more able to provide employment and better equipped to deliver high quality health services and education (22; 26).

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2.2: Projected climatic changes

Temperature:

Projections show that Pakistan is likely to experience temperature increases above the global average in the coming years, with more heatwaves in the north, as well as in the arid and semi-arid regions (12). In the Hindu-Kush region this is likely to increase the rate of snow melt and glacial shrinkage (12). The number of hot days and nights is also set to rise and the number of cold days and nights will be reduced (12). Heatwaves are set to become more intense and more frequent, with more than 5% of working hours each hot day likely to be lost due to the rise in temperature (11). Projections made in 2010 under RCP8.5 suggest an average rise in temperature across Pakistan of 1.4 to 1.8°C by the 2030s, 2.5 to 3.5°C by the 2060s and 4.1 to 5.7°C by the end of the century (12).

More recent projections using the CMIP6 Global Climate Models also suggest statistically significant temperature increases across the entire Indus River basin, with the greatest changes occurring at the higher altitudes (10). Under a future where global temperatures increase by 1.5°C, 2°C or 3°C, the mountains in the northwest would have a greater than 10% increase in average temperature, whereas the south and central area would see a 0.5% increase in the low temperature scenario, but a 5-10% increase for the other two cases. The highest level of warming would prompt a 40% increase in temperature across the far west of Pakistan. By 2100 there is projected to be a rise in days with a heat index of over 35°C of by 9 to 13 days under SSP1-1.9, 16 to 30 days under SSP2-4.5 and of 21 to 39 days under SSP3-7.0 (27).

> "At the global mean temperature scenario of +2°C such a heatwave would become an additional factor of 2-20 times more likely and 0.5-1.5°C hotter compared to 2022."
>
> World Weather Attribution report on the 2022 Pakistan heatwave (41).

Evapotranspiration:

Warming of heat and soil leads to a reduction in water resources, however projections for evapotranspiration are very limited, with wide agreement on the importance of this measure, but little research completed (15; 17; 27). A 5% decrease in relative humidity is projected for Balochistan province, which taken with the projections for increased temperatures, have led to an expectation of increased evapotranspiration (15). Based on CMIP6 climate models, under a 1.5°C temperature increase, evapotranspiration levels would increase by 1.8%, under 2°C by 2.7% and under 3°C by 5.2% (10).

Within these patterns, there are still marked regional differences. Under the lowest temperature increase the north and west would have a 4% increase in evapotranspiration rates with the south having only a 2% increase, but under the highest warming considered, over 50% of the Indus Basin would see a more than 6% rise (10). These increased evapotranspiration rates will limit water availability across the Indus Basin, threatening crops and livelihoods dependent on the productivity of the agricultural sector (13).

Precipitation and monsoon patterns:

Projected precipitation patterns vary widely with both the emissions future considered and the models used to project climate. Climate models have a particular difficulty in simulating rainfall over Pakistan due to the high variability inherent in its position at the end of two separate precipitation bearing weather systems (7; 1). In addition to seasonal trends changing, Pakistan is expected to also see erratic and unprecedented cyclone rainfall (28).

Bashir and Hanif in their 2018 paper about projected rainfall variation under a 2°C warming scenario, expected monsoon rains to increase in the western and northern mountain regions, with areas of Balochistan receiving 40-50% more rain than currently (20). South Khyber Pakhtunkhwa and Central Punjab were expected to be wetter in June, whilst East Sindh and South East Punjab showed a tendency towards being drier. The largest increase was shown to be a greater than 70% precipitation rise in June in West Sindh. This led them to conclude that the monsoon is strengthening in the north and west of Pakistan and weakening in the southeast of the country.

The IPCC has predicted a shift in the monsoon season, with an increased risk of flooding and drought in Punjab and Sindh, based on a stronger and more variable monsoon (12; 7). This will follow from greater rainfall in the south and centre of the country initially, but this is expected to be insignificant in the long term with rainfall declining in the south but increasing by 15-25% in the north over the next century, if emissions continue at their current rate or higher (12). However, this does depend on which RCP is considered, with a low emissions pathway likely to decrease average rainfall in the north and west after 2030, but increase rainfall over the rest of the country (12).

Other projections used in the 2021 International Red Cross Federation report on future climate in Pakistan suggest that the peak of the monsoon rains will shift to August and that the westerlies will produce rainfall in March (11). Across all RCPs for

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CMIP5 models the average increase in rainfall was 2-4 mm up to 2050, with the majority falling in the northeast. After this time, the northwest and south are projected to become the wettest regions.

Using an ensemble of 13 CMIP6 climate models, Abbas et al find that average winter precipitation shows no obvious increasing pattern, but there are significant increases in summer rainfall (29). Under SSP5, which has the largest growth in emissions, there are increases in winter rains on average across the country, but weaker precipitation in central regions. In summer this projection shows higher intensity rainfall, but fewer events. SSP3 shows moderate increase in rainfall of between 0.012 to 0.016 mm per decade in winter, but by 0.05 mm per decade in summer. When SSP1 and 2 are considered these show an insignificant decreasing trend in winter rainfall, but summer increases of 0.004 mm and 0.022 mm per decade respectively. Under SSP1 the northeast and southwest receive more rain in the winter, but under SSP2 there is a significant decrease in winter rain in the east, west and southwest. This is due to a projected weakening of the westerlies weather system in future decades.

Mondal et al also used CMIP6 models, but this time an ensemble of 7 models, which best captured seven different future climate scenarios (10). It was found that working across the different models and different scenarios, precipitation patterns were highly variable and uncertain. A decrease in winter and spring rainfall was projected overall, but within this, more extreme wet events in the upper part of the Indus Basin and dry events in the lower part.

FIGURE 3: RANGELAND NEAR MOUNTAINS IN NORTHERN PAKISTAN.
(IMAGE: SHAKEEL AHMAD ON UNSPLASH)

Glacier and snow cover:

In the future the pattern of shorter springs and hotter temperatures in summer will cause Pakistan's 7000 glaciers to melt faster, without enough time to re-freeze (30; 7; 27). The increased melt rate for glaciers and snow in the northern regions will lead to GLOFs as well as riverine floods downstream on the flood plains (11; 31). The higher stream flows resulting from the rapidly melting snow and glaciers will, in the long-term, lead to scarcer water resources as the glaciers shrink (28; 24). In the next two to three decades this will lead to a new pattern of reduced river flow (32).

Sea level rise:

Projections agree that the sea level will continue to rise, threatening to submerge low-lying areas (27). Under RCP 8.5, by 2100 there is expected to be a rise of 0.61-1.1 m relative to the 1986-2005 period, with the low-lying coast south of Karachi likely to be affected with a 90% level of certainty (11). Impacts of these rises include erosion of beaches, inundation of wetlands and lowlands, salinisation of both groundwater and surface waters and an increased risk of cyclones originating in the Arabian Sea (24). These winds also cause coastal erosion. If tropical cyclones wipe out the infrastructure of Sindh's coastal region, then this will affect Pakistan's GDP as the country's exports largely depend on Sindh's ports (17). Soil and land degradation from sea water intrusion affect grazing and crops, which limits the amount of available cultivable land (11). In Sindh approximately 2.5 million hectares of land is now considered to be water-logged (33). The 2017 Asian Development Bank (ADB) Report also found that the sea level rise was likely to degrade the coastal mangrove forests, lower drinking water quality and decrease fish and shrimp stocks (17).

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SECTION 3: VULNERABILITY TO CLIMATE CHANGE

The need to reduce vulnerability in Pakistan is recognized by its government, national and international scientific organisations (7; 24; 34) . Given the geography of the country, its cultural background and its level of development, there are several categories of risk which are aggravated by extra vulnerability (35). Based on an extensive review of currently available literature, these vulnerabilities are discussed in depth in this section.

Adaptation planning has at its heart the goal to reduce vulnerability. It is hoped that by highlighting these key areas across the whole country, adaptation actions can be targeted and thus the impact of climate change reduced. It has been shown to be increasingly important to consider not just outcome vulnerability, based on the immediate and future impacts of climate change, but also to assess contextual vulnerability, which takes a more multidimensional approach (36). Whilst addressing the first results in short term actions to reduce climate vulnerability, such as improving infrastructure or supplying seeds better adapted to climate change, the second provokes more profound changes that will lead to improved social structures to reduce vulnerability in a longer term and more strategic way. To move climate change adaptation from a continuation of the standard development paradigm to an innovative tool allowing real progress, environmental, social, political, economic and historic factors should all be taken into account.

This section provides a broader overview of key vulnerability factors in Pakistan. It includes recommendations at national and district level, where climate and vulnerability data with a finer resolution is available and this can be combined with local expert knowledge. This report is, however, constrained by scope to give a broader overview.

3.1: Flood risk

Floods are now an annual event in Pakistan, with its high exposure to riverine, flash and coastal flooding (37). Pakistan relies on snow and glacier melt from the north of the country to feed the Indus River, which then delivers water via an extensive irrigation system to areas further south (31). Many areas also rely on monsoon rains to ensure they receive enough water (24). However, as the climate changes, these resources are set to become more unpredictable, leading to both droughts and floods (28).

FIGURE 4: FIRST DAY OF FLOODING, JUST BEFORE WATER ENTERED HOUSES CLOSE TO THE BANK IN SWAT, KHYBER PAKHTUNKHWA, 2022 (IMAGE: KAMRAN KHAN)

On occasion these effects compound each other, with extreme heat from the summer months hardening the ground, meaning that flash floods are more likely from short intense periods of rainfall (11; 10). The key drivers of all flooding events in Pakistan are the upper air circulation associated with the mid-latitude jet stream and the orography of the upper Indus Basin (7). Deforestation and the lack of regular maintenance of canals are the two major issues that are amplifying flood risk from changing climatic conditions (38). Given the impending likelihood of more monsoon floods, flash floods, river breeches, urban floods and coastal floods in the future, water management is crucial and flood barriers and control systems should be a priority in all areas (39; 17).

Flooding and landslides in North Pakistan:

In the north of Pakistan climate change is already having a huge effect. Higher temperatures are causing faster melting of snow and glaciers than before, which can lead to new lakes being formed or existing lakes growing, sometimes displacing whole communities (28; 30; 22). There are currently over 3000 glacial lakes in Pakistan, with 33 of these regarded as hazardous (40). If icy barriers damming such lakes also melt, then this means there is the potential for flash floods which can quickly inundate the surrounding area. These are called glacial lake outburst floods or GLOFs. For example, in 2022 the heatwave triggered an extreme GLOF in northern Pakistan (41). It is estimated that 7.1 million people are at risk from GLOFs and incidents have increased by 300% in the last two decades (40; 42).

Infrastructure up to 60 km from the original glacier can be affected by a GLOF if there are hydrological connections to the glacial lake, depending on the slope of the surrounding terrain (43). Many communities based in the north of the country have not planned for such events and so are very vulnerable to extreme floods and becoming more vulnerable as the climate changes

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(12). For example, in Darkut Village, 57 houses are at risk from heavy flooding, along with the local school, the helipad and the village stockpile of cattle fodder and food (44). One way to reduce this vulnerability would be to have a community-based disaster response and risk management system, which could ensure climate data is not just available, but acted upon at local level (24).

The short-term severity of the GLOFs in the mountain areas of Pakistan also leads to the prospect of long-term freshwater shortages for the region (30). This is not only a challenge for agriculture, but also threatens industry, as much of the region's power is hydroelectric and there is already a growing gap between provision and demand (30). Projected increases in the frequency and intensity of rain and thunderstorms in the north of Pakistan could trigger increased incidences of flash flooding and landslides, but there is no significant trend between intensified rainfall and GLOFs (11; 43).

Landslides are in fact far more likely to happen in northern Pakistan than GLOFs (45). These can be attributed to a range of causative factors including steepness of slope, direction of slope, geology, landcover and distance from faults, roads, irrigation systems and streams (46; 47). In addition, heavy rainfall or snow can also act as a trigger (46; 47). The combination of these criteria make northern Pakistan particularly prone to landslides and with climate change projected to increase rainfall intensity this is likely to become worse in the future (46).

Expansion of crop areas has destroyed natural ecosystems reducing flood water drainage (27). Changing land-use to move from vegetative cover to open, irrigated agricultural land can destabilise slopes, making landslides far more likely. This was shown, in recent research, to be the single factor that contributed the most to increased susceptibility (46). Landslides can kill, displace, and block water sources and roadways, like those that killed 8 people in 2022 and 29 people in 2006 in Khyber Pakhtunkhwa (46; 45). Disasters involving landslides can also be made more serious when whole communities are cut off from resources by the event (27).

Indus Basin:

As the world's largest irrigated basin, the Indus Basin Irrigation System (IBIS) supports the livelihoods of nearly 268 million people (10; 13). The River Indus flows through the middle of the Sindh province, but changes course every 20-25 years (17). Although GLOFs affect communities based in the mountain region, the effects caused by the ensuing flooding downstream are more extreme, as the majority of Pakistan's population live in this area, which is also home to a large percentage of Pakistan's agricultural production (8; 6). The extent of the flooding depends to some extent on the current river path (17).

> "I want to feel settled for once in my life, to live in a place that doesn't get washed away again and again."
>
> Bushra Sarfaraz, a labourer living in a tent camp near Thatta, Sindh (307).

Where the monsoon season brings with it destructively heavy rains, flooding can damage crops and cause large scale migration (20; 17). Crops grown in Sindh's desert regions are particularly vulnerable to agricultural pests and disease outbreaks following flooding and erratic rainfall (8). This is projected to become more severe in future with an increase in wet and very wet days (11).

Due to a combination of floods and coastal intrusion 80% of those who once lived along the Indus Delta have now been displaced, many moving to Karachi (48). In Balochistan there is no system for controlling or storing flood water, so floods bring destruction, but do not recharge local water resources (15). There is agreement between various climate models that the increases in both temperature and precipitation in the north of Pakistan will continue, leading to increased downstream flooding over the coming decades (25).

Development in flood zones:

The flood plains and surrounding areas along the Indus River are the site of many villages, making these developments not only particularly vulnerable to flooding, but also reducing the drainage potential of this land, trapping flood water where it can do most damage (1). To increase cultivable land area, wetlands have been filled in and drained, increasing exposure to floods (33).

Infrastructure damage due to the 2022 floods was largely due to building in flood prone regions (7). Many of the dwellings washed away were traditional mud houses, which provide little to no flood resistance (7). Until regulations are implemented, urban development in flood zones will continue (49). There is in particular a

FIGURE 5: HYDERABAD IN JULY 2022. (IMAGE: ASIANET-PAKISTAN).

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need for legislation to prevent urban development on agricultural land in Khyber Pakhtunkhwa which will further exacerbate both drainage and food security issues (30). Urban flooding is often caused by flash floods, so time to respond is very limited and early warnings may not be effective (7). For this reason it is vital that urban storm drainage is well maintained and regularly cleared (24). After the 2022 floods it was found that impact had been reduced where mature vegetation acted as a shield against incoming floodwaters, showing that development must be carefully monitored and controlled to avoid removing this valuable defence mechanism (33).

Coastal flooding and saltwater intrusion:

It is not only the increase in sea levels that is causing problems along Pakistan's coast. As the flow of the River Indus, approaching the coast, has decreased in the hotter weather caused by climate change, the Indus Delta has shrunk, resulting in intrusion by the Arabian Sea (50). The large population of coastal areas, including the city of Karachi, coupled with the high density of economic assets such as manufacturing, farming and fisheries in these regions, make them particularly vulnerable to coastal flooding and saltwater intrusion (2).

Coastal areas are not just at risk from sea level rise, but also from storm surges, monsoon waves and cyclones, all of which cause erosion (7). If no steps are taken to reduce the level of risk through adaptation, then up to a million people will be having to deal with annual flooding along the coast of Pakistan by the end of the century (6; 51). Small farmers, particularly those depending on rainfed agriculture, are the most impoverished members of the coastal communities and are thus among the most vulnerable (2).

3.2: Disaster preparedness

With climate impacts likely to increase and become more intense, it is vital that adequate disaster preparation to reduce vulnerability and exposure is undertaken in good time, rather than authorities and NGOs being forced to try to mitigate events as they happen (24).

Khyber Pakhtunkhwa is vulnerable to floods, droughts, heatwaves, wildfire, avalanches, landslides and locusts, with disasters becoming more frequent and severe in recent years (30). Whilst the province has no control over the 60% increase in flow recorded for the Swat and Kabul Rivers in the last 100 years, they can ensure that scientific methods are used to intervene when a disaster occurs (30). The issue is that often the understanding of those dealing with a disaster and the financial capacity for adaptation are limited. In cases like the 2022 floods, mass migration is often favoured over other emergency responses (52).

In Sindh where hazards posed by floods and cyclones are compounded by droughts and sea intrusion there is a call to improve early warning and monitoring of climate events, so that information can be used to set up disaster planning mechanisms (17; 21). In addition, practical measures like constructing coastal defences could reduce the impact of sea intrusion, thus rendering Sindh less vulnerable to sea level rise. A $120 million project implemented in 2016-2024 by the World Bank (WB) aims to develop emergency services in Sindh and create an integrated disaster management plan. It is unclear as yet whether this strengthened resilience to the 2022 floods (7).

Better sectorial co-ordination is needed in disaster management across all of the provinces, with improved emergency response training for non-governmental organisations (NGOs) and other volunteer organisations (30; 17; 15; 39). The National Disaster Management Authority (NDMA) notes that the cost of dealing with past disasters could have been reduced through preparedness, prevention and mitigation (32). With ready stocked multipurpose disaster resilient centres, that could be used as both shelters and storage areas for relief goods, people could be temporarily evacuated more safely and there would be less need for migration (17). This would prevent people being evacuated to other elevated places such as mosques, schools and even railway tracks, which are not suitable for medium term habitation, but have been used in the past for as long as two or three months (21). It is also important to plan non-grid power provision in the case where other infrastructure is damaged in a disaster, in this way vulnerability is reduced through extra contingency (17). Setting up a Climate Development and Knowledge Network (CDKN) to prepare even the lowest income groups for possible future hazards would greatly reduce vulnerability to climate disasters and in the long run save money, in reducing the current level of loss (32).

3.3: Water security

Climate change is particularly linked with water resources in Pakistan due to the country's reliance on both snow and glacier-melt and on seasonal monsoon rainfall for its fresh water (24). It is expected that water availability and quality will both decrease in the future, resulting in a water shortfall of 32% by 2025 (23; 39). Almost 13 million hectares of Pakistan's agricultural land is no longer sufficiently wet to be cultivable, so there is a real need for effective irrigation (10). Despite

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Pakistan's heavy reliance on water services, according to the latest report from WB there has been a "near complete lack of public investment in the provision of safe water and sanitation" (27). Water shortages are being exacerbated by leakage from the current canal-based irrigation system. In some cases freshwater is being polluted by waste water from homes and businesses (30).

Plastic pollution of the Indus River is also problematic, with the 164000 tonnes of plastic it carries each year, making it the world's second most plastic polluted river (33). This causes water insecurity which is compounded by Pakistan's limited water storage capacity (23; 30; 11). Extreme shortages of safe drinking water bring with them wider implications for health, agriculture and industry, particularly in a country with fast growing demand (53; 10). A 2019 report from UNICEF noted that 70% of Pakistanis are still drinking contaminated water despite projects to improve water quality (11). Currently between one third and one half of all drinking water contains traces of E. coli at source and with no in-home water treatment, at point of use this figure rises to between 60 and 75% (27).

Drought:

Pakistan is currently 43rd in the global list of countries most prone to drought, but projections show that droughts are set to become more frequent in the future (27). Irregular and decreasing monsoon rains are likely to be a key driver of droughts in Pakistan over the coming decades (24). In Southeast Pakistan these conditions bring with them the threat of water stress, drought and famine (20). In years where the monsoon is weak, upstream areas use the water from the River Indus before it reaches Sindh, which results in crop failure for the region as well as exacerbating drought conditions (17). These include food price rises, widespread malnutrition, disease and migration. 80% of livestock and orchards died during the 1997-2002 drought which is estimated to have cost $114 million and slowed Pakistan's economic growth (15). Higher temperatures are likely to increase evapotranspiration rates, compounding the water shortages (24).

In the Tharparkar district of Sindh, droughts used to occur every 8 to 10 years, but their frequency has now increased, so that in recent years they have become annual events (21). Droughts propagate slowly, but have long lasting effects (14). In Balochistan, 70% of weather stations have recorded a fall in both annual and seasonal rainfall, which taken with the lack of streams and rainwater harvesting, makes the South of the province particularly vulnerable to droughts (15).

> "We have already begun to witness the impacts of climate change in the shape of regular floods, droughts and heat waves across the country. We have seen our northern areas impacted by glacial lake outburst floods."
>
> Romina Khurshid Alam, Parliamentary Secretary of the MoCC (293).

Glacial melt:

The Hindu Kush-Himalayan region is sometimes referred to as the "Third Pole" due to the fact that its glaciers and snowfields store more frozen water than anywhere outside of the polar ice caps (44). Glacial flow from this area is vitally important to Pakistan as 50-80% of the country's freshwater comes from this source. Up to 80% of this meltwater is used to irrigate cultivated farmland (32; 23). As the temperature increases so does the rate of glacial melt, leading to faster river flow (24). Currently Pakistan's glaciers number more than 5000, but they are melting faster than has ever been previously recorded (50). This is likely to continue until 2050 under both the RCP4.5 and RCP8.5 scenarios (27). However new winter snowfall is being reduced as the seasons warm, so the Karakoam anomaly[1] of stable or expanding glaciers is potentially under threat (23; 2; 54).

Projections show that the Karakoam glacier will sustain 50% increased melting in the first half of the century and a 40% reduction by 2100 (30). This means that increased flow constitutes not just a source of vulnerability due to the GLOFs and riverine flooding downstream in the immediate future, but that it will also prompt water shortages, occasioned by this accelerated glacial shrinkage in a few decades' time (24; 17; 23). After 2050, under both RCP4.5 and RCP8.5, river flow is expected to decrease from April to June each year (27). Currently Pakistan has 1000 m^3 of water per capita, but by 2025 this is projected to decrease by a fifth (23). This is particularly worrying given that if there is a 3°C global temperature rise by 2047, then estimates show that there will be an almost 60% increase in water demand across the country, with at least a quarter of this due to climate change (27).

[1] The "Karakoram Anomaly" is termed as the stability or anomalous growth of glaciers in the central Karakoram, in contrast to the retreat of the glaciers in other nearby mountainous ranges of the Himalayas and other mountain ranges of the world (54).

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Irrigation techniques:

Irrigation is vitally important in Pakistan, with 90% of food production coming from irrigated agriculture (14). The Indus River irrigation system is the main water supply network in the country comprising a network of 23 canal systems, water courses, farm channels and field ditches (39). This system is under immense pressure as it was originally designed to provide low-intensity irrigation (55). As it ages and in some areas physically crumbles, efficiency has been reduced to just 39% (56). The devastating flooding events of 2010 and 2022 exposed technical issues that will require immediate attention. For example, failures in irrigation system levees led to devastation in the 2022 floods, whilst silting of canals and the failure of the drainage system at the Indus Delta resulted in large parts of Badin being flooded in 2010 (1; 7). Intensified rainfall in the future could well cause further damage to riverbanks, threatening water security (27). At the same time, water security is also at risk due to longer dry periods, with a 6% decrease in rain leading to a 29% increase in irrigation needs across the whole of Pakistan (18).

> "An ideal irrigation effort aims to cover the deficit between a crop's optimal water needs and what it can take up through natural means."
>
> Sadia Hassan Sherani in the Pakistan and Gulf Economist (308).

The IBIS is poorly maintained, with 40-50% of the water delivered through local community water courses being lost due to canal seepage and waterlogging (57). Another key issue is the lack of storage capacity within the system, with the Tarbela and Mangla reservoirs having lost 20-32% of their storage capacity through sediment deposition (55). The third major problem compounding Pakistan's difficulties when dealing with both droughts and floods is an outdated management system, with at least half a million people estimated to be affected by flooding due to the inadequacies of the IBIS annually (1; 7). The IBIS upper tier of main and second irrigation systems, including barrages, main canals, branch canals, distributaries and minors is run by the public sector, whilst the lower tier of water courses is farmer led (57). Within both management systems there have been problems with corruption and political tension, which threaten to cause hostilities between provinces as water resources shrink (55).

Currently pricing of irrigation water is too low, with the rural elite benefitting from this mismanagement (55). The volume of water available is tied to the size of land being fed, which discriminates against smallholders and also means that the water tariff is a flat rate for each unit of cultivated area, giving no financial incentive to use water more efficiently (27; 15). This leaves the canal water drastically underpriced, as total charges only amount to 20% of the annual maintenance and operational costs of the system (56). In addition, many of the revenues are not collected, so insufficient money is generated for even basic maintenance (27).

In Shabara, in the province of Khyber Pakhtunkhwa, inappropriate irrigation has led to worse conditions when droughts or floods do occur, as there is less groundwater left after pumping to feed into the system in water scarce times and irrigation methods are leading to waterlogging when there is too much water (52). Poorly structured irrigation in areas of northern Pakistan has also been linked with a greater susceptibility to landslides (47; 46). Farmers downstream are increasingly having to use more efficient irrigation practices due to the "theft" of water from irrigation canals by those at the top of these canals (58). For example, irrigation in Sindh is limited by damming upstream which is reducing water availability (17).

The traditional method of flood irrigation is compounding issues of water scarcity and even the more efficient furrow irrigation, loses a lot of water to the ground, stressing plants with alternating plentiful and scarce water supplies (58; 59). In contrast changing to drip irrigation which takes water directly to plant roots was shown in field studies to increase yield by 26-33%, whilst reducing water use by 86% compared to furrow irrigation methods (59; 60). Water efficient irrigation is vital if agriculture's vulnerability to climate change is to be reduced (31; 60). In Balochistan agriculture accounts for 95% of the province's total water use, so control and storage of water must be better addressed in future with variability in irrigation supply currently affecting 80% of irrigated arable land nationally (15; 21). The Indus River provides 40% of irrigation water in this province, but this only reaches 5% of the land, due to poor infrastructure (15). In Punjab 90% of the crops depend on irrigation from the system of canals, so decreasing rains and increasing temperatures are having a negative effect on the region's farmers (12).

Recent research has identified several measures which could improve the climate resilience of the irrigation system. These include additional research into how to predict low stream flow from the Standard Precipitation and Evaporation Index and Standard Streamflow Index which could help with irrigation planning and reservoir management in the future (14). Further adaptation via updating infrastructure has also proved to be effective with new flood mitigation walls in Khyber Paktunkhwa limiting the damage caused to the province in the 2022 floods (7). Above all, there is an urgent need to conserve water and reduce ineffective usage, as over the next thirty years it is expected that 10% of irrigation water will be allocated to other sectors, like industry and healthcare (27). For such a change to happen, widespread education about appropriate water use is essential. The Pakistan Council of Research in Water Resources (PCRWR) is currently working on a number of projects to

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improve water management and water quality using research, engineering techniques and education (61). In 2021 they launched the Pakistan Water Week, which is a combination of academic seminars, industry exhibitions and community activities, such as essay competitions, poster sessions, guided walks and water games aimed at everyone from school children to district stakeholders (61).

Groundwater harvesting:

50% of all water in Pakistan's irrigation system is extracted from the ground (58). This heavy exploitation is not sustainable and figures show that as early as 2030 there will be shortages (23; 27). It is argued that management of surface and groundwater has not been fully co-ordinated between the agriculture, industry, food and health sectors (30; 39). There are no regulations on groundwater extraction in Pakistan and farmers are even encouraged to extract water by an electric tariff subsidy for tube well operation (27).

Farmers in Wana, in Khyber Pakhtunkhwa, have installed over 5000 solar tube wells, which suck water out of the ground constantly, leading to a large wastage of resources and a lowering of the water table in the region (62). In Shabara, in the same province, over 73% of the farmers use tube wells as there is no canal irrigation and no storage of water when it is plentiful (52). Although this is not looked upon as a long-term solution, without any other allocation of water resources fruit growers and farmers see no other option (62). Pumping groundwater depletes the extra water supply buffer that districts have in the case of a drought event and also risks increasing the salinity of the land in some areas (27). In Balochistan, groundwater abstraction is higher than recharge, so in the future the use of floodwater, possibly via spate irrigation might be the only option (15).

FIGURE 6: GROUNDWATER PUMPED BY A DIESEL ENGINE IN PAKISTAN. (IMAGE: ZMS)

Agricultural drought is caused by a significant reduction in soil moisture, which for the Indus Basin is heavily dependent on the stream flows from the Upper Indus (14). It is critical that soil moisture is maintained to prevent desertification, so programs to promote the use of flood water and water conservation are vitally important (17; 15). When there is a low river flow and no rain, then other water sources become relied upon even more. Local communities need to be taught about rainwater harvesting to reduce the need for some of the traditional irrigation methods which do not use this vital resource efficiently and could lead to worse water scarcity in the future (30).

Regional tensions:

There is a lot of tension between farmers at the upper end of the IBIS and the lower end, as water is being "stolen" out of the canal system, leaving farmers in South Punjab and Sindh with inadequate water to grow their crops. Whilst those at the lower end adapt their farming methods to enable some production with reduced water, those at the head of the canals are reported to be removing more than their allocation of water, so that they can use inefficient flood irrigation techniques. Some influential landlords in these areas are accused of pumping water from the system directly onto their land, with a physical survey by a Sindh Farmers' Association finding 650 illegal pumping machines in the 250 km stretch of the canal system between Sukkur and Sanghar (58).

Khyber Pakhtunkhwa and Balochistan do not have adequate storage capacity to make use of their full allocation of water when this is plentiful, so the excess is used by Punjab and Sindh, sanctioned by the Indus River System Authority (IRSA) (55). This has led Balochistan to sue Sindh for PKR7 billion (63; 55). At the same time the lowering of the water table in the canal command areas of both Sindh and Punjab due to overexploitation of groundwater has resulted in conflicts between these two provinces over surface water supplies (55). There has also been a long running dispute since 1984 between all four provinces caused by plans to build the Kalabagh Dam, which only the province of Punjab favours (64). The arguments against this scheme are that Punjab would benefit from extra water supplies and hydroelectricity, whilst water storing pools would be created over the province boundary in Khyber Pakhtunkhwa, resulting in a loss of agricultural land and water currently going to Sindh would be diverted (65).

There have also been questions about the ethics behind the current flood control systems, which divert water surges from cities to rural areas (7). Lake Manchar in Sindh was breached in the 2022 floods, displacing 100000 people from their homes in an effort to save more densely populated areas (66). However, when the Left Bank Outfall Drain (LBOD) started to overflow further

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south in the province, there were protests against a project to cut the banks to ease water pressure, as this would have submerged several villages in a more sparsely populated area in an effort to reduce exposure further downstream (67). In cities there are more tensions around water scarcity with water thefts by organized crime syndicates, leaving many without access to this vital resource (68). Those who can afford to pay for water from tankers, often run by criminal gangs, are having to spend PKR 28000 a month on water that is not suitable for consumption (69; 70). However, this is not an option for many city schools, who are unable to afford these extortionate rates and have resorted to asking students to bring bottles of water with them to be used for everything from drinking to flushing toilets (69). In the city of Karachi, in Sindh, water is in particularly short supply with availability for 4 hours on a good day, but often reduced to 2 hours every other day (48; 68). Such conditions cause tensions not just between people living in the city and the water authorities, but also between city districts as some areas have better access to water than others (70).

3.4: Agriculture

Climate change has a massive effect on agriculture as this sector depends to such a great extent on weather and climatic conditions. Agriculture is the largest employer in Pakistan, accounting for 42.6% of the country's workforce and just under half of its land (6; 8). It accounts for 18.9% of Pakistan's GDP and 80% of its total export earnings (24). However, climate change is making those dependent on agriculture more vulnerable as future production is threatened by drought, heatwaves, unpredictable rains, flooding, soil salinisation and increasing pest and disease problems (8; 39). Extreme climate events increase poverty, food insecurity and malnutrition, with agriculture being the sector most seriously affected (27; 13). As more than 80% of farmers in Pakistan are smallholders with little or no diversification, unpredictable crop yield and poor conditions for raising livestock leave them highly vulnerable (11; 12). Currently the productivity of agricultural water is 37% per cubic metre, which puts Pakistan into the bottom 10% globally (27).

> "Pakistan Vision 2025 identifies lagging agricultural productivity as a threat to national food security."
>
> World Food Programme (8).

In the 2022 floods it is estimated that $2.3 billion of food crops were destroyed (7). This amounted to a near complete loss of crops (27). People living in fragile environments who have very limited coping mechanisms are disproportionately affected by climate change, so areas of high agricultural dependence are amongst the least resilient (31; 16). The poorer the rural community, the higher their dependence is on agriculture (15). It seems that the wealthy large landowners are using their political power to stop the general proliferation of more efficient practices and diversification in order protect their own assets (27). For example, industries such as sugar production have been monopolised by large landowners. Poor farmers who have decided to grow sugar, as it is less climate sensitive than cotton and should yield a greater profit, are not allowed to produce the more expensive brown sugar, but must take their crops to a mill, where mill owners pay only half of the going rate and take the majority of the profits for themselves (71). In some cases wealthy landowners are buying land to improve their political influence, but not investing in the development of rural areas, with the result that economic divisions within the local community are deepened (27). Within the agriculture sector there are many corrupt officials, who will overload fees, making costs of changing farming practices exorbitant for those who don't have either wealth or political influence (72). However, with 80% of agricultural land in Pakistan cultivated by those classed as poor, it is vital that technical, financial and institutional support is provided to everyone (73). Although various projects to improve agricultural practices have been adopted in Pakistan, the lack of follow-up monitoring has led to poor implementation (72).

There are many ways in which provincial governments could help to reduce the vulnerability of the agricultural sector. These include setting up risk management systems involving crop insurance, improving the access of local communities to hazard forecasts and long-term climate predictions, encouraging adaptation through changes to crop choice and planting cycles and co-ordinating livestock monitoring at district level (24). Currently most adaptation seen is led by the farmers themselves rather than through guidance from governments or institutions (16). This includes changes to planting dates, crop types and fertilizer as well as the planting of shade trees (74).

Guidance encouraging a greater variety of activities, both on and off farm and properly administered loans to aid enlargement of farmlands could reduce some of the problems caused by the changing climate (39). However, there is still the issue of water wastage with 60% of the irrigation water set aside for agriculture lost during either conveyance or application in the field (61). This could be reduced by better maintenance of the irrigation systems, guidance from farming institutions on improving conventional irrigation methods and funding initiatives to make these techniques accessible to all (61; 73).

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Arable farming:

Arable farming, the cultivation of crops on agricultural land, accounts for 40% of land-use in Pakistan, but is at risk from changes to the climate (75; 13). Crop yield reductions are likely to be widespread as the temperature continues to increase, with up to 70% hotter summers and more frequent extreme heat days (6; 52). The extra heat is likely to speed up crop growth, shortening the time between sowing and harvesting and in so doing reduce productivity (24; 17). A 0.5 to 2°C increase in temperature is likely to decrease productivity by 8 to 10% by 2040 (17).

> "These findings…emphasise the importance of using climate impact assessments to develop targeted investments and efficient adaptation measures to ensure resilience of agriculture in Pakistan into the future."
>
> Heureux et al in 2022 paper on climate extremes in the Indus Basin (13).

Wheat is an important winter crop in Pakistan, 38% of production rainfed and 62% irrigated (76). In wheat crops the extra heat (anything above 30°C) leads to early grain formation which stunts its size, reducing yield (39; 13). In the province of Punjab, the winter wheat cultivation season has merged nearly a month into the summer season, delaying the sowing of the second crop which also results in reduced yield (16). A reduction in cereal crops will lead to rises in food prices and a reduction in required labour, leaving landless agricultural workers with reduced income and higher food bills (12; 21).

Pakistan's second most important crop is rice, which is predominantly rain-fed (77). Rice crops have a heat threshold of 36°C, but in the areas where rice is grown the number of days above this threshold will greatly increase over the next century meaning that cropping times and plant varieties may need changing (13). Rice is very water intensive if grown as a paddy crop, but new techniques using aerobic rice varieties which can be cultivated in non-flooded areas or the method of sowing seeds directly into the fields are both better suited to water-scarce environments (78).

Although not one of Pakistan's main crops, sugarcane is a high value cash crop in Pakistan, accounting for 0.7% of GDP (78). This crop grows best between 30 and 34°C, so the higher temperatures projected from April to June, may actually increase production (13). It is also popular due to its resilience in the case of flooding, surviving in standing water for up to two months. (79). Another major advantage of growing sugar is that its slow initial growth rate makes it perfect for intercropping with peas, water melons and onions (78). However, it is also a very thirsty crop, which cannot be grown using brackish groundwater (79).

FIGURE 7: PEACH ORCHARDS IN SPRING. (IMAGE: BILAL PHOTOS)

Fruit crops are also being badly affected, with 95% of fruit farmers in the villages of South Waziristan in Khyber Pakhtunkhwa reporting insufficient access to water for their farms (62). Rain fed apple orchards have seen crop yields decrease by over three quarters in the last three years, leading to severe financial losses (62). Temperature increases have also been shown to reduce orchard productivity, with a 2°C rise in average temperature reducing production by 10% (80). In the Indus Delta, the early end of the winter season is causing heat stress problems for banana crops and limiting pollination (17). This is resulting not just in there being less fruit, but also in a reduction to its quality (17).

Pakistan is the world's largest producer of raw cotton (78). Cotton production is very vulnerable to climate change, due to sensitivity to high temperatures, CO_2 concentration, water shortages and increased evapotranspiration (81). For example, a 1°C temperature rise can result in a 24% reduction in cotton plant yield at the vegetative stage and an 8% reduction at the flowering stage (11). Temperatures over 32°C will cause heat stress in cotton crops, so if production is limited to the June to November season in Punjab and Sindh, climate projections show that this will still be a viable crop (13). Flooding of agricultural land is also an issue with 45% of the cotton crop lost in the 2022 floods (7). Without action to overcome some of these issues a reduction in cotton crop yield from 60-80% is projected by the end of the century for both the Punjab and Sindh provinces under RCP8.5 (82). Farmers with more land tend to have the financial resources, diversified livelihoods and access to weather information that increase resilience, whereas small scale farmers are limited in their uptake of progressive methods leaving them vulnerable to productivity shocks (18; 82; 21).

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As one third of the agricultural land in Pakistan is rainfed, the timing of the monsoon season makes a huge difference to crop yields (11; 12). Small delays in the start of the rains can cause large scale crop failure and equally too much rain at the wrong time can damage or completely inundate agricultural land (20). Unseasonal rains in Thar, in the Sindh province, in 2019 destroyed bean crops and fodder for livestock (22). By contrast, in Balochistan there was a 33% reduction in average crop production during the 1985-2005 drought, rising to 69% for rainfed crops and in Khyber Pakhtunkhwa a lack of rain added to an ineffective irrigation system has led to the need to buy wheat from other provinces (30; 15).

Increased rainfall often results in more pest attacks (52). For example, in the desert area of Sindh incidents such as desert locust swarms are becoming more frequent due to changes in rainfall patterns (8). In Punjab more pest attacks were also seen, in addition to increases in weeds and fungal diseases, due to both erratic rainfall and extreme temperature events (16). Increases in weed germination could reduce rice and wheat yields by as much as 200 kg/ha in this region (16). Changes to season timings also increase vulnerability to pests, with late sowing of cotton crops increasing the likelihood of infestation by white fly and pink bollworm (12).

Farmers are using, and in many cases over-using, water, fertiliser and pesticide to ensure the best possible yield, but then post-harvest, there are massive losses with 35-40% of fruit, 10-15% of cereal and 20% of milk never reaching the market (27). This makes arable farming 1.5 to 4.2 times below field potential, which is worrying given the sluggish sectorial growth, as land resources are exhausted (27).

> "We consider earth as our mother but we ourselves are killing it by poisoning it."
>
> Dr Hafizullah Babr, director of the Soil Fertility Institute at the Sindh Agriculture Research Institute on the abuse of fertilisers in Pakistan (300).

Raising livestock:

Livestock is the main agriculture sub-sector in Pakistan. 53% of the agricultural GDP of Pakistan is from livestock raising (11). Pakistan currently has the world's fifth largest beef herd and supplies 6% of all milk (27). High temperatures and drought conditions are threatening livestock productivity (12; 11). 87% of livestock rearing is currently based in the arid region of Balochistan (11). However, there has been a recent shift from cash crops to livestock raising in other areas of the country due to land degradation and crop loss from flooding (7).

The extended drought period between 2015 and 2017 reduced livestock output by 48% in the worst affected districts in Southeast Sindh (6). The number of head of livestock in Pakistan is increasing by 3% a year, but with a dwindling gene pool the dairy herd is rapidly becoming less healthy (27). Added to this, high temperature can cause heat stress which results in lower survival rates, food intake, productivity and fertility (12).

Floods are also an issue for livestock rearing farmers, causing food shortages, dehydration infection and zoonotic diseases in the long term as well as direct impacts such as drowning and electrocution (12; 21). In the 2022 floods there was a near complete loss of livestock in the affected districts (27). As global warming affects the hydrological cycle, livestock raising practices will need to adapt (24). Unmanaged grazing is already putting an intolerable stress on Pakistan's extensive rangelands (27). The practice of transhumance livestock farming[2] involves grazing livestock for 5 months at higher altitudes where there are green pastures and then 7 months at lower levels where livestock feed on fodder and kitchen waste (83). However, the low availability of fodder and its poor nutritional value are leading to cycles of malnutrition and then overfeeding for animals, which in turn results in less meat and wool and more disease (30).

FIGURE 8: A HERD OF SHEEP GRAZING BY THE RIVER. (IMAGE: BILAL PHOTOS)

Diversification, such as using animal dung as fuel, could help to reduce poverty where livestock grazing is being threatened by climate change (17). In South Punjab, livestock is one of the main sources of livelihood, however this is proving to be high risk as both droughts and floods lead to degradation of the rangeland, loss of shelter and fodder, more diseases and often

[2] Transhumance is a mobile method of livestock farming, where herds are moved to geographically-distant places based on regular, seasonal cycles (311).

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the death of the animals, where evacuation strategies are not fully planned (39). Where livestock were once kept to supplement the income of those involved in the fishing industry, the loss of grazing areas to coastal erosion is preventing this livelihood diversification and thus rendering people more vulnerable to climate change effects (53).

Fisheries and aquaculture:

Pakistan's fisheries and aquaculture constitute an integral component of agriculture, providing employment, food and nutritional security to people, particularly the rural poor. Pakistan earned US$250 million from exports of fish and fishery products in 2018 (84). Pakistan has 1120 km of coastline and 3102408 hectares of the inland water reserves.
Lakes, rivers and natural ponds are being used for aquaculture sector development such as breeding trout for recreational fishing. However, the sensitivity of the fish to changes in water temperature could be a problem as the climate continues to heat up (30). Increased water temperature and reduced dissolved oxygen can lead to spawning time changing, which then means that fish are more susceptible to parasites and that their feed conversion ratio is reduced (17). This means that the aquaculture sector is particularly vulnerable to climate change.

Marine fishing, however, is also threatened by the extra heat and acidification of the sea, which affect fish and shrimp growth and reproduction (17). Both Sindh and Balochistan have been affected by sea level rises bringing with them higher coastal erosion and salinisation (11). In Sindh 65% of the population depend on catching and drying fish, but as fish species decrease due to increased temperatures and the removal of mangroves for charcoal production, fishermen are having to go further out and rely on more dangerous deep sea fishing opportunities (53; 53). Along the Balochistan coast, rising temperatures have been depleting fish stocks and limiting income for those dependent on this livelihood (12). The China-Pakistan Economic Corridor (CPEC) Port Qasim Power Project along the Arabian Sea coastline is reported to have further destroyed livelihoods by damaging fragile coastal ecosytems (48).

Regional tensions over natural resource management:

Regional tensions over natural resources are caused by poor management and increasing scarcity of these commodities, as well as a lack of strategic planning for livelihood diversification. Where coastal erosion and sea water intrusion have reduced cultivable and grazing land in Badin, in Singh, the local communities have turned to fishing. However, this attempt to adapt to a new livelihood strategy, has caused tensions between these new groups and already established fishing communities as they race to land diminishing fish stocks (2).

In Khyber Pakhtunkhwa cultivable land is being lost to urbanisation in some areas, which is increasing competition for what remains (30). Fruit farmers in the province are also seeing what is left of their land becoming less and less productive as water becomes scarcer (62). The lack of a proper allocation of water resources for this area, combined with no guidance on how to manage climate risks is causing tension between the farming community and the local government (62). In Multan in Punjab and Hyderabad in Sindh urban housing has replaced 7600 hectares of cultivated land (27). As agriculturally productive land becomes less abundant there have been conflicts between communities who need space and water for livestock grazing and those trying to raise crops (2).

Environmental degradation:

Climate change causes a decline in soil fertility and a degradation of ecosystems (21). However, farmers are in some cases exacerbating problems by not using agricultural land safely and efficiently. This can lead to further soil degradation which renders them more vulnerable to poor crop yields (30). There is also the threat of wider spread environmental pollution from overuse of pesticides and fertilisers (52). In 2021-22, Pakistan imported 24.1 million tonnes of toxic pesticides, which are leading to soil contamination (33). In Khyber Pakhtunkhwa 20% of agriculture is owned by small farmers, who are, in some cases, using banned pesticides or more than is permitted (30). Fertiliser use is estimated to be 120 kg per hectare in Khyber Pakhtunkhwa, but rises to 370 kg per hectare in Sindh province (33). Increases in production will need to be met by intensification of land use, as there is no further arable land to expand into, but this leads to further problems (8). Over-grazing, over-cultivation, excessive use of fertilisers and over-exploitation of water resources all degrade the land quality and expand the uncultivable drylands (6).

In Punjab farmers reported that excessive use of insecticides and pesticides was leading to an alarming increase in the penetration of harmful chemicals reducing both water and soil quality (16). Nitrates being washed from over fertilised fields into the water system are linked to stunted growth in children, with 38% of under-fives in Pakistan suffering from stunting despite improvements in poverty status (27). Under the high emissions pathway, there is significant potential for this land to become hyper-arid and already some regions have seen these changes during drought conditions (6). Forest degradation due to over-grazing and over-harvesting is also an issue, amplifying risks of landslides and flash floods in hilly areas as well as increased

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flooding downstream (33). However, land degradation is not all manmade. Intense rain can lead to soil erosion and nutrient depletion, which also constitute environmental degradation and pose a further challenge to arable farmers and those raising livestock (30; 52; 11). For example, rangeland in Sindh is being degraded by wind and water erosion, water logging and salinity (17). Growing crops better suited to changes in climate and soil is one way to adapt to climate change, but this entails the need for a comprehensive research programme, as methods must be fine-tuned to each region and so cannot be rolled out across all areas (52).

Key digital initiatives to support agriculture in Pakistan

In an attempt to increase productivity of the agriculture sector despite the challenges posed by climate change, public institutions and NGOs have launched a range of digital support schemes for those involved in farming and fishing.

For example the PCRWR has created an advisory message service which is sent via Short Message Service (SMS) to show how much water has been consumed by a particular crop during the previous week and how much water may be needed in the next week (61). Using this farmers can adjust their irrigation systems to avoid over watering.

Farmers in Punjab now have access to guidance from an automated phone-line, linking them to advice from specialists. Using digital surveys of the questions asked by farmers, the content can be tailored to the needs of a specific region and all farmers can then benefit from pertinent guidance, which is particularly useful in the case of a localised issue such as a pest infestation (85). A study found that 34% of farmers who used the tool adopted at least one new farming practice that had been recommended to them (85).

In pilot projects across Pakistan farmers have been given free access to the internet, since October 2021. Farmers meet in a locally designated room, where tablets and laptops are provided that can connect to the internet through a small satellite dish. Information accessed so far includes accurate weather forecasts, market prices and farming tips (86). Elsewhere tablets are being used to control irrigation systems through similar technology (86).

A mobile app has been launched by WWF-Pakistan, which will link those involved in aquaculture to important data about fish stocks. The app provides assessments of both numbers of fish and variety of species in each fishery. By involving those working directly in this sector with the collection of the data, it is hoped that they will be more invested in the use of the information which can be applied to guide strategic planning and conservation as well as harvesting (87).

3.5: Education and communication

At the moment in Pakistan there is a lack of climate change information, training and risk awareness (21). This has been observed at all levels, but it causes the most vulnerability amongst the least well educated (21; 12). By including disaster preparedness as part of the elementary school curriculum, it can be argued that future generations would be readier for impending hazards (88).

Lack of climate change awareness:

Although awareness of climate change science might be low across Pakistan, the local communities are noticing shifts in the weather and in climate patterns. 87% of farmers across all four provinces surveyed by Alia et al said that they had noticed changes in rainfall, monsoon timings and temperatures over the last ten years (18). In the villages surveyed by Ullah et al in Khyber Pakhtunkhwa, the elders had heard of climate change through electronic media, but this knowledge was not always widely communicated and there was a feeling that the resources to adapt were lacking (52). In Balochistan dissemination of weather information and future projections is needed by many communities who are still without this information (15).

> "There is a gulf between the policies at the top and the voices at the bottom."
>
> From World Weather Attribution Report on the 2022 floods in Pakistan (7).

This awareness gap could be reduced by using the already established communication channels. The vulnerability of local communities could be reduced by broadcasting updates on mitigation strategies for both immediate climate hazards and also long-term changes affecting farming and other livelihoods, across TV, radio, cell phones and newspapers (12). Low awareness of such issues among the population could exacerbate the existing problems. For example, where communities have a reduced understanding of climate change, they do not seek to conserve water and so they become more vulnerable to scarcities in this vital resource (24).

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Although there are opportunities to study environment and climate related degrees at universities, the topic of climate change is often neglected in primary and secondary education (88). In view of this it is thought that climate change study should be included as a subject in its own right so that young children learn to adapt their behaviour and lifestyles naturally, rather than being forced to adapt when they have already established set habits (89). It has been shown that where environmental behaviours are praised at an early stage of education, this leads to a more pro-environmental mindset, which can also influence older generations through discussion within families (88).

In Khyber Pakhtunkhwa farmers surveyed said that they had not been offered training by local government and so, despite recognising the increasing risk posed by climate change, did not feel they could act to reduce their vulnerability (52). In the districts of Malakand and Swat in the same province, over 70% of farmers wanted training in understanding how to cope with climate change and 64% were keen to access agricultural finance to aid implementation of adaptation and mitigation strategies (35). More educated farmers have been shown to be more likely to adapt, adopting new technology and methods and thus education is a critical tool for reducing vulnerability to climate change (18). Including climate change as part of the elementary school curriculum has also been shown to be a key tool in educating the masses about climate adaptation, through both developing pro-environmental habits in the young, but also promoting intergenerational climate awareness (88).

Understanding and acting on the Early Warnings:

Although there have been improvements in Pakistan's Early Warning System (EWS), with 7 million people now receiving more timely information about flooding events, the delivery cascade is still not entirely clear (7). If EWSs are going to reduce vulnerability, then it is vital that weather alerts reach people (11). Often warnings are not reaching some areas or are not being understood at a local level, making communities more vulnerable to climate hazards.

The provincial government of Khyber Pakhtunkhwa has suggested establishing communication hubs at each village and tehsil, where warnings would not just be passed on, but translated into local language (30). In the 2022 floods, early warnings were received 24-48 hours before floodwater arrived in Khyber Pakhtunkhwa which it is estimated did save many lives (7). In Sindh it is recognised that including local communities in the planning of how early warnings will be disseminated may make them more likely to react to warnings and thus less vulnerable (17). This technique would prevent any lack of trust between locals and government officials from causing early warnings to be ignored, as is sometimes currently the case (52).

There is even call for an early warning system to warn of disease outbreaks in the aftermath of a disaster, to help to prevent secondary deaths (90). To ensure everyone has access to early warnings, links should include not just the radio and television, but also mosque loudspeakers and SMS (30; 61). An exercise in which local risk is mapped at community level would ensure that everyone has a clear understanding of climate vulnerability and thus more readiness to respond to climate warnings (11).

Literacy and education:

Literacy and education have not been a main focus in Pakistan over the last few decades resulting in high rates of illiteracy and large numbers of out-of-school children (91). In Pakistan 44% of all school age children are not in school, the majority of these being girls (27). This has led to a learning poverty rate of 75%, 19% higher than for most lower-middle income countries, which means that three-quarters of children are not able to read and understand a short age-appropriate text (27). The overall literacy rate in Pakistan is 58%, which makes a huge proportion of the population vulnerable to climate change, through a lack of education (12). There is no point in promoting climate related research if the people in need of the results of such undertakings are not in a position to understand them (24). Both formal and informal education are vital in tackling climate change (17).

FIGURE 9: SCHOOL IN PAKISTAN. (IMAGE: AFP (302))

There is a need for capacity building in adaptation, whether this is to understand scientific projections or just how to access funding and that must start with a reasonable level of literacy and numeracy (24). It has been shown that those without a good level of education are more vulnerable to climate change, so training is a key tool in reducing risk (18). Training on vulnerable ecosystems could make communities dependent on these more resilient. In Sindh one scheme that could help in this way is to offer courses in business and sustainable fishing, particularly to the region's fisherwomen (17).

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Membership of organisations:

As a response to some of the challenges faced by the people of Pakistan a number of civil society organisations have emerged. Those who are members of civil society organisations have been shown to be less vulnerable to the effects of climate change, as they are able to network with others and share adaptation strategies (30). Climate information tends to be passed on informally through large social networks, which bypass many of those involved in small scale agriculture in Pakistan. This can lead to major losses in productivity (81).

> "Transformational change is impossible if the citizenry at large does not take ownership and contribute positively to the process of change."
>
> From Vision 2025, created by the Ministry of Planning, Development and Reform, Government of Pakistan (182).

In Balochistan it is recognised that there need to be workshops for farmers so that they are more likely to adapt their practices and thus become less vulnerable to everything from droughts to floods (15). This is not, however, just restricted to farming practices, but can equally reduce health issues due to sharing traditional methods that have proved effective in the past (11).

Knowledge flow from one generation to the next is also vital, as more experienced members of a community can share adaptation methods, whilst younger members, if given sufficient education, can explain the challenges of climate change (17). Oxfam has suggested establishing climate youth clubs to raise awareness of these challenges amongst younger members of communities informally (53). Through public organisations livelihoods can be protected from loss and damage by discussing policies that could reduce a community's vulnerability to more frequent climate induced hazards (32). Unfortunately, one issue preventing more climate science outreach is the low training and expertise of officials at the public institutions who are expected to provide it (16). Where new social initiatives are established, "training of trainers" is needed to ensure that the local leaders are well prepared to communicate climate information and educate communities.

3.6: Health risk

Human health is a major factor in the vulnerability to climate change of people across Pakistan, especially given the poor state of the country's health system (51). It is now widely recognized that the increased frequency and intensity of extreme weather events such as hot and cold waves, heavy or too light precipitation and strong winds have serious implications for human health (24). Current healthcare services are described as inadequate, with access issues including a lack of personnel, a lack of equipment and a flawed referral system (92; 17; 30). In the aftermath of climate disasters, the healthcare system is even less able to cope, with facilities damaged or cut off by floods (17).

> "My youngest son is constantly sick. We are using local remedies to treat him as there are no health facilities near us."
>
> Zeenat Bibi, part of Sindh's fishing community (301).

One of the major needs is a disease outbreak early warning system in order to prevent vector borne diseases becoming endemic in nonendemic areas (90). Even with private sector involvement, the lack of co-ordination of efforts undermines any pre-disaster planning (17). Sanitation and waste management are key issues not just at times of disaster, but in general, with effluent disposal neither adequately monitored nor properly regulated (33). On top of physical health vulnerability caused by food shortages and exposure to previous climate related catastrophes, the population of Pakistan also has to deal with the mental health effects of such events (24).

Food and nutrition security:

Pakistan is classed by the Global Hunger Index as "largely food sufficient, but not food secure", hinting at the struggles ahead as the country tries to grow enough food for its increasing population within the context of climate change (93).
Effects of droughts and floods are exacerbated by already high levels of food insecurity, which in turn are amplified by further extreme climate events. Malnutrition due to food insufficiency is the main driver of health issues related to climate change (92). Across Pakistan almost 44% of under-fives are chronically malnourished and in the province of Sindh child anaemia rates are at 73% (12; 17; 23). In women of reproductive age, malnutrition is at 62% in Sindh and across Pakistan it has been shown to be increasing, leading to reduced fetal growth and a 45% rate of stunting in children under five (12; 17).

Part of the problem is that the population is increasing faster than the crop yields and as staple foods become too expensive, families are reducing meal sizes and eating less frequently, with cheaper less nutritious foods being substituted (12). 60% of households in Pakistan are reported to be food insecure, ranking Pakistan 99th out of 121 countries featured in the Global Hunger Index (12; 11; 94). Rural communities are the least food secure, particularly where dietary diversity is low (12; 92; 17) . Environmental disasters cause greater food shortages occasioning additional price volatility (12). Over the last two decades this

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has been evident in Pakistan, with wages rising more slowly than food prices. This affects the poorest members of society the most as they must spend the majority of their income on food (12). Often vulnerable households need to sell assets or take on debt in order to eat, which in the long term leads to further problems. For example to buy food, seed for the next crop to be sown is sold at a loss, but when it is time to plant, the farmers must buy new stocks which are often more expensive or else they must use cheaper, inferior seed (21; 12). In this way less resilient crops are grown and the reduced productivity leads to less income after the next harvest (35).

Those who have taken adaptation measures to ensure their livelihoods seem to have a better level of food security (18). However, as climate change increases the frequency and severity of droughts and floods, food shortages are likely to reverse any improvements made (92). In the immediate aftermath of the 2010 floods, for example, many were weakened by lack of food in the district of Muzaffargarh, in Punjab as aid did not arrive for several days (21). From 2030 onwards climate related effects on agriculture are likely to decrease crop yield and significantly affect food security (8). The two key risk factors for excess, climate-related deaths are a lack of fruit and vegetables in diets and health complications caused by the increasing prevalence of people who are underweight (6). Climate risks to food security, such as crop loss and failure, will add to the already critical levels of malnutrition (23). Projections show that by 2050, under RCP8.5, there will be 9.32 climate related deaths per million linked to lack of food availability, however this does not include potential climate-related changes to the nutritional content of food (6).

Waterborne diseases:

Incidence of waterborne diseases, caused by pathogenic micro-organisms that are transmitted in water, increase following a climate impact. With more heatwaves leading to water scarcity in some regions, whilst in others increasingly frequent floods contaminate drinking water, the lack of clean water is leading people to rely on unsafe sources (12). Floods leave pools of stagnant water in which pathogens can breed easily (95). This is increasing the chance of waterborne diseases, such as diarrhoea, scabies and cholera in all provinces (12; 92; 30; 15; 24; 95). There are two main causes for increases in diarrheal illness after floods: the first is contamination of water sources due to disruption of sewage systems and water purification plants, while the second is due to crowding of displaced communities leading to fecal-oral spread of gastrointestinal pathogens (95; 96).

After the 2010 monsoon season left 20% of Pakistan under floodwater, infectious disease outbreaks were triggered by contaminated drinking water, with attempts to remedy the situation confounded by the unhygienic conditions in makeshift relief camps (23). Some women even reported having to feed their newborn babies on muddy water sweetened with sugar, as this was the only way to keep them alive in the wake of the floods (21). The 2014 floods resulted in 1218 cases of cholera and this will only increase as flooding becomes more frequent (92). Both the 1993 and 2022 floods saw an increase in skin and eye infections alongside the other waterborne diseases (7; 95). This is due to the combination of contaminated water and high temperatures (95). People often feel they have no choice, but must wade through floodwater, unaware that this direct contact leads to wound infections, dermatitis and conjunctivitis (95). With the majority of Pakistan's population living along the flood-prone Indus River, diarrhoeal disease from drinking contaminated water is a leading cause of morbidity and mortality (23). Currently 60% of Pakistan's child mortality is due to water and sanitation related diseases (97).

Post flooding event there is also the issue of lack of sanitation with open defecation increasing exposure to pathogens and higher temperatures increasing microbial growth in water (92). When rainfall becomes intense, problems with city sewerage can cause drains to overflow, increasing the risk of waterborne disease outbreaks (33). By 2050 the World Health Organisation (WHO) predicts that the proportion of deaths in Pakistan from diarrhoeal causes will have risen to 17% (98) .

Vector borne diseases:

Vector borne diseases are caused by parasites, viruses and bacteria transmitted by the bite of blood feeding arthropods. There is now more evidence than ever before that climate change is linked to increasing incidences of vector borne diseases (90). Maladies such as malaria and dengue fever are sensitive to temperature and rainfall and thus incidents of these diseases can be expected to rise with expected changes in climate (24; 90). Floods are also associated with outbreaks of leptospirosis caused when infected rodents excrete (95). Bacteria from these faeces live in fresh water, damp soil, vegetation and mud creating sources of infection for those walking bare foot (95). Cases of leptospirosis are mostly minor, but where there are complications there is a 40% fatality rate (95). Incidences of malaria are not immediately increased in the case of floods, with flood water reducing mosquito breeding in the first instance (95; 90). It is only as the water recedes and pools are left that are perfect for breeding, that there is a sudden increase in malaria cases (95). This amounts to a 6-8 week lag between the ends of the floods and the start of an epidemic (95). After the 2006 floods, drug resistant infections were noted and at the end of the 2012 floods, cases of malaria in Pakistan rose by 54% (92; 95).

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Dengue fever is currently an issue in Pakistan for three months of the year, but as temperature increases inherent in climate change expand the number of suitable breeding sites, this timeframe is likely to become longer (92). Dengue cases have now been recorded in all provinces with the highest incidence along the border between Sindh and Balochistan (90). In the provinces of both Khyber Pakhtunkhwa and Sindh higher temperatures and more rainfall have already been linked to in a rise in the rate of vector borne diseases (17; 30). Amongst those migrating from poor rural areas to cities, displaced by climate effects, there is even greater chance of disease transmission and evidence now shows that vector-borne diseases disproportionately affect those living in poverty (30; 99).

Respiratory and other diseases:

Respiratory diseases, which affect the airways and lungs, can range in severity from mild to life-threatening. In the aftermath of a climate disaster there is likely to be an increase in cases of respiratory diseases such as allergic bronchitis, asthma, chronic obstructive pulmonary airway disease, pneumonia and viral flu, which can lead to secondary infections (95). In fact these conditions are among the most common causes of mortality post floods, normally due to a loss of shelter and exposure to flood water and rain as well as a lack of healthcare resources (100).

The risks associated with acute respiratory infections are increased by overcrowding, poor ventilation, poor nutrition and cold weather, all of which can occur in overstretched relief camps (96). However, these conditions, along with high pollution levels, are now also being seen in overcrowded cities, leading to an increase in respiratory illnesses in many urban regions of Pakistan (51). In rural areas, the use of solid fuel stoves is adding to deaths from lung cancer, strokes and heart disease, particularly in women (51).

Cases of hepatitis are also likely to be increased by disruption in water and sanitation facilities (95; 96). There have been reports of increased Hepatitis A after floods and after the 2005 earthquakes in Pakistan Hepatitis E swept through camps housing those who had been displaced (95; 100; 96). In 2018, 30-35% of people living in the coastal areas of Sindh were found to have viral hepatitis (97).

Heat related health impacts:

It is not just the fast-onset climate change events that are making Pakistan's population increasingly vulnerable. Heat related morbidity leads to 326000 deaths per year, with the elderly, children, women, the socially isolated and outdoor workers most at risk (92; 41). A combination of under nourishment and intense heat affects cardiac function, which in part explains why Pakistan has one of the highest known rates of cardiovascular disease (50). This is only going to rise, as the country faces increasing average temperatures, which will compound the already high baseline values (6).

> "If we stop working every time it gets hot, how will we eat?"
>
> Muhammad Musa, 65 year old farm worker in the rice fields of Jacobabad (242).

Punjab, Sindh and Balochistan are the regions most vulnerable to heatwaves, with a trend for increasing heatwaves in Balochistan looking set to cause more frequent and longer droughts (20). Under the higher emissions pathway, it is thought that days with a temperature of over 35°C will rise from 120 to 150 per year by 2050 (6). Urban centres are warmer than their surroundings, so in heatwaves, the occurrence of prolonged high temperatures in cities poses a threat to the elderly, infants and those living in poverty (20). Where concrete has taken the place of natural groundcover, the urban heat island effect is evident (27).

Even under lower emission pathways, heatwaves are expected to become a regular occurrence in Karachi, Peshawar and Lahore, which are considered to be among the cities most vulnerable to increases in extreme heat (6). For example, the heatwave of 2015 sent the temperature in Karachi up to 49°C, leading to more than 1200 deaths (23). As Karachi's temperature is maintained by a land-sea breeze circulation, any interruption to this weather system can cause even higher temperatures and the probability of this occurring is projected to increase in the future under a 2°C warming scenario. (20). In fact across all of the province of Sindh, an increase in death and injury from high temperatures has been recorded, with the Heat Moisture Index worsened by the combination of hot and humid weather (17). Temperatures are set to exceed the limits of human survivability in future years, with deaths of over 65s projected to rise from 10 to 63 deaths per 100000, under the RCP8.5 scenario (92; 41).

Agricultural labour productivity has dropped by 10% during peak months due to heat stress and under an RCP8.5 pathway this could double to 20% by 2050 (6). One way to reduce such vulnerability is to plant shade trees which shelter both the crops and those working in the fields (52). Equally, in cities which are less paved, with a higher proportion of natural landscape, like Quetta and Islamabad, temperature extremes are projected to pose less of a hazard (20). In addition to direct deaths from extreme temperatures, increases in the frequency of heatwaves is likely to intensify the effects of respiratory ailments, malaria, dengue

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fever and gastroenteritis, particularly for women and children (92; 30; 27). Cold waves can also have a severe impact, adversely affecting the elderly and children. In 2011 and 2013, sudden large rainfall caused the temperature to drop in the Tharparkar district of Sindh which led to many cases of severe and even fatal pneumonia and fever (21).

Disabilities:

In a climate emergency, people with disability (PWD) are often the most adversely affected with records showing they have both higher rates of death and illness in a disaster (101; 27). Although there is no formal definition of PWD in Pakistan and equally no national register, it is estimated that it is home to more than 20 million disabled (102; 103). Disability rates are particularly inflated due to the historic high incidence of polio in Pakistan (11). PWD suffer from poorer health and a worse quality of life due to a lack of access to rehabilitation services and assistive technology in Pakistan (102). On top of this, there is still a current of socio-cultural discrimination against PWD which adds to their vulnerability (104). Despite a number of laws being passed since the 1980s to afford rights and improve living conditions, there has not been any real change (102). There is still an increased risk of adverse impacts of climate change for PWD including health, food security, water, sanitation and livelihoods (101).

The issues faced by PWD are amplified by extreme climate events, as they are often the poorest and least able to escape from disaster zones, whether in terms of transportation or an ability to migrate (105). It is reported that having a disability increases risk in a disaster fourfold (11). In the district of Muzaffargarh, members of the community reported difficulty in moving disabled family members during the floods, as there was no government help. One mother was forced to wheel her blind son through the flood water in an open trolley, whilst another had to pay an exorbitant hire fee for a private rickshaw to move his disabled grandmother (21). Even without the extra issue of such emergencies, it is estimated that 7 million PWD in Pakistan are forced to stay at home as they have no access to wheelchairs (103). During a disaster, those who are lucky enough to have assistive devices will often find they are lost or damaged, with relief efforts seldom including provision for their replacement (101). In addition PWD do not have enough time to plan their emergency response, as they are often excluded from early warnings and climate information due to lack of accessibility for those with disabilities (101).

3.7: Gender-based differences

In Pakistan, gender-based inequality is a huge issue, arising as it does from the country's patriarchal culture (106; 1). There have been a number of recent projects to improve women's rights from Dawood Global Foundation's Ladiesfund, encouraging female entrepreneurs to found climate friendly businesses, to water and sanitation projects run jointly by the Punjab Provincial Government and ADB (107; 108). In 2018, thousands of women demonstrated on International Women's Day for better women's rights in Pakistan and this theme is also central to the work of the Equal Access International Group who have been organising theatre performances, radio broadcasts and films with female empowerment as a central theme (109).

However, despite these initiatives, Pakistan remains 146 out of 147 countries on the Global Gender Gap Index Report 2022 released by the World Economic Forum (WEF), making it the second worst country regarding gender equality in the world (110). Climate change is highlighting the vulnerability of women in Pakistan still further with many of their daily chores, such as finding water, fodder and firewood made harder (30). It has also been shown in recent research that the level of disaster preparedness increases when all genders (male, female and transgender) are given equal opportunities to plan (111).

Livelihoods:

Livelihoods data shows that women are particularly vulnerable to climate change, as their livelihoods are more likely to rely on natural resources (112).
In addition to household chores and childcare, women often work in the fields or raising livestock (21). However, their lack of decision-making power and authority, with the vast majority owning no property, makes it harder for women to take steps to adapt their way of life to cope with changes to the climate (11).

According to the Government of Khyber Pakhtunkhwa, 72% of women work in agriculture in the province, but despite their important role in the farming community they are still not given the same treatment as their male counterparts (30). For example, women are often not given the same

FIGURE 10: HINDU WOMEN CARRY WATER IN THE THAR DESERT. (IMAGE: AMEER-GREAT)

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level of information as men about the storage and use of pesticides, herbicides and insecticides which are increasingly necessary due to land degradation following droughts and floods. This puts them at greater risk of accidents and makes them less likely to use more sustainable methods (30).

As men move to non-farm work, more women are running farms, but without the necessary training and access to services (27). In Sindh, women do the majority of agricultural work, but they gain no financial benefit as any earnings from agricultural production will be paid directly to the male head of house (17; 21). Women are allowed to own and cultivate land, but in practice there are many legal, social and bureaucratic barriers to this, with even those inheriting property often being denied any financial control or benefit (11; 21). This is reflected in the fact that 96% of households in Pakistan have a male head (18). An estimate of women's earnings shows their income to be less than one fifth of that of men in Pakistan, with livelihoods often being insecure (8; 11). Any earnings they do have are unlikely to be in their control and they are rarely included in household financial decisions (8).

In the event of a climate catastrophe, women are not entitled to government compensation (11). Women are less likely to have access to credit and finance services, reducing their ability to adapt to climate change (30). Initiatives like Ladiesfund, which supports female entrepreneurs to access loans from the State Bank of Pakistan, are helping, but currently only on a relatively small scale with 15000 loans organised over the last 13 years (107).

Healthcare:

There are already many reasons why women suffer from a higher health risk in Pakistan than men, from their heavy manual workload to the high birth rate and lack of access to sanitation (11). Women are also more vulnerable to health impacts of climate change (17; 21). They have been shown to be more prone to adverse impacts of heatwaves than males, as well as lacking access to the early warning resources and climate communications that could allow them to be pro-active in coping with extreme weather events (20).

If women do become ill, then their access to healthcare is limited, as their movements are restricted and they must have a male chaperone and also need to see one of the very few female healthcare professionals in Pakistan (11). Pregnant and lactating women also face more health problems due to climate change, being more susceptible to reduced food and increased vector and water borne diseases. In the case of a flooding event, it has been shown that pregnant women are more likely to lose babies and newborns are less likely to survive, due to lack of resources and the likelihood of mothers being malnourished (21).

Water and food resources:

A decline in crops will affect women more than men, as not only are women more vulnerable to malnourishment and malnutrition, but they are also more likely to reduce their food intake in favour of feeding their families (21; 11). Providing water for the family is part of a woman's role and can entail long daily treks to access clean wells, journeys that are made longer and more arduous in drought conditions (21; 12). As climate change progresses it is thought that Pakistan will suffer from worsening heatwaves and droughts. Projections for Punjab show a shortfall of 32% of the province's water requirements and the whole Indus Basin region, with its growing population, is also likely to be harmed by future water shortages (29; 53). Coastal regions are already experiencing reductions in available drinking water as sea water intrusion has reached areas 85 km along water courses (53). These shortages will make finding clean sources of drinking water ever more difficult for women, with journey times likely to increase.

In Punjab, a water and sanitation scheme was launched jointly by the provincial government and ADB, which aimed to reduce the number of hours in a day that women had to fetch water by supplying more local sources (108). However, in case studies looking at climate migration in Muzaffargahr in Punjab and Mithi in Sindh, it was noted that only 6% and 2% of households in these respective regions have piped water, with the vast majority of households reliant on women trekking to shared wells (21).

Education:

Women witness greater inequality in access to education (110; 8), leading to a literacy rate of 47%, 11% below the country average (12). Even from initial enrolment there are 10% fewer girls educated in schools than boys, with women in rural areas even less likely to have received any schooling (30). This limited education leads to fewer business opportunities later on and means that women do not have the means of livelihood diversification which is crucial in coping with climate extremes (107). More educated farmers were found to be more aware and more interested in adopting new technology and methods to increase crop yield under changing

> "No nation can reach its full potential without 50% of its population. Getting girls into school is a key driver of growth."
>
> Dr Christian Turner CMG, UK High Commissioner to Pakistan (309).

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climatic conditions, showing that education is a critical tool for reducing climate vulnerability and so uneducated women are far more likely to suffer the negative effects of climate change (18).

Women are also less able to access information on climate, weather and early warnings, making female led households more susceptible to climate emergencies (12; 30). However, in some remote villages in northern Pakistan, the non-profit Zindagi Trust has set up schemes through which university students who are studying climate related subjects, go into girls' schools to spread awareness of mitigation and adaptation policies (88). Girls have been particularly targeted, as they are thought to be able to influence daily lifestyle choices and are more likely to instill climate friendly behaviours in their children (88).

Violence:

More than 90% of the female population experiences domestic violence and more than 1000 girls and women are victims of "honour killings" each year (106). Since 2020 there has been an anti-rape law in Pakistan, but numbers of convictions remain low (113). Climate change can compound these issues. After a climate emergency, families are often forced to live in relief camps, sometimes without male members of the household who may have left to find work. Given the lack of security in the camps, there are reports that women have been subjected to rape and children have been abducted (21). In some cases girls seeking refuge in temporary shelters, away from their usual neighbourhoods, have been drugged and raped by locals (21). This extra vulnerability of females is not only unjust, but also completely gratuitous. However, similar incidents can only be prevented in future by both cultural and regulatory changes.

3.8: Climate migration

As temperatures rise and incidences of floods and droughts become more frequent, it has become impossible in some areas of Pakistan for those depending on rural livelihoods to remain on their ancestral lands (114). In some cases just one male household member will migrate for work, but in others whole communities are forced to move (21). Migrants often start by moving a small distance, prompted by inundated lands or drought conditions, but then may be forced to migrate again, when their new home is affected by another climate event (11; 21). Eventually many migrants are attracted towards the cities of Pakistan, as these are seen as more secure, with the promise of learning new trades to become electricians, motor mechanics or even entertainers (21; 20). However, this can backfire, with 50% of city dwellers living in slums with inadequate waste and sanitation facilities and city expansion resulting in the concreting of vegetation and the loss of previously open spaces (11; 20).

Push factors in migration:

Flooding, droughts, rising temperatures, erratic rainfall and coastal erosion are all factors likely to hasten climate migration from the south of the Sindh province towards the cities of Karachi and Hyderabad (2). Urban centres are a huge draw for those migrating from rural areas, with their better education systems, more varied employment opportunities and improved healthcare facilities (20). 70% of those displaced by the 2010 floods settled in cities rather than returning home (22).

As climate change continues to threaten the production of agricultural crops in the Sindh province such as cotton, rice, wheat, corn, sugarcane and chickpeas, resources will continue to dwindle, leaving those dependent on agriculture with very little choice but to migrate and find new livelihoods (2; 6). The same is true for residents of Balochistan's Western Dry Mountains, this time driven out by underdeveloped market facilities, water shortages and drought degraded land (2; 15). In fact economic concerns lie at the root of nearly 80% of rural to urban migration (2). However, from the Western Plateau of Balochistan, migration is not entirely due to the drought conditions, but also to on-going conflicts between Pakistan and Baloch separatists.

FIGURE 11: CUTTING CORN IN KUNRI, SINDH. (IMAGE: AMEER-GREAT)

People in the Northern Dry Mountain region of Khyber Pakhtunkhwa are struggling to survive with reduced crop yield, due not just to changing rainfall patterns, but also to conflict-induced crop losses. For many households the answer is either permanent or seasonal migration to other rural areas or else to cities (2). In the last decade, 63% of those migrating from Balochistan have moved to urban areas, with 56% choosing to go to a provincial or federal capital (15). Across all four provinces 15-20% of the population has moved to the cities since the 2010 floods (22). This is illustrated by the dramatic rise in the population of Islamabad, from 500000 before 2010 to 2.2 million ten years later (22).

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The province of Punjab, with its strong economy and well-developed institutional capacity is less vulnerable to climate events than other areas of Pakistan and so sees fewer migrants leaving, whereas the strongest migration is between Khyber Pakhtunkhwa and the city of Karachi (114).

Effect on vulnerability:

In some cases the migration leads to greater prosperity. Rural households in the Northern Dry Mountains of Khyber Pakhtunkhwa benefit from up to 31% of their income coming from earnings due to seasonal or permanent migration (2). However, there are many reports of migration leading to additional vulnerability, with migrants often marginalised to hazard prone land (11). They are also less likely to know how to use climate resilient farming practices on their new fields or how to make adaptations as the climate worsens (18). As newcomers, the migrants often lack access to local information networks and healthcare (18; 11). In a study of two districts in Punjab, data showed that the northern district, Sialkot, which housed a majority of migrants, was less well prepared for flooding than the southern district of Muzaffargarh, which is home to a majority local population, due to the lack of community spirit and concern for neighbours (111). Displacement and migration can, therefore, lead to greater inequality, with displaced rural households least well prepared to cope with droughts and floods (21). Some will choose to resettle in a rural district due to the lower cost of living, but this can mean that they are still affected by shortages of housing, food, medicine and jobs (11).

Where male-out migration occurs this has consequences for the family left behind. Their status and power will be at the least reduced and most probably disappear altogether, leaving them with no political or institutional support in the case of a new disaster (21). Those who migrate from rural areas to the cities may find themselves living in slums, which are vulnerable to flash floods, cyclones, dust storms and extreme heatwaves, intensified by the urban heat island effect, as there is no affordable housing outside of flood zones (11; 21).

> "Once in urban centres, climate migrants are likely to experience additional social hardships in the form of discrimination, competition for employment and precarious living conditions."
>
> Sara Hayat of The Asia Foundation (303).

One major issue for those deciding to migrate who do not own property, is that they are often already in debt to landowners, whose farms they work. In order to leave their land, they must obtain a new loan to pay this off from a lender who may charge exorbitant rates of interest, thus trapping the migrant in cycles of debt, which limit their freedom to move again if they need to (21). Loans taken out to allow migration, mean that money sent home from a new job must be split between the bank and the family (21).

Potential conflict:

As climate migration will make competition for scarce resources more intense, there is the potential for violent conflict (8). This is already in evidence in Karachi and Hyderabad with the large numbers migrating from the rural areas of Tharparkar and Umerkot sparking sectarian violence (2). Such unrest is not surprising with rates of urban population at 37% and growing by 2.7% a year (27). In addition, a large migration flow from rural areas towards cities, as rural areas suffer further climate induced degradation, will make recruiting easier for urban based armed gangs, such as mafia-style groups which already operate in the large cities (8; 2). Added to this is the increased tension between Baloch separatists, Pakistani armed forces and Tehrik-e Taliban as more refugees flee into Pakistan from Afghanistan (2).

3.9: Poverty

Pakistan's public debt currently stands at more than $200 billion and economic growth is limited by a low export rate, leading investors to lose confidence (27). This has exacerbated already high poverty levels, which make the growing population far more vulnerable to climate change (1; 24). The extreme poverty and lack of financial resources means that Pakistan is ranked as one of the countries with the least adaptive capacity (74).

Despite 48 million Pakistanis coming out of poverty between 2001 and 2015, high inflation and political uncertainty have made further progress more difficult (27). The poor are most at risk due to their high dependence on natural resources and their lack of assets to adapt (12; 24). Where efforts have been made to hasten development and reduce poverty over the last few decades, climate change threatens to undo this work (24). Pakistan has a goal of ending poverty and hunger by 2030 (40). According to figures from ADB, in 2021 3.7% of Pakistanis lived in a state of absolute poverty on less than $1.90 per day (115). Over a third of the population currently live in a state of multidimensional poverty (8), defined as:

"the various deprivations experienced by poor people in their daily lives - such as poor health, lack of education, inadequate living standards, disempowerment, poor quality of work, the threat of violence and living in environmentally hazardous areas" (116).

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Although Pakistan has achieved significant poverty reduction in the last two decades, gains in sustained economic growth have not been distributed equally, with 45% of the total income being earned by just 10% of the population in 2019 (8; 117). Further development has been hampered by the costs of loss and damage from environmental disasters and the fact that Pakistan relies on short-term, ad hoc sources of funding from outside the country when these events happen (32). The 2022 floods are likely to push another 9.1 million Pakistanis into poverty and a further 1.9 million into multi-dimensional poverty due to a lack of services and resources at a local level (27).

FIGURE 12: BOY IN PAKISTAN (IMAGE: MUHAMMAD MUZAMIL ON UNSPLASH)

Pakistan is the sixth most populous country on Earth, with its population doubling since 2004 to 229 million in 2022 (8; 118). The birth rate increases are particularly marked among those below the poverty line (24). As the population grows, demand for food outstrips production rates and so large price rises are inevitable.

Despite Pakistan's large and growing population, the country does not contribute massively to climate change, with its total emissions less than 1% of the world's total (119). However, limiting population growth by reducing fertility would lead to lower climate change vulnerability by improving water and food security, limiting negative impacts on biodiversity and allowing women to access a higher level of education (27).

Poorest areas in Pakistan:

There are wide discrepancies in levels of socio-economic development across the provinces of Pakistan and even between districts of the same provinces (8). Severe poverty is most prevalent in East Sindh, West Balochistan, some of Khyber Pakhtunkhwa and in a few isolated parts of Punjab (12). The poor in rural agricultural communities are those most affected by climate change, as they have very little means to adapt to the alterations in temperatures, water availability and growing seasons (18). Floods have caused severe economic losses wherever they have struck Pakistan, with high costs in terms of infrastructure damage, reduced agricultural productivity and rehabilitation (18; 32). It was reported in the district of Muzaffargarh in Punjab, that when floods did happen, relief efforts favoured those with the most political influence, ignoring the poorest members of the community and therefore, increasing their vulnerability (21).

> "Poverty is the strongest determinant for vulnerability to climate change."
>
> Sara Hayat of The Asia Foundation (303).

In cities, it is seen that resilience to heatwaves depends very much on the number of lower income households within the city. Those with money are able to withstand the conditions better, as they can afford to adapt to the effects of climate change (20). This is obvious from the housing materials used by each subset of the population, with poorer dwellings made of bamboo, mud and reeds, making them vulnerable to both meteorological and geological hazards (48).

Rural areas:

Although there are high poverty rates in many of Pakistan's cities, the poorest of the population live in rural areas (11). Wealthier farmers and those with more land are more likely to adapt, leaving the poorer unable to, lacking as they do both the necessary finances and the technical capacity (18; 24). This leads to lower levels of poverty for those who have matched their farming practices to changing weather patterns, thus widening the divide between the economic strata (18). Great inequality is evident between landowners and landless farmers, who are less likely to have access to institutional support which has been shown to aid adaptation (21; 18; 12).

Tenant farmers are also more vulnerable to climate change as they have informal contracts which can be dissolved when lower productivity leads to less need for labour (35). Most farmers in the Tharparkar district of Sindh have large debts to landowners and even if the land has been environmentally degraded, so that yield is dramatically reduced, they must still work it, due to this debt (21). This leads to taking out more debt with other landowners to pay off the first debts. If land is lost then permanent migration to another rural area requires money for building and starting farming again (11).

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Access to funding:

According to the World Food Programme (WFP) reports there are a number of funding initiatives currently active in Pakistan, such as the National Rural Support Program, the Pakistan Poverty Alleviation Fund, the Sarhad Rural Support Program (SRSP) and the Benazir Income Support Program (8). All of these aim to reduce poverty, particularly in rural areas, by providing loans or even cash transfers to the poorest households. In 2018 over 5 million families nationally were being given aid (8). These schemes are backed by federal government, supported by international donors, such as WB and ADB. There are also educational scholarship programmes, such as the National Poverty Graduation Initiative, that aim to improve quality of life through sponsoring the poorest students (8). In the event of a disaster, there is the Crisis Resilient Social Protection Program to help particularly badly affected households, which was given $600 million by WB in 2021 (8). In addition there are provincially administered Annual Development Programs, with Khyber Pakhtunkhwa having a budget of over $2.1 billion, Sindh a budget of $1.1 billion and Balochistan $988 million (120). This money is used at the district and tehsil level to ensure that local planning priorities are funded.

However, despite this apparent wealth of investment in reducing poverty, at a local level it is difficult for the people most in need to access support. For example, in Sindh the provincial government found that investments were "fragmented and unco-ordinated" with no coherent strategy (17). In Badin, Oxfam reported that there was not enough investment in adaptation and development, with "haris", informal loan agreements with landlords for money advances, still causing exploitation amongst the most impoverished (53). In Punjab, farmers needing loans to cultivate a new crop when the previous yield was reduced by variable rainfall, disease or insects, found that there was no availability of credit for such emergencies (16). Access to financial compensation after a disaster was further hindered by only 34% of farmers in the semi-arid districts of Punjab having a bank account and 18% reporting that they would rather not take out loans due to high interest rates (82). In the Khyber Pakhtunkhwa districts of Malakand and Swat, tenant farmers reported not being able to access any credit support or crop insurance schemes in the event of climate issues (35).

> "The Prime Minister urged the need to improve risk mapping, capacity building, access to climate finance and loss and damage assessment ability."
>
> Dunya News article reporting on the first meeting of the Pakistan Climate Change Council on 19th October, 2022 (42).

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SECTION 4: INFORMATION FOR RISK ASSESSMENTS

4.1: Impact of climate-related disasters

Across Pakistan there are different weather systems in evidence, causing variation in climate between different regions, particularly in the North and the South of the country. In the case of precipitation, North Pakistan's localised convective activity and orography mean that climate projections are very hard to make (29). The analysis of historic events shows that between 1992 and 2021, a combination of heatwaves, droughts, landslides, floods and cyclones caused $29.3 billion in economic losses (27). On top of this, the catastrophic flooding of 2022 is estimated to have cost Pakistan $15.2 billion in economic losses and an additional $14.9 billion in damages (121). By considering previous extreme weather impacts, we can start to consider the risk of such events occurring in the future despite the inherent uncertainties in climate projections.

Here all disasters occurring in Pakistan that are included on the EM-DAT database are considered between 1992 and 2022 (45)[3]. In order to appear in this global list, a disaster must have resulted in at least one of the following:

1. 10 or more people killed
2. 100 or more people affected
3. a state of emergency declared
4. a call made for international assistance (122).

Each of the 185 disasters recorded for Pakistan over these last three decades is taken as a distinct incident if it is separated by region or timing. The number of disasters occurring annually between 1992-2022 is shown in Figure 13. In this diagram, in the case of droughts or epidemics which stretch over more than one year, a separate instance is recorded for each year in which they occur increasing this total to 191 events.

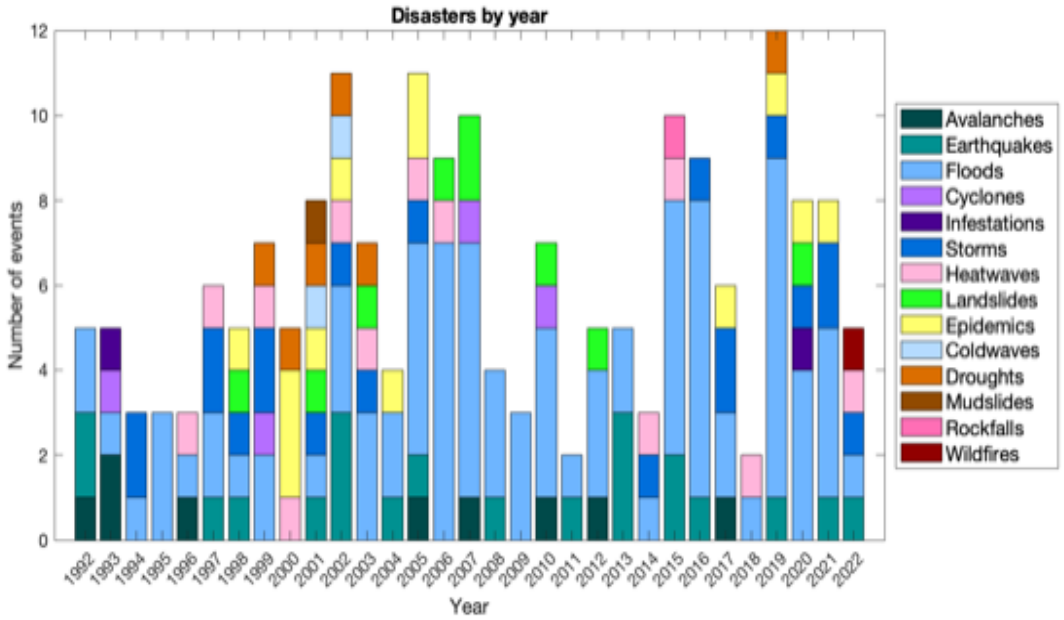

FIGURE 13: DISASTERS PER YEAR IN PAKISTAN

This shows no particular increase in instances of climate related disasters across the whole of Pakistan in terms of number of distinct events, but it is clear that floods occur most often. Storms, heatwaves and drought events tend to be clustered as these are particularly closely linked. The graph does not show how intense or widespread each event was and also only registers those events which caused one of the outcomes listed above. As communities become more prepared and thus less vulnerable, the same scale of climate event, could have a more limited impact.

Of the 185 disasters recorded, estimates of the number of people affected were recorded for 113. Figure 14 shows that the vast majority of those affected were involved in floods.

[3] Thirty-one years of data are considered, as both 1992 and 2022 have seen particularly extreme flooding events and not all data for 2022 are recorded at time of writing.

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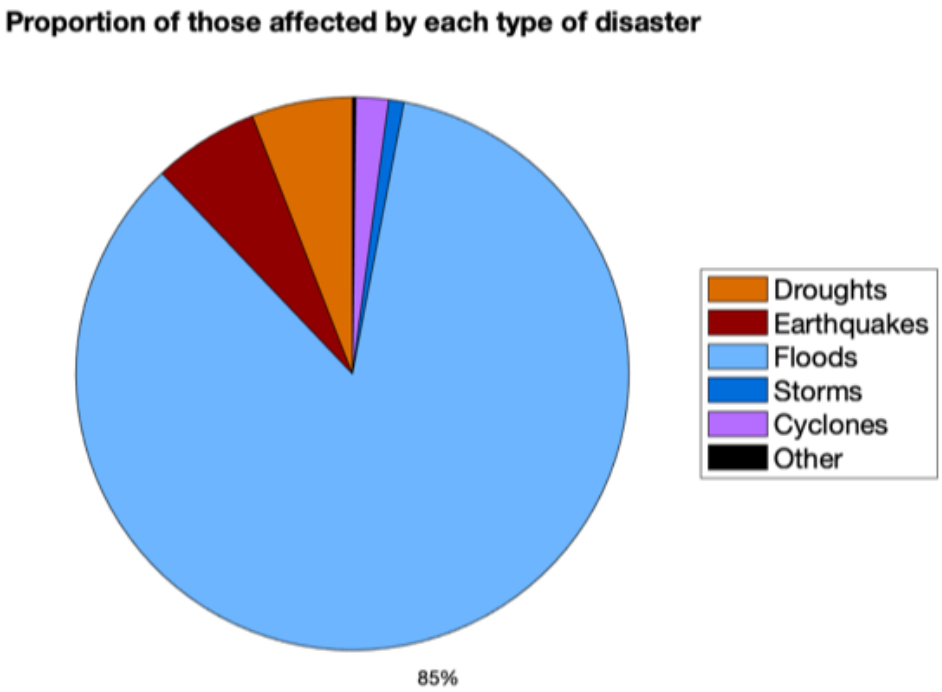
FIGURE 14: PROPORTION OF THOSE AFFECTED BY EACH OF THE MOST SEVERE KINDS OF DISASTER.

Of climate induced disasters, floods affect the most people and have also had the highest death rate since 1992. Overall the highest deathrate is actually due to earthquakes, which are not climate change induced, following the devastating quake in Kashmir in 2005. Large scale earthquakes are not thought to occur more frequently due to climate related changes, although at a microseismic level (less than 1 on the Richter scale) droughts and pumping of groundwater both "unweight" the Earth's crust, leading to small stresses on fault lines (123).



Disasters can be categorised in many ways, but here the system used in EM-DAT is applied (124). Hydrological disasters are related to surface or subsurface water, so the category includes any floods, be they riverine, flash floods or recorded as non-specific (NS) as well as landslides, avalanches and mudslides. Meteorological disasters are related to short-lived atmosphere changes, particularly with regard to weather. Examples of these include cold and heat waves, convective storms and cyclones. Again in the database, some NS storms are recorded, where no specific type of storm was given in collected data. Climatological disasters are classified as those which are again related to atmosphere changes, but this time in the long-term. These include droughts and wildfires. Biological disasters, which are caused by the enormous spread of a living organism or vector-borne diseases they may carry, are either epidemics or pest infestations in the case of Pakistan. Geophysical disasters such as earthquakes and rockfalls, which are caused by a hazard emanating from solid earth are also included here.

Estimates for deaths due to flooding in Pakistan by year, shown in Figure 15, underline the frequency of the most severe events. In the same figure, the strength of the El Niño-Southern Oscillation Climate Pattern is also shown, as studies have suggested a link between the La Niña years and severe monsoons leading to the worst floods (125; 49). The La Niña induced conditions in the north of Pakistan in both 2010 and 2022 caused spring heat which resulted in GLOFs, followed by pre-monsoon thunderstorms, increasing the length of the monsoon period (125). In both cases the intensity of the rainfall was also unusually strong (49). In Figure 15 the intensity of the ENSO event is marked from -3 for a strong La Niña event to +4 for a very strong El Niño event. It is worth noting that from May to July in both 2010 and 2022 the La Niña conditions were the strongest recorded in the 21st century (125; 126).

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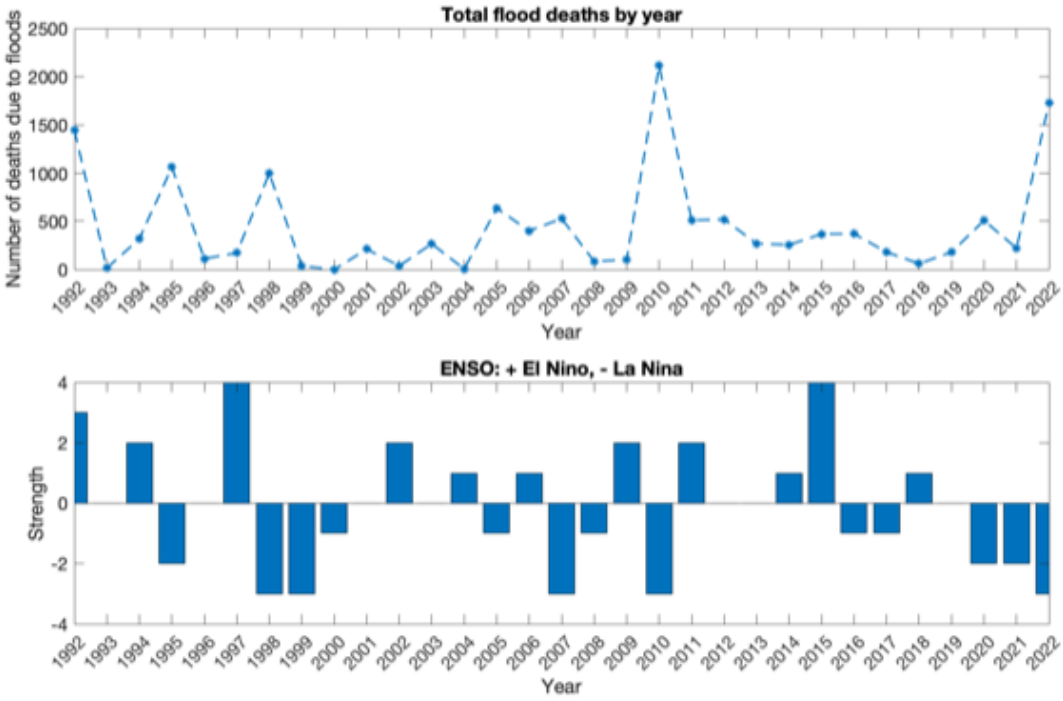

FIGURE 15: DEATHS DUE TO FLOODING BY YEAR COMPARED TO STRENGTH OF THE ENSO PATTERN

Looking by province it is possible to see which particular climate hazards are most prevalent in any region. However, it is important to recognise, that many of the disasters recorded spread across multiple provinces as displayed in Figure 16. Thirteen disasters affected all four provinces, with nine of these being flood events, two being epidemics (dengue fever and COVID-19), one being a locust infestation and one being a storm.

Due to Khyber Pakhtunkhwa's particular susceptibility to landslides and GLOFs this province had the most localised disasters.

Balochistan and Sindh, which share similar issues with droughts and coastal intrusion share 8 disasters.

Khyber Paktunkhwa and Punjab share 10 events, which is more due to their long stretch of common boundary, than any provincial similarities.

No events have just affected Punjab and Balochistan, without also involving at least one of the other provinces, as although these two provinces are both prone to droughts and floods, any such events also tend to affect at least Sindh.

What all of this highlights is the need for inter provincial co-operation and co-ordination when it comes to disaster management, something which is currently often neglected (127).

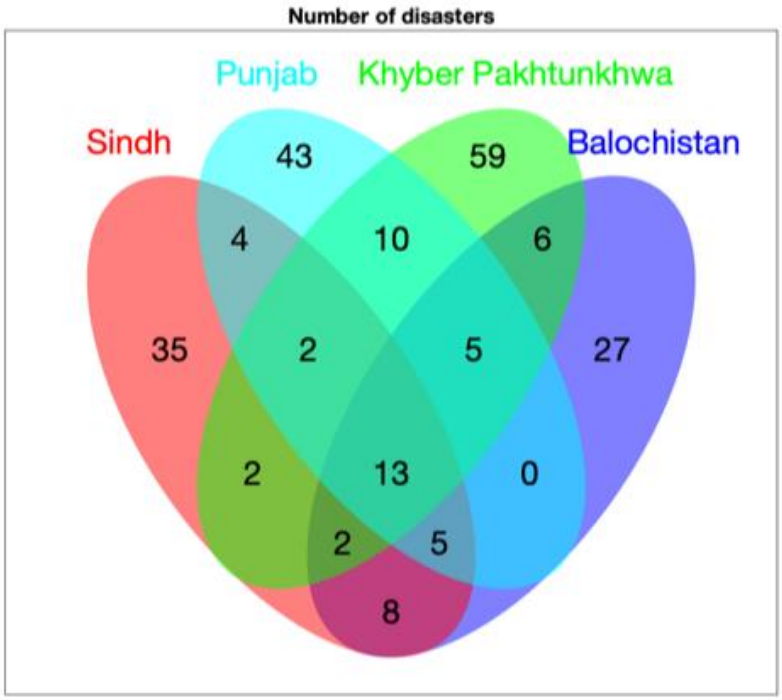

FIGURE 16: NUMBER OF DISASTERS AND WHICH PROVINCES WERE AFFECTED

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Categorising disasters by their subgroups as in Figure 17, it can be seen that whilst biological disasters seem to affect all provinces equally, Balochistan is most prone to climatological disasters and Balochistan and Khyber Pakhtunkhwa to geophysical disasters. Hydrological disasters occurred most frequently in Khyber Pakhtunkhwa, although on average only about 3000 people were affected by each event, compared with an average of a million people for both Punjab and Sindh (45). Although Khyber

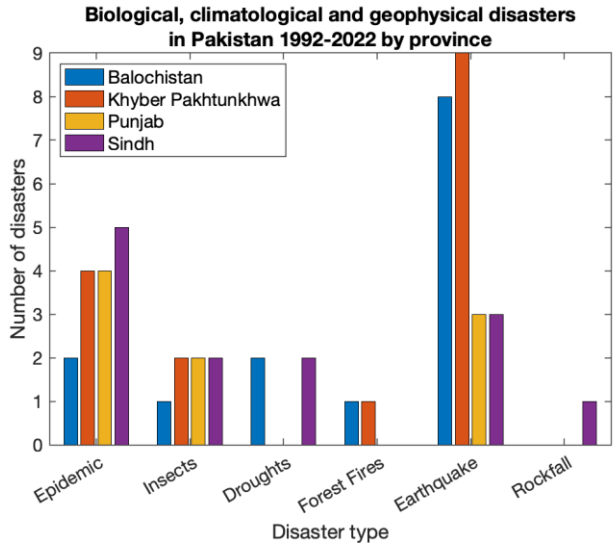

FIGURE 17: BIOLOGICAL, CLIMATOLOGICAL, GEOPHYSICAL DISASTERS

Pakhtunkhwa has the second lowest population of Pakistan's provinces, the number of people per square kilometre is second highest and so it must be concluded that the events were less severe or more localised than those recorded in the other provinces, rather than affecting fewer people due to a lower population density (128).

Hydrological disasters in Pakistan are dominated by floods as can be seen in Figure 18. This is mainly due to the geography of the region, with much of the population living on the Indus flood plains. However, as cities grow and drainage is not fully considered, urban flash floods can become more common.

In Khyber Pakhtunkhwa, where the majority of the flash floods were recorded, these were due to higher temperatures causing increased glacial melting and reduced refreezing, resulting in glacial lake outburst flooding.

Meteorological disasters, shown in Figure 19, often affect all provinces, but heatwaves are most prevalent in the east of Pakistan, whilst convective storms are active in the north and tropical cyclones affect the southern provinces, particularly along the coastal regions.

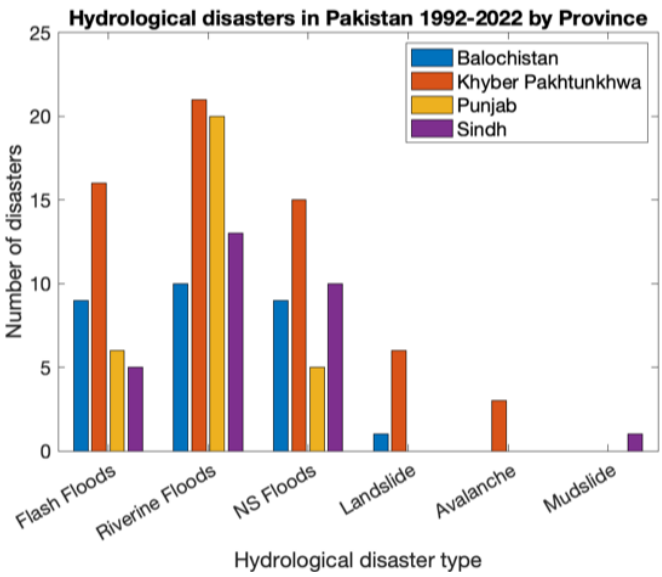

FIGURE 18: HYDROLOGICAL DISASTERS

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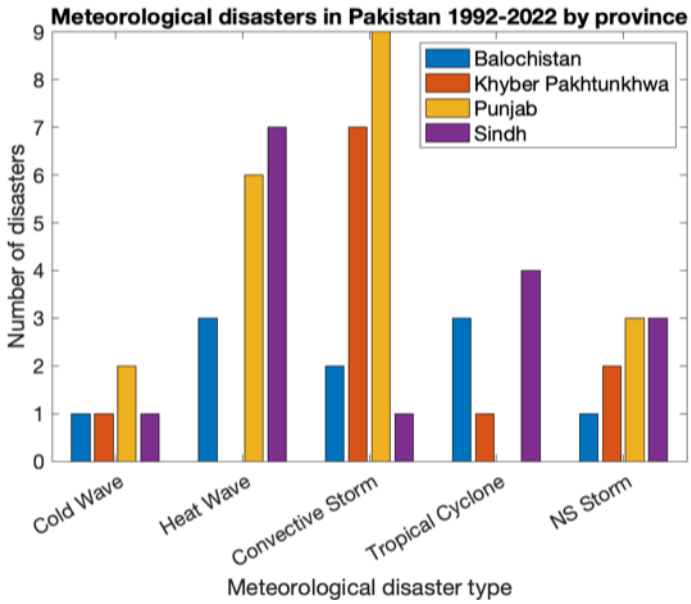

FIGURE 19: METEOROLOGICAL DISASTERS

However, the disasters cannot be completely separated as often one causes another or increases its impact. The total number of disasters that were registered on the EM-DAT database in each of the four provinces are shown by year in Figure 20. This reflects the fact that Khyber Pakhtunkhwa is the site of the most events and also that the number of events in the provinces does seem to be increasing with time. However, events seem to cluster around severe La Niña years, with the three, five and seven year rolling averages for events across the provinces displaying alternating periods of high and low disaster instances, as shown in Figure 21.

Separate types of event are reviewed in more detail in the sections which follow.

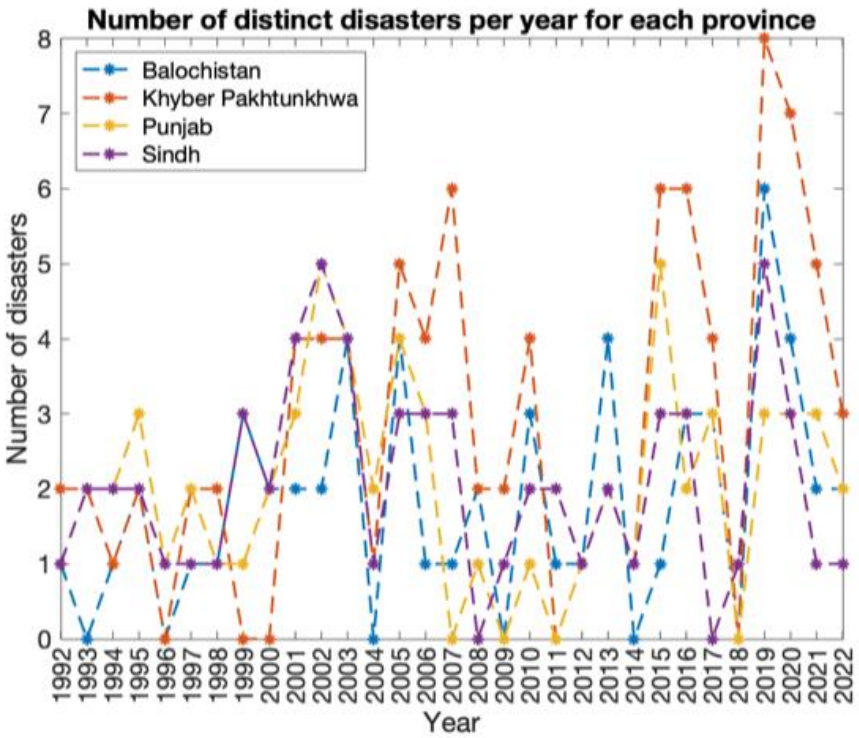

FIGURE 20: NUMBER OF DIASTERS REGISTERED IN EACH PROVINCE

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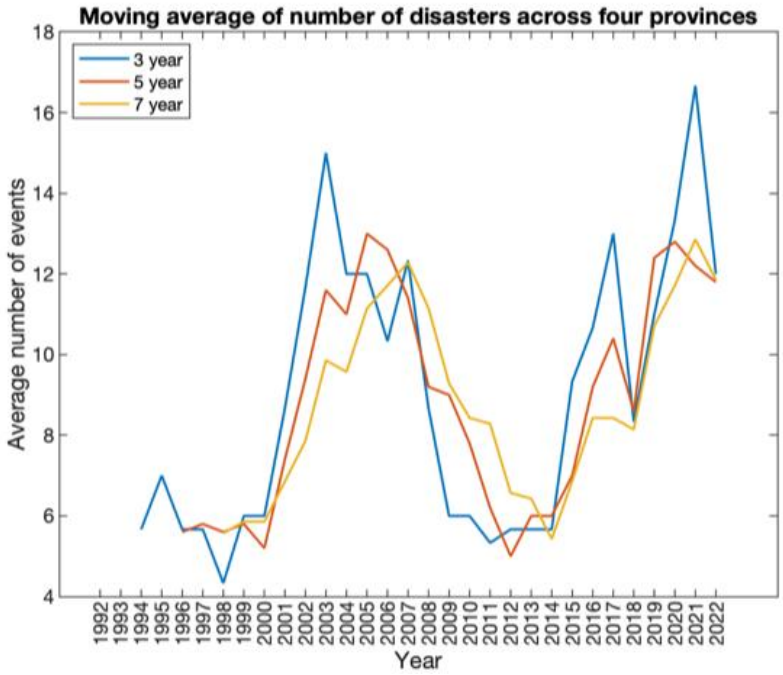

FIGURE 21: MOVING AVERAGE OF NUMBER OF DISASTERS ACROSS ALL PROVINCES TO REFLECT TIMESCALE OF ENSO

Impact of floods

Floods result in more loss of life and damage of property than other natural hazards (129). In Pakistan their intensity and frequency has increased since Pakistan was formed in 1947 (129). Flood events between 2010 and 2014 destroyed 43000 km^2 of crops in Pakistan (11). Since then, the 2022 floods have destroyed a further 26305 km^2 of crops, which is particularly worrying in such an agriculture dependent country (130). Table 1 summarises the causes and effects of recorded floods over the last 3 decades.

TABLE 1: DETAILS OF PAST FLOOD EVENTS IN PAKISTAN

Year	Region affected	Causes	Effects
1992 July-Sept	Sindh, Punjab and Azad Kashmir	• Heavy rainfall due to monsoon depression interacting with intense westerly (131).	• 6.6 million people affected (132). • 1000 died (133). • 13208 villages affected (133). • 38758 km^2 flooded (134). • 875000 homes damaged or demolished (132).
1993 July	Punjab	• Heavy rainfall caused riverine floods (135).	• 261295 people affected (45). • 1328 villages affected (135). • 665 km^2 of crops damaged (135). • 1080 homes demolished or damaged (135).
1994 July-Sept	All four provinces and Islamabad	• Torrential rain initially caused urban floods with generalised flooding later (136).	• 431 died (134). • 1622 villages affected (134). • 5568 km^2 flooded (134). • 7314 km^2 of crops affected (136).
1995 June-July	All four provinces	• Rivers and canals flooded due to heavy monsoon rain (137).	• 591 died (134). • 6852 villages affected (134). • 16686 km^2 flooded (134). • 132455 homes lost or damaged (138). • 15375 cattle lost (138).
1996	East Punjab	• Heavy rains (139).	• 2024 villages affected (139). • 2173 km^2 flooded (45).

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Aug-Sept		• Swollen streams and irrigation canals flood villages (139).	• 111 died (45). • 1300000 affected (45).
1997 July-Sept	Khyber Pakhtunkhwa, Punjab	• Monsoon rains caused riverine flooding (45).	• 1929 km^2 flooded (45). • 851384 people affected (45). • 15000 left homeless (45). • 848 people died (129).
1998 March	Balochistan	• Torrential rain caused flash floods (140). • Area normally arid, floods very rare (140).	• 200000 people affected (129). • 1000 died (38). • 202 km^2 flooded (45). • 20000 livestock and all wheat crop lost (140).
1999 March & July	Sindh first then Balochistan	• Very little information is available about these floods.	• 14 died in Sindh (45). • 20 died in Balochistan (45).
2001 July	Islamabad, Khyber Pakhtunkhwa, Punjab	• Monsoon rains caused urban flash floods (38).	• >200 died (38; 45). • A landslide also resulted (45). • 1500 families left homeless (38). • Large number of cattle died (38). • 400000 people affected (129; 45).
2002 Aug	Khyber Pakhtunkhwa	• Flash floods and riverine flooding (45).	• 4900 km^2 of Khyber Pakhtunkhwa inundated (45). • 36 died (45). • 3000 affected (45).
2003 July & Sept	In July all provinces: Sindh and Balochistan particularly affected. Sept: Khyber Pakhtunkhwa	• Above normal monsoon rains (141). • Second wave from 22nd July especially heavy (141). • Major flooding along Indus River (142). • Sept: Flash flood caused by brief torrential rain (45).	• 230 people died (129). • 1.3 million people affected (129). • Increase in diarrhoeal disease, malaria and typhoid following flood (143). • 14160 houses destroyed or damaged (143). • 170000 people living in relief camps by August (143). • Issue of pollution associated with flood waters (45). • 36 died in September flood event (45).
2004 July-Sept	Punjab	• Riverine floods due to heavy monsoon rains, but very few details available (45).	• 5 died (45).
2005 Feb-March & June	All provinces, although only Balochistan and Khyber Pakhtunkhwa in February floods.	• Initially heavy rain and snow, followed by high temperatures (45). • Later monsoon rains continued to swell rivers (45).	• 1000 people died (129). • Over 7 million people affected (129). • 302850 km^2 flooded in Khyber Pakhtunkhwa and Balochistan in spring (37). • 3856 km^2 flooded in Sindh and Punjab in summer (129). • Landslide caused in Khyber Pakhtunkhwa (37). • River banks burst during both events (37).
2006 July-Sept	Punjab, Sindh and Khyber Pakhtunkhwa	• Heavy, intense monsoonal rains caused riverine floods (37).	• 380 people died (45). • 1000 villages affected (129). • 16872 houses damaged (129). • Landslides caused by heavy rain (37).
2007 Aug	Sindh and Khyber Pakhtunkhwa	• Storms and torrential rain caused both flash floods riverine flooding (37).	• 526 people died (129; 45). • 2.5 million people affected (129). • 6500 villages affected (129).
2008 Aug	Punjab, Balochistan and Khyber Pakhtunkhwa	• Riverine floods due to torrential monsoon rains (37).	• 83 people died (37). • 300000 people affected (37). • 800 villages affected (129).

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2009 Apr & July- Aug	Sindh and Khyber Pakhtunkhwa	• In April and August flash floods in Khyber Pakhtunkhwa due to heavy rain (45). • Intense monsoon in Sindh in July caused riverine floods (45).	• >100 people died (129; 45). • 75000 people affected (37). • 89 villages affected (129). • 400-450 houses damaged (129). • 41000 km^2 flooded in total (37).
2010 July	Riverine flooding north to south of Indus Basin Balochistan, Punjab, Sindh	• Heavy rainfall following mid-latitude westerly depression, causing extra low level moisture over Himalayas (7). • Silting of drainage channels and failure of the Left Bank Outfall Drain prevented outflow (7).	• Over 20 million affected, over 2 million displaced (12; 22; 7; 129). • 160000 km^2 flooded (12). • >1985 died (12; 45). • 17553 villages affected (12). • 1.8 million homes destroyed or damaged (7; 32). • Just under 25000 km of roads destroyed (134) • $9.7 billion in damages was paid out to 46 of the 135 districts (7). • 80% of national food reserves were damaged (7). • Over 0.5 million tonnes of wheat lost (12). • Reconstruction estimated to cost $2.6 billion (144).
2011 Feb-March	Balochistan, Sindh	• Western disturbance caused widespread rain and isolated heavy rainfall and snow(11).	• 881000 hectares of crop growing land flooded (12). • 27581 km^2 flooded (12). • 516 died (12). • 38700 villages affected (12). • 9 million people affected (129).
2012 Aug-Oct	All provinces	• Heavy monsoon rain caused riverine floods (37).	• Over 500 died (134; 45). • Over 5 million affected (37). • 14159 villages affected (134). • 120000 km^2 flooded in total (37).
2013 Feb & Aug	Punjab, Khyber Pakhtunkhwa in Feb. All in Aug	• Heavy rains in the north in winter followed by intense monsoonal rain in August caused riverine floods (37).	• 268 died (45). • 8297 villages affected (134). • 463000 km^2 flooded (37). • 1.5 million affected (37).
2014 Sep-Oct	Punjab	• Erratic rains (12). • Monsoon intensity caused riverine flood (37).	• 255 died(37). • 4065 villages affected (134). • 254000 km^2 flooded (37).
2015 Feb-Mar & June-Aug	Khyber Pakhtunkhwa and Punjab in winter. All provinces in summer.	• Flash floods in Balochistan and Khyber Pakhtunkhwa (12). • Riverine flooding due to torrential rain (37).	• 318 died in total (134; 45). • 4634 villages affected (134). • Over 200000 km^2 flooded (134; 45). • Food stocks, crops and livestock destroyed (12). • Disease outbreak (12).
2016 Mar-Apr & July-Aug	Khyber Pakhtunkhwa Balochistan and Punjab in winter. All provinces in summer.	• Heavy rains caused widespread flash floods and riverine floods (37). • Lightning struck a house in Khyber Pakhtunkhwa (145).	• 153 died (134). • 43 villages affected (134). • Landslides in spring and summer (37). • Flooding caused a transport accident in July in Khyber Pakhtunkhwa (37). • 133000 km^2 flooded (37).
2017	Balochistan in Jan.	• Continuous rain and snow in Balochistan in January (37). • Torrential rains in the summer (37).	• 180 died in total (134; 45). • Landslide and avalanche both occurred on 17th Feb in Chitral district (146). • Landslide caused by heavy monsoon rains (37).

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Jan & June-Sep	Balochistan, Punjab and Khyber Pakhtunkhwa in summer		• 63000 affected (37).
2018 May	Gilgit-Baltisan	• Heavy rains (37). • Debris blocked Immit River, lake formed (40).	• 88 died (134). • Downstream flooding when debris removed (40).
2019 Feb, Apr, July-Sept	All provinces	• Intense and torrential rains were responsible for all flooding events (45).	• 235 died (38). • Caused 5 landslides and a mudflow (37). • 670 houses damaged (147).
2020 March, June & Aug-Sept	Mainly in Khyber Pakhtunkhwa, but summer floods spread to Sindh and Punjab.	• Heavy rains in spring and a strong monsoon in summer (45).	• 410 died in the main flood event in August with over a 100 more deaths in the earlier events (38; 45). • In March heavy rains caused a landslide and a cold wave (45). • Heavy rains in June affected 5000 (45). • Monsoon flooding from August to September affected over 1.5 million (45). • Karachi flooding put down to inadequate drainage (148).
2021 March, June-Sept	All provinces	• Khyber Pakhtunkhwa had heavy rains, storms and floods in March, July and September (45). • All provinces had flooding due to monsoon rains (45).	• 220 died (45). • Over 300 affected in total (45). • 497 houses damaged or destroyed (149). • Despite trying to clear drainage after 2020 floods, Karachi suffered flash flooding with cars being submerged (148).
2022 June-Aug	All provinces	• Record breaking monsoon rain which began early (7; 49). • Intense low pressure air in Arabian Sea led to heavy rain along coast in June (49). • Estimated to have been exacerbated by climate change by 50-75% (33). • Main issue was Indus River flooding, but also urban flash floods, landslides and GLOFs (7). • Heatwaves in April and May meant air could hold more moisture, so more intense monsoon (49). • More than three times average rainfall across Pakistan, more than five times in Sindh and Balochistan (49). • Sindh got 726% of normal August rain and Balochistan 590% (49). • From July to August 190% more rain than 30 year	• Displaced 33 million, with 15% of the population affected (49; 1; 45). • Over 1500 died (7; 45). • 10-12% of Pakistan's land area was flooded (1). • $14.9 billion damage and $15.2 billion loss (121). • In Karachi industrial estate effluent overflowed into the streets for several days (33). • Limitations to assessment of damage and loss due to a number of factors including poor communication of loss and damage via collection forms, lack of monitoring of flood over geographical area, limited engagement with NGOs, difficulty in verifying and quantifying satellite data, data provision often qualitative and not evidence based (33). • 1.2 to 1.7 million houses destroyed or damaged (49; 1). • 22000 schools forced to close and 1460 health facilities affected (1; 7; 27). • 6700km of road submerged (49; 7). • More than 800000 livestock killed (1). • $2.3 billion food crops destroyed (1). • 269 bridges destroyed (49; 7). • Outbreaks of cholera, malaria and skin infections (1). • Diarrhoea occurrences five times higher than normal (150).

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		annual average, 1% chance of this, but large uncertainty (1). • Glacier melt contributed to faster river flow, but much smaller contribution than rainwater (49; 1). • 85-96 year return period under current climate for 60 day maximum precipitation over Indus Basin (7). • 100 year return period under current climate for 5 day maximum precipitation level over just Balochistan and Sindh (7).	• 6 million have no home sanitation (150). • 8 million require health assistance (150). • Elongated lake in Sindh 100 km wide, as nowhere to drain to (49; 7). • Landslides recorded due to heavy rains (45). • Floodwater caused Left Bank Outfall Drain to overflow in Lower Sindh (67). • Right Bank Outfall Drain overflowed due to high pressure and weak banks, submerging hundreds of villages (67).

Droughts and heatwaves:

Droughts, as shown in Table 2, are estimated to happen in Pakistan once every 16 years, although heatwaves are more frequent (12). There have been significantly more heatwave days per year in the last four decades, with an increase of 31 days between 1980-2007 and since then even larger rises (11). Droughts have become more pronounced in Balochistan and Sindh, with South Punjab experiencing "intense dry spells" (11). Droughts are being aggravated by increasing evapotranspiration, which adds to their persistence (10). These droughts will be more likely in the winter amplifying the risk of forest fires (11). Projections also show that the precipitation will be lower than the rate of evapotranspiration in the south in future, leading to droughts, whereas in the north this pattern is reversed, making wet events more likely (10). In the southern Thar dessert, Southwest Balochistan and South Punjab recent droughts have shrunk available land for crops and livestock, which has led to widespread migration to the cities (22).

TABLE 2: DETAILS OF PAST DROUGHT AND HEATWAVE EVENTS IN PAKISTAN

Year	Region affected	Causes	Effects
1996 June	Sindh	• Temperatures > 40°C (45).	• 19 died (45). • Hundreds of birds and cattle also died (151).
1999-2003	Balochistan, South Punjab, Sindh	• Prolonged dry period (45). • Reduced precipitation started with 1998 El Niño event (12).	• 143 died (45). • 2.2 million affected (45). • Hundreds of thousands of livestock died (12).
2000 June	Punjab	• Temperatures > 46°C (45).	• 24 died (45).
2002 May	Balochistan, Punjab, Sindh	• Temperatures > 50°C (45).	• 113 died (45).
2003 May-June	Central and southern Punjab	• Temperatures > 50°C (45).	• 200 died (45). • Sunstroke was main cause (152).
2005 June	Balochistan, Punjab, Sindh	• Temperatures > 50°C (45). • Heat index $\leq$ 54 °C (153). • 57% humidity (153).	• 106 died (45). • Most deaths due to sunstroke and dehydration (153).
2006 May	Balochistan, Punjab, Sindh	• Temperatures > 50°C (45). • Low pressure system (154). • Between 1 and 19 days of over average temperatures depending on district (154).	• 84 died (45).

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2014 Jan-Apr	Sindh	• Heatwave led to drought (45).	• 139 died (45).
2015 June	Sindh, Punjab	• Temperatures > 45°C (45).	• 1229 died (45). • Lack of power and water (155). • Power outages in Karachi blamed on illegal hook-ups overloading power lines (155).
2015-2016	Far North West worst hit (12).	• Strong El Niño event reduced precipitation by 50% (12). • Temperatures of over 45°C, but with high relative humidity so heat index 7-12 °C higher (156)	• Deaths due to heatstroke and severe dehydration (157). • Power outages prevented operation of pumps in Karachi so water supply inaccessible (157). • State of emergency declared in hospitals (157). • Return period estimated as 4 years for humidity and 2 years for heat (156).
2018 May	Sindh	• Temperatures > 42°C (45).	• 180 died (45). • Power outages (158).
2019 Jan-Dec	Sindh, Balochistan	• Erratic rainfall and a long dry spell led to a drought (11).	• Affected 5 million (11; 45). • Food shortage (45). • 77 died (45).
2022 Mar-Apr	Khyber Pakhtunkhwa, Gilgit-Baltisan (India affected too)	• Temperatures > 50°C (7). • Below average rain (159). • Temperatures 5-8 °C above normal (159). • Caused by high pressure system (159).	• Loss of wheat and livestock (7). • Forest fires (7). • Impacted water supplies (159). • Triggered at least one GLOF (159). • Hundreds of millions affected (159). • Power outages (27). • Extensive crop losses (27).

GLOFs and Landslides:

Heavy rains, deforestation and poor land management are all driving an increase in landslides in northern Pakistan (12). Both the frequency of landslide events and their severity have increased in the last decade (160). Khyber Pakhtunkhwa is the only province to have suffered more than one landslide considered severe enough to include in the EM-DAT disaster database over the last three decades (45). Many of the landslides in the north of Pakistan occur along mountain roads, resulting in road closures and difficulty accessing disaster sites (160). Landslides triggered by seismic activity have not been included in this list, as they are not exacerbated by climate change. The most likely times for climate related landslides to occur are in the winter and during the monsoon season (160). Between 1900 and 2020 landslides have cost Pakistan $18 million (27).

Higher temperatures are hastening snow and ice melt, leading to GLOFs (10). Over 3000 glacial lakes have been created by melting glaciers and 33 of these are considered hazardous (40). Past occurrences of avalanches, GLOFs and landslides are all shown in Table 3.

TABLE 3: DETAILS OF PAST GLOF AND LANDSLIDE EVENTS IN PAKISTAN.

Year	Region affected	Causes	Effects
1992 Mar	Khyber Pakhtunkhwa	• Avalanche associated with heavy rain (45).	• 55 died (45). • 200 affected (45).
1993 Mar	Khyber Pakhtunkhwa	• Avalanche (45).	• 58 died in total (45). • 314 affected (45).

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	and Gilgit-Baltisan		
1996 Mar	Kashmir	• Avalanche (45).	• 44 died (45).
1998 Mar	Kashmir	• Landslide (45).	• 13 died (45). • 3000 affected (45).
2001 July	Sindh, Khyber Pakhtunkhwa	• Mudslide in Sindh (45). • Landslide in Khyber Pakhtunkhwa (45).	• 31 died in total (45).
2003 May	Khyber Pakhtunkhwa	• Landslide caused by heavy rains (45).	• 12 died (45).
2005 Dec	Khyber Pakhtunkhwa	• Avalanche (45).	• 24 died (45).
2006 July	Khyber Pakhtunkhwa	• Landslide caused by monsoonal rain (45).	• 29 died (45).
2007 Jan & Mar-Apr	Khyber Pakhtunkhwa and Kashmir	• Avalanche in Khyber Pakhtunkhwa caused by heavy snowfall in spring (45). • Landslides in Kashmir in January (45).	• 63 died in total (45). • In Wasij, Chitral 26 homes destroyed by avalanche (161). • Other avalanches also hit Terich, Phostiki and Momi killing 18 (161).
2010 Jan	Gilgit-Baltisan Region	• Heavy snowfall (45). • Landslide blocked Hunza River (22).	• Initial landslide buried a village (162). • River blockage led to flood which submerged 5 km of Karakoram Highway (162). • Huge lake formed in the place of villages (22). • 1000s migrated from the area (22). • 3000 cut off by water (162). • 26700 affected (45).
2012 Apr & Nov	Kashmir	• Avalanche and landslide (45).	• 153 died in total (45). • The avalanche in April hit a Pakistani military base, burying 129 soldiers and 11 civilians (163).
2016 Mar-Apr	Khyber Pakhtunkhwa	• Torrential rain triggered landslides (164). • Deforestation weakened mountainside (164). • Lack of land planning (164).	• >140 died (164). • 700 houses damaged (164).
2017 Feb	Khyber Pakhtunkhwa and Balochistan	• Avalanche due to snow followed by heavy rain (45).	• 9 died (45). • 113 affected (45).
2020 Oct	Gilgit-Baltisan Region	• Heavy snow and rain (11). • Landslides and avalanches (11). • Construction to widen road (165).	• 106 died (11). • Bus caught in landslide along mountain road (165).
2022 Jan	Khyber Pakhtunkhwa	• Heavy rain caused landslide (166).	• 8 died (166).

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Cyclones and tropical storms:

Table 4 shows that cyclones and tropical storms are infrequent, but projections show that instances may increase in the future due to climate change (167; 11). They can hit the coast in Sindh and Balochistan in either May and June before the monsoon season or after the monsoon rainfall in September and October (12; 167). Cyclonic storms developing in the Arabian Sea only have a one per cent chance of moving towards the Pakistani coast (167).

TABLE 4: DETAILS OF PAST STORMS AND CYCLONES IN PAKISTAN

Year	Region affected	Causes	Effects
1993 Nov	Sindh	• Category 1 hurricane (167). • Weakened due to wind shear (167). • Huge rainfall (167).	• 609 died (45). • 200000 displaced (167). • Massive flooding (167).
1999 May	Sindh, Balochistan	• 270 kph winds (45). • Cyclone 2A (167). • Most intense ever (167).	• Led to a flood (45). • 231 died (45). • 535940 affected (45).
2007 June-July	Sindh, Balochistan,	• Cyclone Yemyin (167). • 130 kph winds (168). • Torrential rain (168).	• Led to a flood when a dam burst (45). • 242 died (45). • 1650000 affected (45). • Key roads swept away (168).
2010 June	Sindh, Balochistan	• Cyclone Phet (167). • Category 1 cyclone (167). • 155 kph winds	• Led to a flood (45). • 23 died (45). • 4000 affected (45). • Power outages in Karachi for several hours (169). • Delayed the monsoon season (170).

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4.2: CMIP6 Climate analysis

Climate analysis cannot be conducted thoroughly using downscaling within the scope of this report. Therefore, the following information has been accessed from the World Bank Climate Change Knowledge Portal. CMIP 6 information is not available for separate climate models, so the median, 10th and 90th percentiles have been used for results from an ensemble of 31 models to try to give an idea of the scale of model uncertainties. Full data details can be found in the Metadata documentation (75).

Shared Socio-Economic Pathways (SSP) are used alongside Representative Concentration Pathways (RCP) to describe not only the level of radiative forcing in Watts per square metre by 2100, but also the possible global socio-economic pathway that means this is reached. SSP1 represents the "Green Path" characterised by nations committing to SDGs, respecting the environment, investing in health and education, reducing inequality and using energy and resources sparingly. RCP2.6 is linked to a 1°C temperature rise between the baseline period (1986-2005) and the future period (2081-2100). SSP2 is called the "Middle Road", as progress on SDGs in this scenario is expected to be slow, leaving the environment degraded and resulting in no big changes to society. Resources are expected to be used less on this path, but the levels of economic inequality across the globe will still be challenging. The associated RCP of 4.5 would mean a 1.8°C increase in baseline temperature. SSP5 is the most extreme case, known as the "Highway". In this scenario there are competitive global markets and rapid innovations in technology that would help to reach SDGs as well as considerable investment in health and education. However, resources and energy are both in high demand in SSP5. This extreme case is associated with RCP 8.5, which would give a rise of 3.7°C by 2081-2100.

Change in 5-day Maximum Rainfall

This data is based on the largest 5-day consecutive precipitation amount in mm. Data from SSP1-2.6, SSP2-4.5 and SSP5-8.5 is shown across the time periods 2020-39, 2040-59, 2060-79 and 2080-99 on a monthly basis to allow shifts in monsoon patterns to be noted. As this data has not been bias corrected, the difference between the projections and the baseline historical period was taken. Data is a mean value for each month across the 20-year time period. The ensemble of 31 CMIP6 climate models has been re-gridded to a 1° by 1° resolution for all models by bi-linear interpolation. The median of the ensemble results gives the main point, with the bars showing the 10th and 90th percentiles to give an estimate on the spread of the model data.

Plots for the whole of Pakistan (Figure 22 andFigure 23: All Pakistan 5 day maximum rain using an ensemble of CMIP6 models, Monthly changes under SSP2-4.5 and SSP5-8.5Figure 23) show a large increase in the intensity of the monsoon under SSP5-8.5, but less of an increase under SSP1-2.6 and only a slightly more marked increase under SSP2-4.5. Month by month, under SSP1-

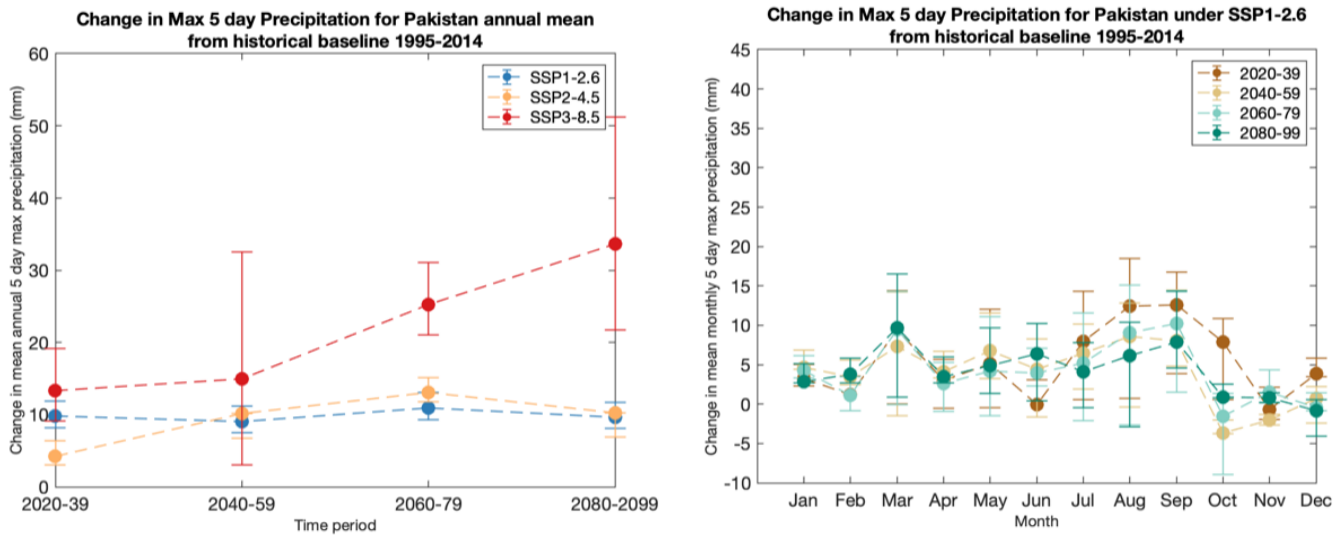

FIGURE 22: ALL PAKISTAN 5 DAY MAXIMUM RAIN USING AN ENSEMBLE OF CMIP6 MODELS, ANNUAL CHANGES AND MONTHLY CHANGES UNDER SSP1-2.6.

2.6, the monsoon seems to spread into October, although in the later time periods the autumn seems drier.

Under SSP2-4.5, rain intensity increases in the longer term in summer and spring, but winter and autumn have reduced 5-day maximum rainfall. The spread of model data is far higher here. Under SSP5-8.5, the projections split, so that the first half of the century has more intense rain in summer, with the rest of the year staying much the same, whilst in the last half of the century increases in intensity are more marked across all seasons with a large peak in the second half of the summer. However, the spread of model data is particularly marked for August to October.

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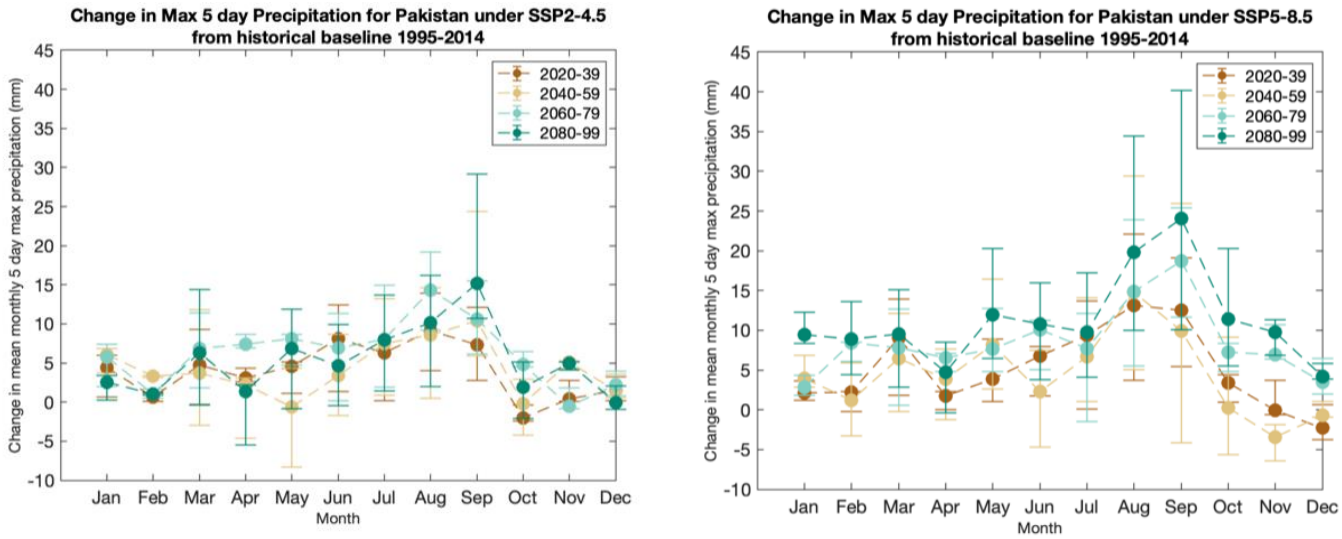

FIGURE 23: ALL PAKISTAN 5 DAY MAXIMUM RAIN USING AN ENSEMBLE OF CMIP6 MODELS, MONTHLY CHANGES UNDER SSP2-4.5 AND SSP5-8.5

In the next four sections the same method will be applied to data at a provincial scale. This is again obtained from the World Bank Climate Change Knowledge Portal.

Sindh: rainfall changes

Plots for Sindh (Figure 24 and Figure 25) show marked increases in monsoon intensity between July and September under SSP1-2.6, but a shift to more intensity from June to August under SSP2-4.5, with less intensity in September. Under SSP5-8.5 there is slightly more intense rain in May, but a larger increase in the rest of the summer, with slower autumn intensity reductions towards the end of the century.

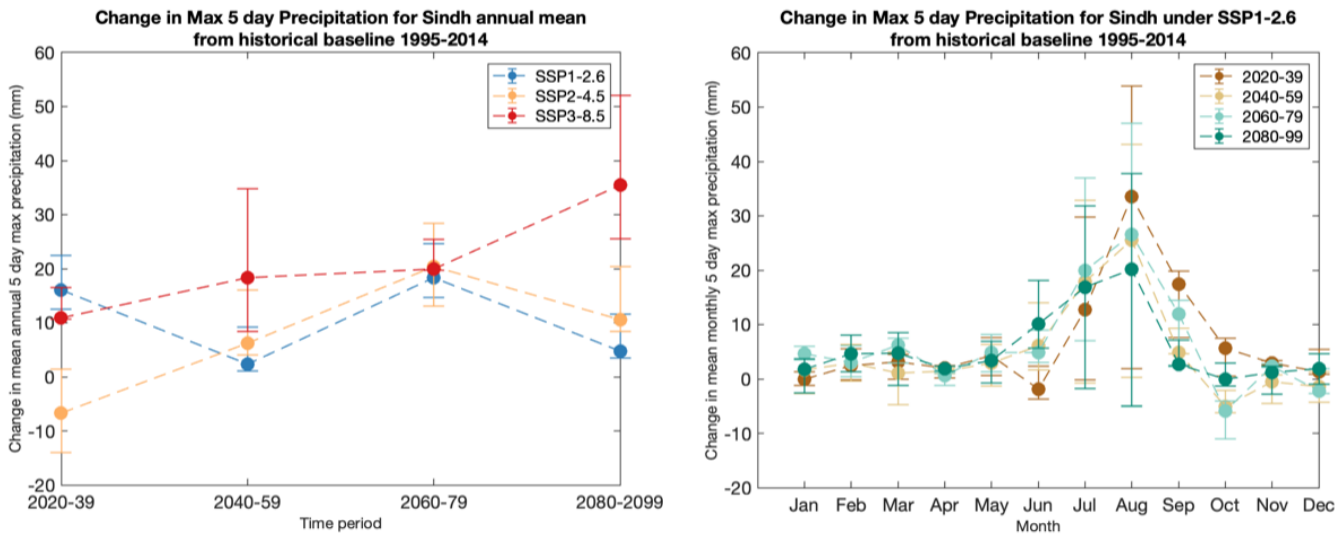

FIGURE 24: 5 DAY MAXIMUM RAINFALL FOR SINDH USING AN ENSEMBLE OF CMIP6 MODELS, ANNUAL CHANGES AND MONTHLY CHANGES UNDER SSP1-2.6.

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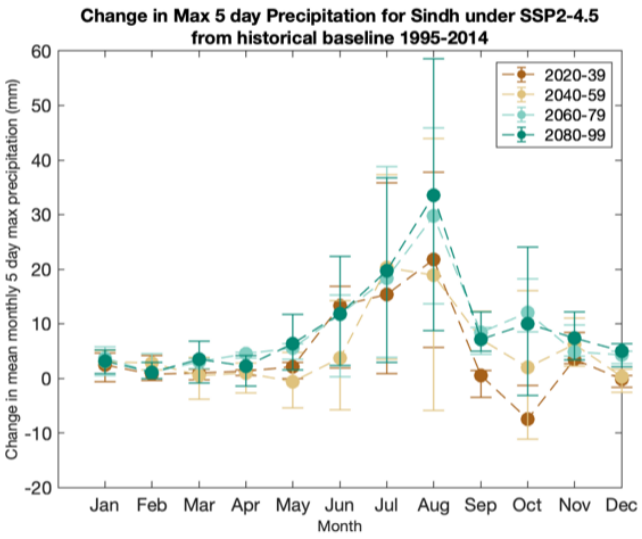


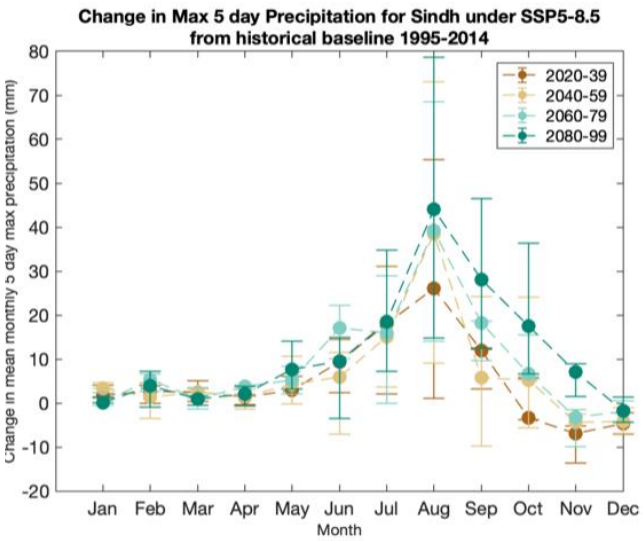
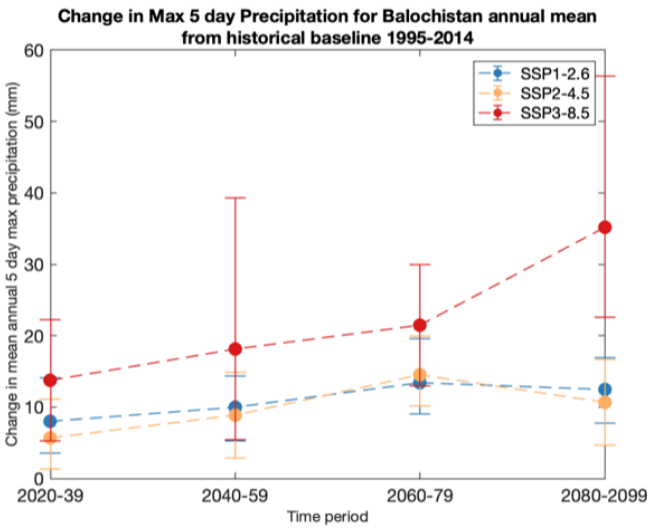
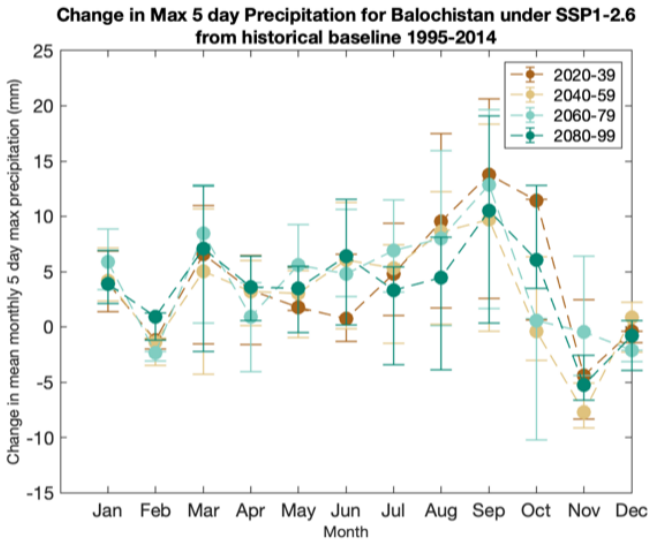
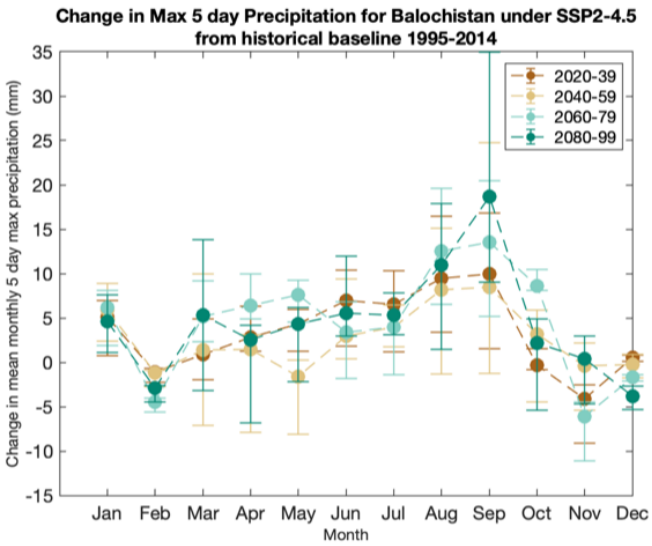


FIGURE 25: 5 DAY MAXIMUM RAINFALL FOR SINDH USING AN ENSEMBLE OF CMIP6 MODELS, MONTHLY CHANGES UNDER SSP2-4.5 AND SSP5-8.5.







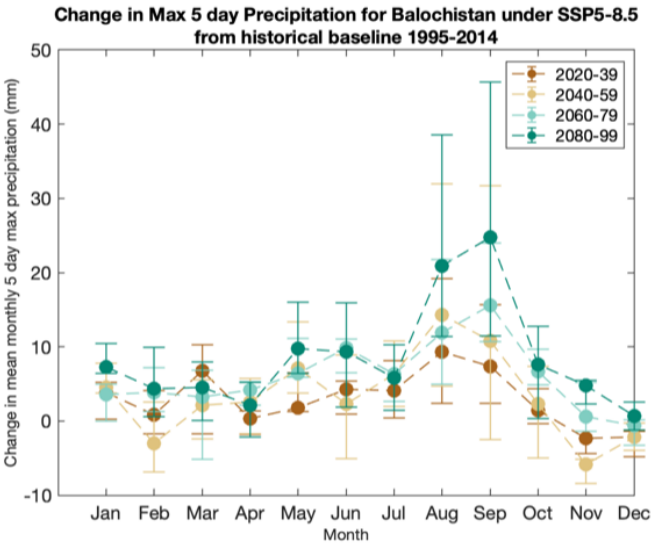


FIGURE 26: 5 DAY MAXIMUM RAINFALL FOR BALOCHISTAN USING AN ENSEMBLE OF CMIP6 MODELS.

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Balochistan: rainfall changes

Plots for Balochistan (Figure 26) show similar patterns to those for Sindh, but without the decreases to intensity in the winter. Under SSP1-2.6 Balochistan sees increased rain intensity in March, with a later shift to the focus of the monsoon season in the first and last time periods. There is a marked reduction in intensity in November. Under SSP5-8.5, the monsoon spreads into September, with a reduction in rainfall intensity in July. Again, November has less intense rainfall.

Punjab: rainfall changes

From Figure 27 it can be seen that Punjab has a larger increase in rain intensity in 2020-39 than for the other provinces, but there is a large split between the patterns under SSP1-2.6 and SSP2-4.5 and the more extreme SSP5-8.5. Under SSP1-2.6 there is a slight dip in rainfall intensity in October, December and January, but an increase in February and March. The monsoon season seems to start earlier. The first 20 years considered show a large increase in five day maximum rain, but this is less marked in later projections. Under SSP5-8.5 intensity is reduced in autumn and winter, but there are large increases from May to September.

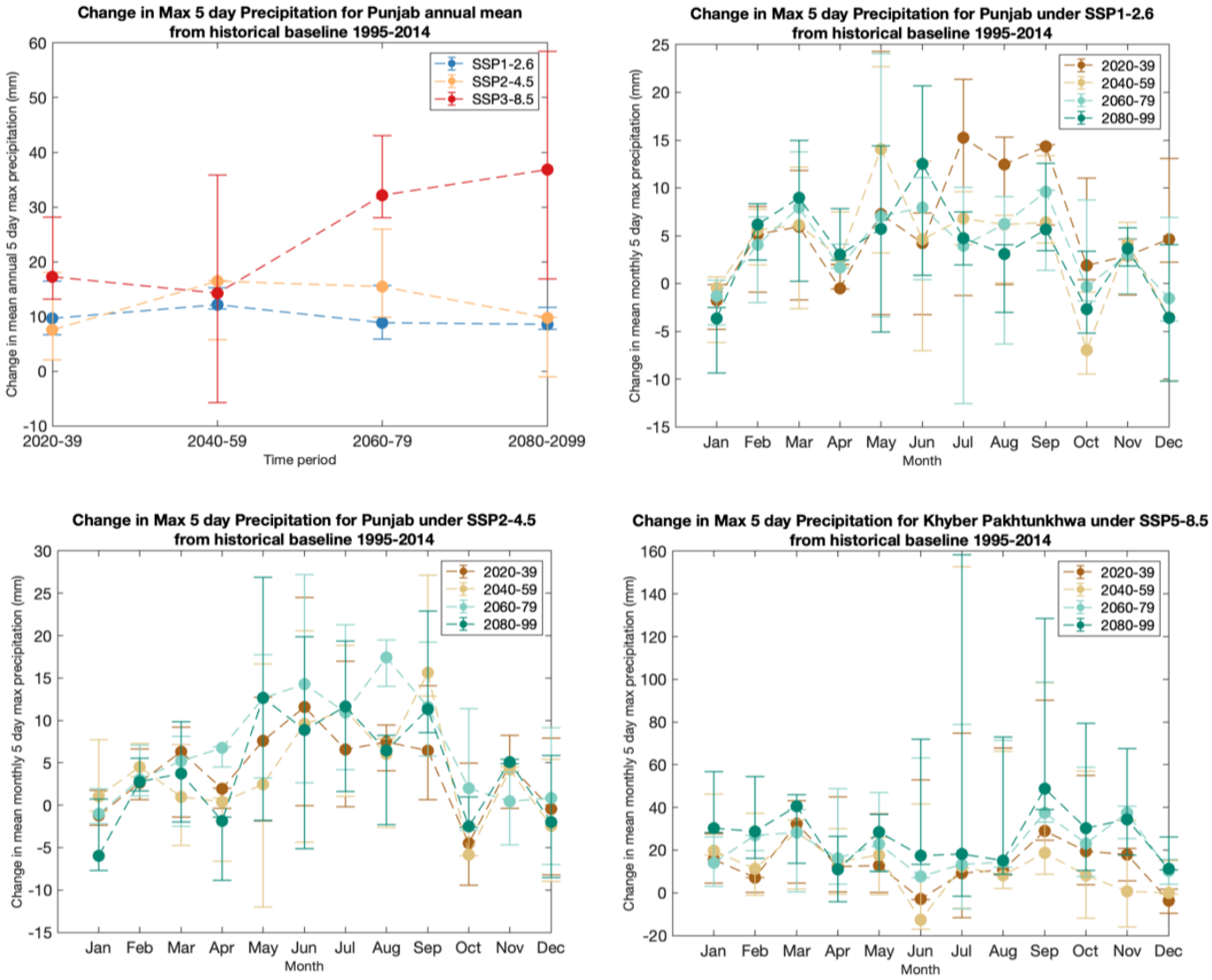

FIGURE 27: 5 DAY MAXIMUM RAINFALL FOR PUNJAB USING AN ENSEMBLE OF CMIP6 MODELS.

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Khyber Paktunkhwa: rainfall changes

In Khyber Patunkhwa (Figure 28) there is an increase in rain intensity in the spring, with early summer seeing less intense rainfall. By September this seems to increase again under SSP2-4.5 and SSP5-8.5. There is much uncertainty in these results with a very wide spread of data across the ensemble, more so than for other provinces. Winter could have more intense or less intense rainfall during the 5 day maximum, depending on SSP and time window.

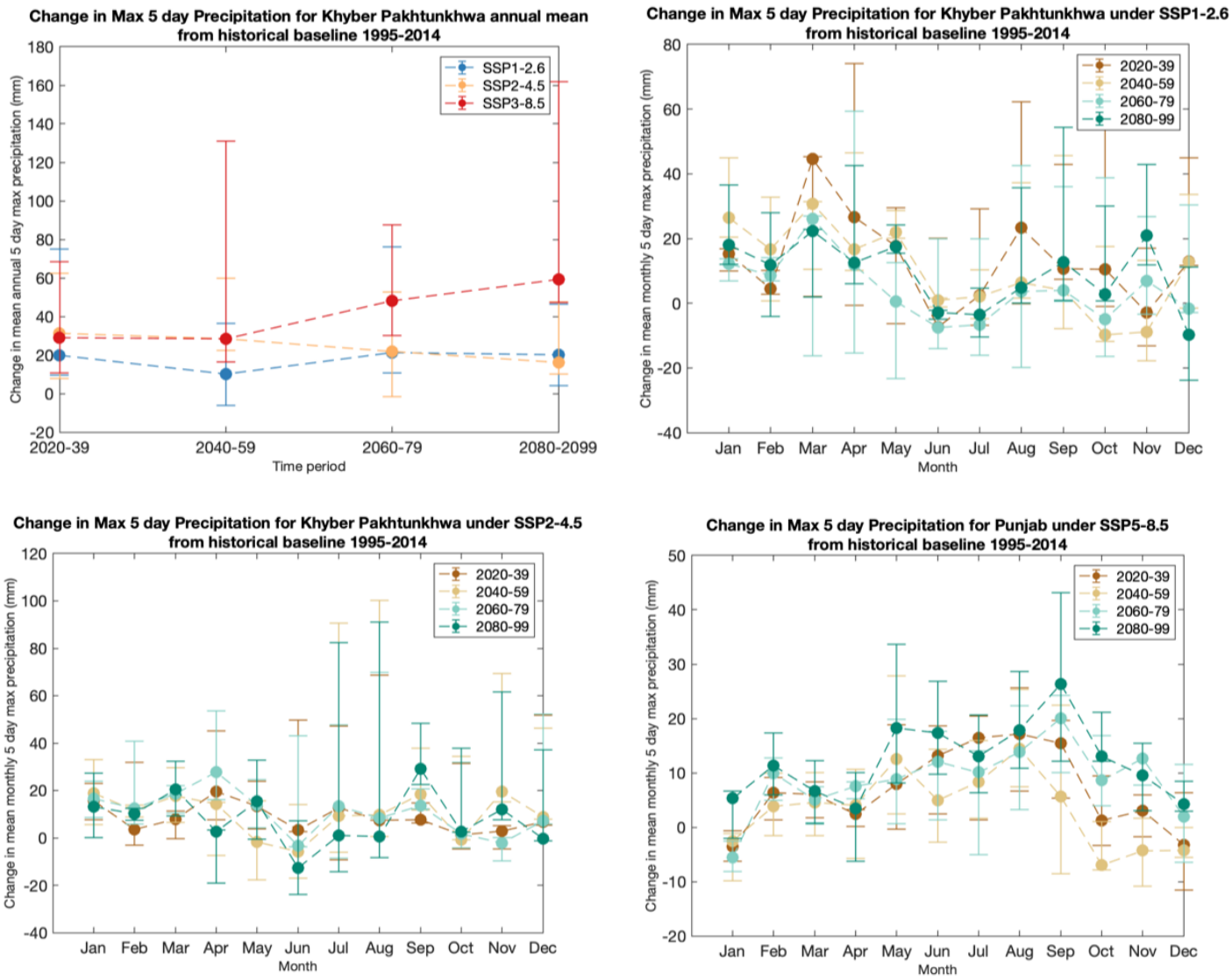

FIGURE 28: 5 DAY MAXIMUM RAINFALL FOR KHYBER PAKHTUNKHWA USING AN ENSEMBLE OF CMIP6 MODELS.

Conclusion: rainfall changes

Overall, the projections seem to show that rain will be more intense in the monsoon period in future for Sindh, with an earlier start to the season. In Balochistan the shift seems to be towards more intense rain in the later summer, with the potential for this to continue into October. Results for Punjab show greater intensity in the summer, but also an increase in 5-day maximum rainfall in the spring. In Khyber Pakhtunkhwa there is likely to be more intense rain in spring, but results are very uncertain.

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Change in Maximum Consecutive Dry Days against Change in Days with a Heat Index Greater Than 35°C

Here the data for the maximum number of consecutive dry days is looked at along with the number of days with a heat index of over 35°C which makes the heat 'dangerous' to health. Heat index is a measure of how hot it really feels given the level of relative humidity, as moist air generally feels hotter (75). It is calculated using both the temperature and the relative humidity (75; 171). This is considered for the whole of Pakistan as well as for Balochistan, Punjab and Sindh separately. These indices were chosen, as the literature implies a tendency to drought and issues with heat in these regions. Only the seasons which are likely to be affected are considered. These are the spring, summer and autumn. Definitions for these seasons have been drawn from the WB Portal Metadata, giving spring as March, April and May, summer as June, July, August and September and autumn as October and November.

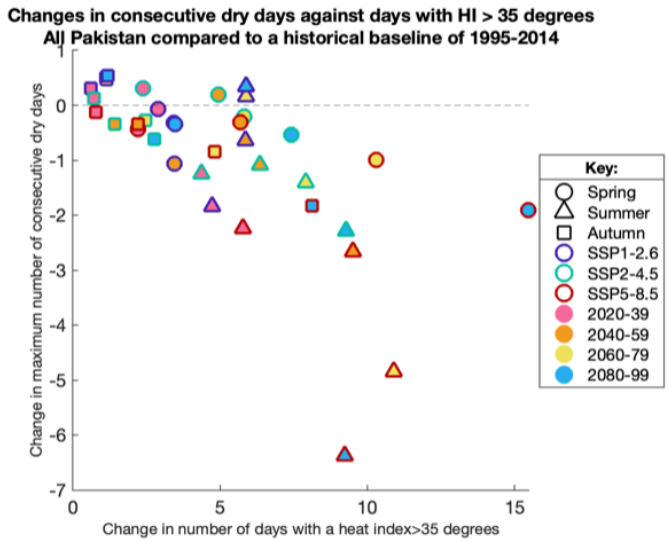

FIGURE 29: ALL PAKISTAN, CHANGES IN CONSECUTIVE DRY DAYS AGAINST HUMIDITY INDEX CHANGES.

The plot of results from all of Pakistan (Figure 30) show that the length of dry spells will generally be shorter, but there will be more dangerously hot days. These effects increase in the summer, particularly under the most extreme scenario SSP5-8.5

Balochistan: dry days and heat index

In Balochistan (Figure 31) this pattern is repeated in the summer, whereas in spring there are longer dry spells. There is little change in autumn unless SSP5-8.5 is considered, under which dry spells are shorter and there are more days with a heat index in excess of 35°C.

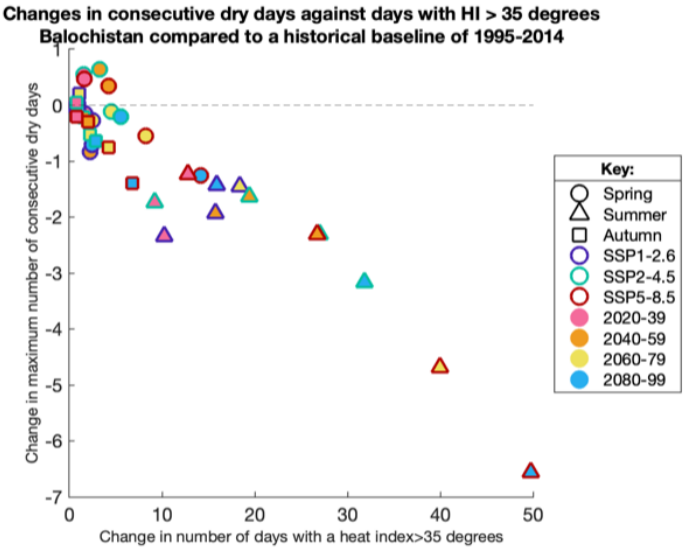

FIGURE 30: CHANGES IN CONSECUTIVE DRY DAYS AGAINST HUMIDITY INDEX CHANGES FOR BALOCHISTAN.

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Punjab: dry days and heat index

Data from Punjab (Figure 32Figure 32) shows fewer consecutive dry days and a decrease in dangerously hot days in the summer, which could be linked with the cooling effect of monsoon rains. However, the autumn and spring have more hot days and shorter dry spells. Under SSP5-8.5 the dry spells are much shorter, but there are also many more days of dangerous heat.

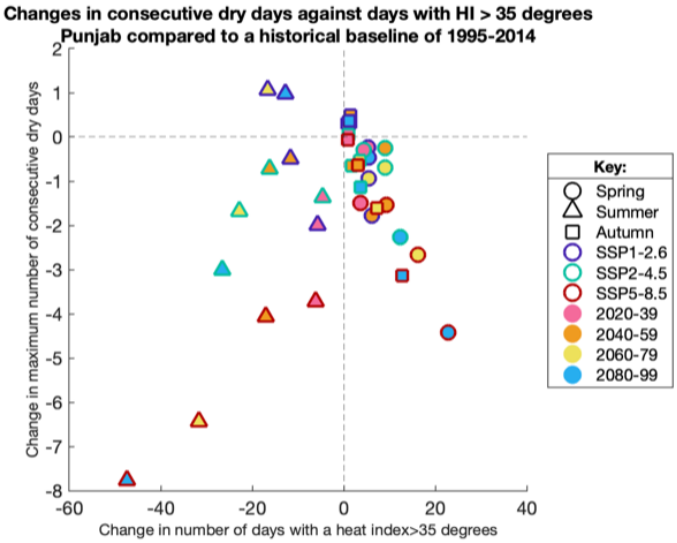

FIGURE 31: CHANGES IN CONSECUTIVE DRY DAYS AGAINST HUMIDITY INDEX CHANGES FOR PUNJAB.

Sindh: dry days and heat index

In Figure 33 it can be seen that Sindh generally has a decrease in the number of consecutive dry days, but increases in days of extreme heat index. In the autumn this is more marked under SSP5-8.5 and in the second half of the century.

Conclusion: dry days and heat index

In general, this data shows that most provinces can expect more days of extreme heat, but that only Balochistan has longer dry spells projected for the spring.

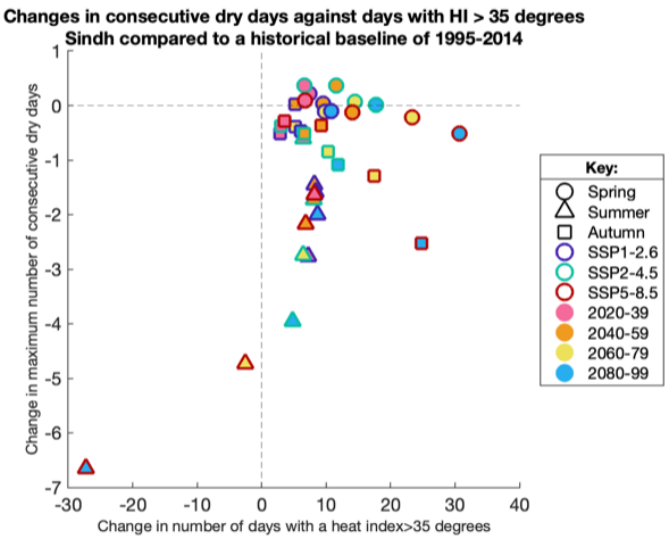

FIGURE 32: CHANGES IN CONSECUTIVE DRY DAYS AGAINST HUMIDITY INDEX CHANGES FOR SINDH

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Change in Number of Ice Days against Percentage Change in Precipitation: All Pakistan and Khyber Pakhtunkhwa

Here the data for the number of days where the maximum temperature does not exceed 0°C is taken along with the percentage change in precipitation. Pakistan as a whole and the separate province of Khyber Pakhtunkhwa are considered here. Data on Khyber Pakhtunkhwa is taken as the total of data for both the North-West Frontier and the Federally Administered Tribal Area as these were merged to form the province in 2018. Key issues for this region are the change in glaciers due to a lack of refreezing time and landslides resulting from greater rainfall. Data from SSP1-2.5, SSP2-4.5 and SSP5-8.5 is shown across the time periods 2020-39, 2040-59, 2060-79 and 2080-99 as before, but this time across the seasons of autumn, winter and spring. Winter is considered to include the months of December, January and February (75).

Figure 34 and Figure 35 show that the results for all of Pakistan and for Khyber Pakhtunkhwa are very similar, as this province contains the majority of the areas where ice days are of interest.

There are generally fewer ice days under all scenarios, particularly in winter. There is an increase in precipitation in winter and spring. Under SSP1-2.6 and SSP2-4.5 there is some decrease in precipitation in autumn. Under SSP5-8.5 there is the largest drop in ice days and the largest increase in precipitation in spring and autumn.

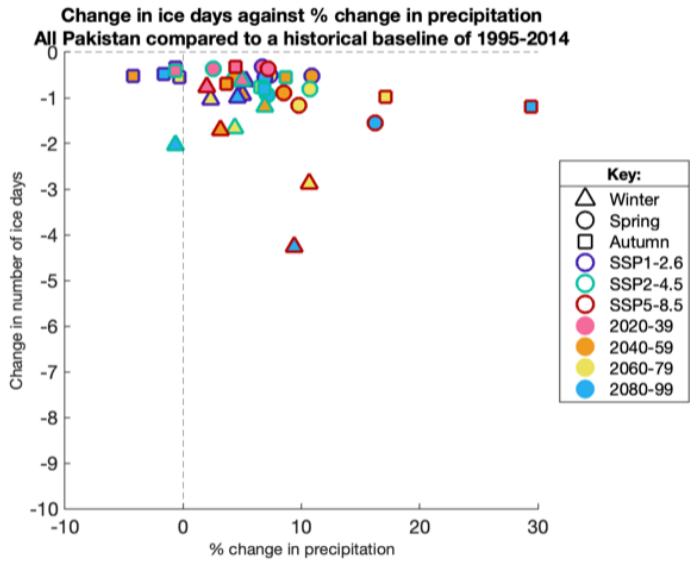

FIGURE 34: CHANGES IN ICE DAYS AGAINST PRECIPITATION CHANGES FOR ALL OF PAKISTAN.

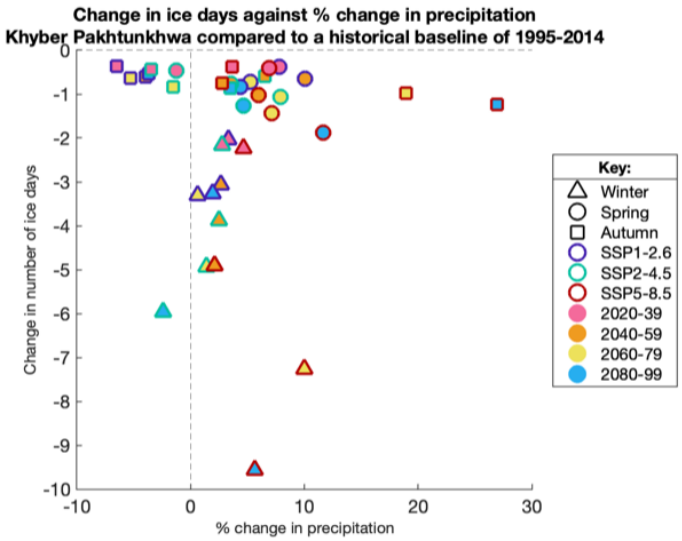

FIGURE 33: CHANGES IN ICE DAYS AGAINST PRECIPITATION CHANGES FOR KHYBER PAKHTUNKHWA

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SECTION 5: PROVINCIAL FOCUS ON FOUR SECTORS

This section should rely on stakeholder input as well as findings from previously published literature. Due to the lack of engagement so far, what follows is mainly based on literature, with the addition of stakeholder information from an initial questionnaire circulated by the MoCC and from later more in-depth contributions from three experts in development, agriculture and environmental protection, here labelled as AN[4], MA[5] and AK[6].

It has been noted that centralised adaptation policies often fail to produce successful outcomes, as risk itself is highly contextualised (74). After 2010 when the 18th constitutional amendment was passed, the federal government devolved responsibility for such policies to the provincial governments (172). This means that the federal government no longer has any authority to legislate on environmental issues in the provinces (MA). They do, however, still produce the National Climate Change Policy, which tries to ensure that climate considerations are prioritised in vulnerable sectors of the economy and that Pakistan is steered towards "climate compatible development" (MA). Whilst all provinces are required to produce Provincial Adaptation Policies, these are not all in place and the resources afforded to adaptation in each province depend largely on the local political economy (AN). Where the federal government create templates of policies for the provinces to follow, often the resources and capacity to implement these action plans is lacking (MA, AN).

Leadership plays an important role in balancing pro-active and reactive responses to climate change, in order to allow constant evolution of adaptive policy and a reduction of inertia (74). The federal government has been involved in a number of initiatives and, according to stakeholders, a discussion of climate change is already incorporated into policies on:

- water and sanitation
- coastal areas
- biodiversity
- environment
- energy
- forests
- national climate change
- national climate action
- flood plans and management
- CPEC plans and strategies
- economic action
- agriculture and orchards
- tourism.

However, these policies are not necessarily effective and "mostly get shelved" (AN).

Stakeholders mentioned a number of federal government initiatives, from irrigation efficiency awareness to tree planting that are under way currently, but with no hierarchical structure to link provincial and national initiatives, policies and actions can become diluted and the overlap of responsibilities between different departments can lead to confusion and inaction. It was also noted that funding for adaptation seems less available to newly merged districts within a province, increasing the vulnerability of such areas. Further information from stakeholder input can be found in Annex 1.

Following a detailed description of the state of water resources, agriculture, health and disaster preparedness in each province, a chart ranking risk within each province at district level is included.

[4] Amjad Nazeer, Executive Director of the Institute of Development, Research and Corresponding Capabilities, Islamabad.

[5] Professor Doctor Muhammad Ashfaq of the Faculty of Social Sciences and Humanities, MNS University of Agriculture, Multan, Punjab.

[6] Afsar Khan, Deputy Director for Climate Change at the Environmental Protection Agency, Khyber Pakhtunkhwa.

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Risk charts to inform storylines

Without localised stakeholder information, performing a district level risk analysis is not possible. In view of this, information that is already in the public domain was used to create risk charts giving an overview of the sort of challenges faced by each district and to what extent these will impact communities resident there.

Under each four sector summary there is a risk chart (example given as Table 5) based on the following data:

1. Drought Hazard: Number affected by 2018 drought (in 1000s of people) (173).
2. Heat Hazard: Expected Annual exposure to High Heat Stress (in 1000s of people) (27).
3. Poverty Headcount 2019/20 (% of population) (27).
4. River Flood Hazard: Expected Annual Impact Built-Up Damage (in hectares) (27).
5. River Flood Hazard: Expected Annual Impact Agricultural Land Damage (in hectares) (27).
6. GLOF Hazard based on data from National Disaster Management Authority (174).
7. Landslide Hazard: Number of landslides and avalanches recorded for specific district from 1992-2022 (where only a province is given this is not included in the data) (45).
8. Flash Flood Hazard: Number of flash floods recorded for specific district from 1992-2022 (where only a province is given this is not included in the data) (45).
9. Riverine Flood Hazard: Number of riverine floods recorded for specific district from 1992-2022 (where only a province is given this is not included in the data) (45).
10. Storm Hazard: Number of severe storms recorded for specific district from 1992-2022 (where only a province is given this is not included in the data) (45).
11. Population density (in people/km^2) (175; 176).

In the case of newly formed districts, data has been assumed to be the same as for the district of which it was previously a part, except for population density data which has been accessed separately (177). If no data is available, ND is shown in the relevant cell. Data is coloured to show whether the hazard in a particular district is ranked as in the top 10, 20, 30, 40 or 50% of such hazards across all districts in the province. This allows provincial teams to decide how to prioritise adaptation. Where data has been taken from grouped data sets there are many ties in the ranking, but with more local knowledge, actual figures could be used allowing a finer discretisation of priorities. The datasets chosen reflect the key priorities in adapting to increase resilience and reduce vulnerability and exposure, but these are not an exhaustive set and discussion with stakeholders will allow particular provincial information to be included as necessary. Only relevant categories for each province are included.

TABLE 5: EXAMPLE RISK CHART

District	1:Drought (1000s)	2: Heat (100s)	3: Poverty (% of population)	4: River flood: Built-up (hectares)	5: River flood: Agriculture (hectares)	6: GLOF (31 year total)	7: Landslide (31 year total)	8: Flash flood (31 year total)	9: Riverine Flood (31 year total)	10: Storm (31 year total)	11: Population density (people/km^2)
A	<50	<50	39-52						2		4
B	100-200	<50	52-65					2			49
C	100-200	<50	39-52				1	1			5

Top 10%
20%
30%
40%
50%

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5.1 Balochistan

The province of Balochistan is particularly vulnerable to climate hazards, with half of the land area classified as seriously at risk (178). Balochistan is also considered to be the poorest and most deprived province of Pakistan (179). Although it is 34.7 million hectares in area, it has a population of only 8 milllion due to 80% of the land being classed as intermountainous, whilst the rest consists of flood and coastal plains (180). Those living in Balochistan are quite young with 58% being between 25 and 50 and 40% under 50, which means they are more likely to be receptive to new ideas and adaptation strategies (18; 178). However, literacy levels are comparatively low, making comprehension of climate change and dissemination of warnings more challenging (178).

The adaptation policy of Balochistan is still in progress according to MA and "work on different climate change aspects is poor".

Water resources

FIGURE 35: CRACKED GROUND DUE TO DROUGHT. (IMAGE: BILAL PHOTOS)

Balochistan has been badly affected by droughts in the last three decades, with 64.7% of the population having been exposed to drought directly or indirectly (178). However, there are also monsoon floods almost every year (180). The projected temperature rises and unpredictable rainfall for the region will lead to water shortages, as there are very few natural water sources in what is principally, a barren and mountainous landscape (178). The Mirani Dam project on the River Dasht was designed to provide effective irrigation to much of the surrounding area by harvesting flood water, but has been controversial after backwash from the system flooded several thousand homes in 2007 (181). In the original Vision 2025 plans, the Water and Power Development Agency (WAPDA) suggested that the dam would provide irrigation for 33200 acres, but the 2017 audit explained that after a full 10 years, only 12500 acres had been irrigated (181; 182). As land is uniformly arid in the province, all agriculture relies on irrigation (180). Sea level rises also threaten to decrease accessibility of freshwater, as salinity increasingly pollutes water sources (178). A field survey of the district of Zhob conducted in 2021 showed that 43% of farmers in the district had adopted some form of water management practices, whilst the others were still reliant on mud water channels (178). Despite the scarcity of water in the province, this valuable resource is still being used inefficiently (180). The likelihood of embracing new water saving and harvesting techniques is in part dependent on annual income and access to credit (178). Water resources in Balochistan comprise 39% form the Indus Basin, 4% from groundwater sources and 57% from floodwater, but currently less than 34% of this is actually available to farmers, principally due to a lack of rainwater harvesting (183). The extensive use of solar powered tube wells in Zhob has lowered the water table, but this practice attracts a government subsidy and so those with limited resources are likely to use this system (178). 25 districts of Balochistan use groundwater, the majority of these over-pumping as there is a lack of regulation and no incentive to use the water efficiently (183). In the future it is hoped that the traditional Karez system in Balochistan can be rehabilitated to supply fresh drinking water and water for irrigation (61; 184). This system is a series of underground sloping tunnels dug out by hand and used to tap subterranean water using gravity, rather than needing any kind of pumping equipment (184). Another project involves the construction of a leaky dam, which is a flood prevention measure that slows water down and prevents silt and soil from escaping (61; 185). These vital pieces of research, which are running from July 2021 to June 2024, are being undertaken by PCRWR, with integrated local community involvement (61).

> "Experts have already predicted that the province will run out of water in the next decade or so."
>
> Balochistan Water Resources Development Sector Project (15)

Agriculture

Since the 1980s, agriculture in Balochistan has been declining, despite 45% of the population being involved in raising crops (178). Even so many farmers from Sindh are moving to arable lands in the east of Balochistan, increasing pressure on resources (180). The lack of productivity of the agricultural sector has led to widespread poverty in the province (15). Non-staple high value crops are cultivated in the north, whilst cereal crops are grown in the northeast (183). Wheat and maize are the favoured crops in this region as they have a high temperature resistance and give a high yield, as long as winter rains are sufficient (178). If these fail, then farmers often turn to groundwater pumping. The prolonged droughts and heat induced increased evapotranspiration have meant that water for irrigation is scarcer, but in more demand than ever before (178). Based on these findings experts have predicted that the province will run out of water in the next decade (15). Educating farmers about which crops have the best chance of surviving as the climate changes is vital in safeguarding their livelihoods. However, there is still a

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gap between knowledge and implementation based on socio-economic status. In Zhob, 94% of the region's farmers have over 15 years of farming experience, which has been shown to decrease vulnerability as seasoned cultivators are more likely to understand the need to adapt (178). However, the small size of individual properties makes applying new technology and using multi-cropping schemes to protect livelihoods more difficult (178). To help arable farmers to cope with climate change, one plan is to encourage small farms growing the same crops to form clusters, thus making it easier to share machinery and new ideas (183).

Another key issue for farmers in Balochistan is the poor physical infrastucture (183). The province has the lowest density of roads in all of Pakistan, which makes transporting produce to markets more difficult (180). 70% of the fruit grown in Balochistan is sold outside of the region, but without refrigerated transport, much is lost (183). One future project that would help here, would be to encourage food processing, to give the end product greater longevity (183). Fruit growers have also suffered with the lack of water and high temperatures, making them unable to grow grapes and peaches successfully, but managing to maintain reasonable yields from apples and apricots (178). In some cases where whole orchards have been lost due to droughts, it has been more productive to replace these with crops like fodder and grass to feed livestock (15). Onions, tomatoes and potatoes have also been affected with a 29-43% reduction in productivity (178). Often where adaptation is visible in Balochistan farmers are making changes to ensure a profit and not due to understanding of the warming climate (15). For example in the district of Zhob 86% of farmers have adapted by using mixed cropping techniques and 80% have changed to crops perceived as more profitable as they are less vulnerable to climate change (178).

Livestock accounts for 60% of the provincial GDP (15). By also raising livestock, as this is likely to generate income faster than growing crops, 60% of Balochistan's farmers have increased their resilience (178). An additional 4% of the workforce are involved in business activities and a further 20% export goods and provide services within the area to supplement their income (178). Although it is hard to forecast exactly what changes to precipitation can be expected by Balochistan in the future, an increasingly variable monsoon season is likely to lead to decreased agricultural productivity and quality (178). Rainwater harvesting and better water management are vital if areas of Balochistan with no streams are to remain not just cultivable, but even habitable under climate change (15).

Health

Balochistan lacks properly equipped healthcare facilities and the fact that around 30% of the population cannot access basic services is adding to poor health outcomes in the province (179). With climate change, it is projected that cases of malnutrition, anaemia, heatstroke, respiratory diseases and cardiovascular diseases will all increase (183). In addition, climate disasters will increase instances of vector borne and waterborne diseases, so one key issue across Balochistan's health service is the lack of any kind of infection control policy or training for staff in this area (179).

> "The malnutrition situation continues to exist in 22 districts of Balochistan."
>
> Amber Munir, program officer in the not-for-profit healthcare company: People's Primary Healthcare Initiative (186).

With the majority of people in Balochistan living in poverty, food is often scarce, which leads to malnutrition and more susceptibility to other diseases (178). Balochistan has the highest provincial rate of food insecurity at 38.4% (48). This has contributed to it also having the highest proportion of undernourished inhabitants and, unlike in the other three provinces, this level is still rising (48). Additional factors contributing to this situation are poor feeding practices, frequent infections and absence of micronutrient supplements (186). The poor particularly lack the ability to recover after a climate disaster which has resulted in amplified health risks (48). Low levels of literacy are compounding the problem, as currently there is little understanding of healthcare issues (179). Almost 47% of children in Balochistan are stunted and 19% suffer from childhood wasting (48). As coastal water temperatures rise there is also the risk of increased cholera cases, according to Balochistan's Provincial Disaster Management Authority (PDMA) (180).

Balochistan has the highest provincial level of dengue cases, particularly along its border with Sindh (90). It also has a high number of Chikungunya virus cases, which is carried by rodents and Crimean Congo haemorrhagic fever is widespread in the province (90). Despite the obvious disease risks, there is still only 50% immunisation coverage in 16 of Balochistan's districts (187). This shows that health education is in urgent need of promotion across the province to reduce infections and diseases being spread due to lack of understanding of potential preventative action (179).

There is a general need to reduce corruption in public health projects, so that money earmarked for providing services across Balochistan's districts actually makes a difference to the standard of healthcare provided (179). There have been reports of nutritional supplements sent by the government being sold at a large market both by healthcare staff and sometimes even by patients (187). Recent surveys of those involved in healthcare in the province showed that delivering a good healthcare service is prevented by the lack of healthcare staff and the low levels of training that the available staff are able to access (188). Where there have been recent conflicts, the healthcare situation is even worse. In these areas there is a lack of human resources, due

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to fear of attacks and the reduced access to certain areas, has led to non-functional healthcare facilities and irregular monitoring (187).

Disaster preparedness

Although Balochistan is particularly vulnerable to intense precipitation in the summer and flash floods, the province lacks a sufficient planning strategy to deal with floods on the scale of those seen in 2022 (189; 180; 48). The flash floods have brought with them loss of life and property, with standing crop and livestock losses alone being valued at billions of rupees (189). With its 770 km coastline home to fast developing new cities like Gwadar, Balochistan is also vulnerable to cyclones and tsunamis, with four districts at a critical risk level (48; 180). There is poor urban planning, which, with an urban growth rate of 4.5% per year, is putting pressure on urban services (180). Rural structures tend to be made of mud and even in the poorer urban areas mud is used in combination with concrete and metal sheeting, which makes the houses more susceptible to intense rainfall and flooding (180). This lack of forward planning means that in the wake of the 2022 floods, Balochistan must now concentrate on providing relief and co-ordinating the efforts of the PDMA, army and navy, rather than focusing on how to prevent such devastation in the future (189). Disasters often have most impact where multidimensional vulnerability is already high, meaning that communities find it far harder to bounce back from an event. There are District Disaster Management Authorities (DDMAs) set up across the province, with District Emergency Control rooms available for planning of communications and information gathering, but these are left at monitoring level until there is a state of emergency (180). Clearly a more pro-active stance must be taken.

In order to prepare for the inevitable climate events to come, it has been shown that having enough education to understand the risks involved is vital (88). However in a survey of 200 households in the Zhob district of Balochistan, although 95% of people felt that the climate was changing, only 20% had any knowledge of global warming and many believed disasters were a punishment sent by deities for a lack of worship (178). Despite the importance of working at district level to educate people, plans for the promotion of district level disaster drills in Balochistan and engagement with stakeholders, in an effort to reduce disaster risk, have been stalled by the need to respond to disasters as they happen (180).

Balochistan risk chart

TABLE 6: RISK GRID FOR BALOCHISTAN BASED ON RANKING WITHIN PROVINCE

District	1:Drought (1000s)	2: Heat (100s)	3: Poverty (% of population)	4: River flood: Built-up (hectares)	5: River flood: Agriculture (hectares)	7: Landslide (31 year total)	8: Flash flood (31 year total)	9: Riverine Flood (31 year total)	10: Storm (31 year total)	11: Population density (people/km^2)
Awaran	<50	<50	39-52					2		4
Barkhan	100-200	<50	52-65				2			49
Chagai	100-200	<50	39-52			1	1			5
Chaman	200-700	50-200	65-78					2	1	324
Dera Bugti		50-200	39-52				1			31
Duki		50-200	26-39							36
Gwadar		50-200	13-26					2		21
Harnai		<50	52-65						1	39

Top 10%
20%
30%
40%
50%

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Jafarabad	50-100	50-200	39-52	0.1-2.5	100-200			4		313
Jhal Magsi	50-100	<50	39-52	0.1-2.5	20-50		3	6		41
Kachhi	50-100	50-200	52-65		20-50					55
Kalat		<50	65-78				1	1		28
Kech		50-200	13-26					4	1	40
Kharan	<50	<50	39-52							11
Khuzdar		50-200	65-78	0.1-2.5			2	2		23
Kohlu	<50	<50	52-65				3			28
Lasbela		50-200	26-39		5-20		1	3		28
Loralai		50-200	26-39					1		65
Mastung		<50	39-52					1	1	80
Musakhel		<50	26-39							29
Nasirabad	<50	50-200	39-52	0.1-2.5	20-50		2	4		144
Nushki	<50	<50	26-39	0.1-2.5		1				31
Panjgur	<50	50-200	52-65							19
Pishin	100-200	50-200	26-39					1	1	119
Qila Abdullah	200-700	50-200	65-78					2	1	91
Qila Saifullah	<50	<50	39-52							50
Quetta	<50	<50	13-26					3		658
Sheerani		<50	39-52							35
Sibi		<50	39-52		5-20		2	2		25
Sohbatpur		<50	39-52	0.1-2.5						250
Surab		<50	65-78				1	1		264
Washuk	50-100	<50	26-39							5
Zhob	100-200	<50	39-52					`		19
Ziarat		<50	52-65					1	1	48

5.2 Khyber Pakhtunkhwa

Khyber Pakhtunkhwa began as the North-West Frontier Province, but was renamed in 2010 (190). It was expanded in 2018 by the addition of the Federally Administered Tribal Areas and the Provincially Administered Tribal Areas (31). It is still, however, the smallest province by land area (30). Climate change causes a range of hazards in this region, including regular heatwaves, flash flooding in the mountainous areas and riverine flooding on the cultivated plains (30).

Khyber Pakhtunkhwa provides 10% of Pakistan's GDP, which reflects the fact that 11.9% of the population live there, 70% in rural areas (74). The province's population growth rate, at 2.89%, is increasing 0.49% faster than that of Pakistan as a whole, in part due to an influx of more than three million refugees from Afghanistan (191). It is a very young population with 68% under the age of 30 (30). The literacy rate of the province is already low, at 51.4%, but for women this falls to an alarming 36.8%, making females much more vulnerable to the effects of climate change than their male counterparts (191). In addition to vulnerable humans, this province is also home to endangered animals such as snow leopards and markhor (AK).

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Khyber Pakhtunkhwa already has an adaptation policy that has been approved by the provincial cabinet after wide-ranging discussion with local institutions, but according to MA no observable implementation is yet visible (74). However, according to AK, a Provincial Climate Change Policy Implementation Committee (PCCPIC) has been set up in the province. This will report back to the National Climate Change Policy Implementation Committee (NCCPIC), who in turn are overseen by the Prime Minister's Committee on Climate Change (192). This group comprises members of relevant provincial ministries, a representative from the corporate sector, one from civil society organisations and three climate change experts (192). In the case of Khyber Pakhtunkhwa, a member of the SRSP[7] represents civil society and a member of the Chamber of Commerce is the corporate sector representative (AK). Civil society organisations in the province also provide vital support, to ensure that the provincial government continues to focus on climate change (74). Currently areas likely to flood are being given the highest priority (AK).

Water resources

As part of the Hindu Kush-Himalayan mountain range lies in Khyber Pakhtunkhwa, it houses huge natural reservoirs of freshwater (30). The province has over six thousand kilometres of rivers, almost 6400 hectares of lakes and almost nine times this area of reservoirs (193). However, better management of this water is needed to improve access for domestic use, power generation, industry and agriculture, as currently chemical dumping in surface water, over extraction of groundwater, intensive use in manufacture, inefficient irrigation schemes and a growing population are all reducing available water resources (192).

FIGURE 36: RIVER KUNHARIN THE KHYBER PATUNKHWA PROVINCE. (IMAGE: ADEEL.AHMED)

In the north of the province, there are sufficient water resources, but the south is classified as water deficient (52). The increasing length of the regular heatwaves that occur in Khyber Pakhtunkhwa is increasing evaporation rates and leading to a large increase in demand for irrigation water in the south, but at the same time the north of the province is experiencing more intense rainfall leading to severe flooding in both regions (30). Up until 2030, projections are for greater rainfall in Khyber Pakhtunkhwa, with more falling in the spring and less in the autumn (194). After this period, however, precipitation is likely to decrease during all seasons (194; 31).

Irrigation canals in Khyber Pakhtunkhwa are leaking due to damage to the linings, so fixing these needs to be a priority (30). This issue is being further amplified by inefficient crop irrigation schemes, with on-farm losses of 51%, which worsen conditions in the event of floods and droughts (52; 194). In both Gulabad and Shabara, households do not store water for use in winter when there are often droughts, despite ample water availability in the summer (52). Education about water harvesting would allow individuals to help to restore the province's water balance (194). Currently only 24.5% of the urban and 21.4% of the rural population use piped water, although 77% of people have access to improved drinking water and sanitation (191). More worryingly 93% of wastewater in the province remains untreated (194).

Although Khyber Paktunkhwa as a whole is currently classified as water abundant, abstraction is causing water tables to drop fast and recharge is inadequate (194; 195). In southern districts water quality has deteriorated due to saline intrusion and many farmers have been forced to dig their wells deeper in search of freshwater (194; 195). Even the government departments charged with monitoring water extraction and management lack the data, funds and equipment to report on this situation, although a 2019 report suggested a 60 m drop in the water table in Mohmand and Khyber districts in just five years (195). An information cascade to provide education on efficient water use is needed, so that both agricultural workers and domestic water users understand the need for water conservation in the projected climate (194). More regulations regarding water pumping are also planned by the provincial

> "It is high time to plan and implement strategies to make use of the water resources available."
>
> Javed Iqbal, Director General of the Directorate of On Farm Water Management (310).

[7] SRSP: Sarhad Rural Support Programme, "assists people affected by crisis" and "works to alleviate poverty" (296).

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government via a newly set up "Groundwater Authority" which will issue well permits and collect revenues, whilst ensuring that recharge is prioritized, perhaps using artificial recharge wells like those that have proved successful in 2022 in Islamabad (194; 196).

Given the province's vulnerability to climate change, it is vital that efficient adaptation methods are put in place to conserve water (194). Multi-purpose small dams improve water storage and flood defence capabilities, whilst having the added bonus of providing hydro-electricity and irrigation, so the government is also searching for feasible dam sites in the province (30; 197). Further projects will depend on harnessing the right expertise to provide inexpensive, but effective solutions to water resource issues (198). Currently there is a lack of clarity on roles and responsibilities with respect to service delivery and public participation in water governance with nine different government departments all dealing with water extraction and management (199; 195). In view of this the Government of Khyber Pakhtunkhwa, via their Integrated Water Resource Management Strategy are inviting "integrated governance" of water supplies, so that goals and objectives can be met by stakeholders outside of the public sector (194). ADB has already agreed a $3.6 million loan to fund a Water Resources Development Project in the province (200).

Agriculture

In Khyber Pakhtunkhwa, the Agriculture University of Peshawar is using climate projections downscaled to district level to help train local farmers (74). In the north of the province warmer weather has increased the yield of rice, maize, wheat and vegetables, but in the south and central districts the excessive heat and humidity have led to reduced crop productivity (30). So climate information is essential in planning future planting in each region. An example of this is that under future climate conditions, 50 to 60% of wheat producers in Dera Ismail Khan and Peshawar will be less well off, whereas in Chitral wheat yield will increase (201). On balance, however, this still leaves Khyber Pakhtunkhwa with a wheat deficit, which must be balanced by wheat bought in from other provinces (30). Research must be undertaken to find the best crop combinations not just for each district, but even for each farmer. In addition, protecting crops from growing numbers of pests must be considered, without adding to the problem of pesticide over-use, which has been linked to soil degradation and water pollution. The government are involved in initiatives to reduce instances of crop losses due to pests, by introducing pest-resistant crops or Integrated Pest Management in which the emphasis is on disturbing the ecosystem as little as possible (202).

The keeping of livestock in Khyber Pakhtunkhwa provides extra income and food to the rural poor. However, despite its potential, this sector is viewed as not being efficiently exploited due to farmers' reluctance to adapt and investors lack of confidence in returns (203). Transhumance Livestock Farming is practiced in the region, with livestock fed on fodder for 7 months of the year and pasture grass at higher altitudes for the other five months (192). As the quality of the available fodder declines, animals are being exposed to a cycle of malnourishment followed by over nourishment which is causing a lower milk yield (30). To combat this, the Government of Khyber Pakhtunkhwa are encouraging contour farming in the mountains (30). In this way they hope to generate employment at the rural level, which will go some way to alleviating poverty in the region (203). Unfortunately, one barrier to this ambition is the lack of vet services, including personnel, equipment and drugs, which is increasing the challenges associated with livestock raising in the province (192).

Fisheries in Khyber Pakhtunkhwa have also been affected by climate change, with both the water flow and water temperature damaging trout hatcheries (30). In answer to this the Directorate of Fisheries has begun a new scheme to promote the development of cold water fisheries, through which declining fish species can be reintroduced and local communities will be given the necessary information and resources to manage the fisheries in a sustainable way (193; 204).

According to MA the Khyber Pakhtunkhwa Agriculture Policy includes information and guidance on climate change, adaptation and mitigation, with strategies provided for the water, agriculture and energy sectors. However, Khyber Pakhtunkhwa does not have as many institutional links and as great a capacity, both in terms of human resources and finances, as some of the other provinces (74). As cultivable land is lost to urbanization or becomes prone to waterlogging and salinity, migration from rural to urban regions becomes more likely (30).

Health

Climate change is projected to bring with it diverse health issues, but part of a region's risk depends on what facilities exist to deal with disease outbreaks and how resilient the local communities are (50). As the climate becomes warmer, more viruses and bacteria are likely to spread, meaning that the currently inadequate health infrastructure in Khyber Pakhtunkhwa will need to be improved, especially in rural areas (30). As it has been shown that undernourishment decreases immunity to infectious diseases, it is particularly worrying that over 40% of women in Khyber Pakhtunkhwa have nutritional health problems (191). In the north of the country there are also issues with post-traumatic stress, linked to both climate disasters and armed conflicts (205; 206). This reduces immunity to infectious diseases and is associated with low birth weights, both of which result in

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increased health risks (205; 206). Other common ailments exacerbated by climate change include eye infections, gastro illnesses, skin infections and heatstroke (30).

There are many weaknesses in the Khyber Pakhtunkhwa health service provision, most notably the poor access and low quality care faced by most of the province's population (191). Healthcare in the conflict hit areas of Khyber Pakhtunkhwa has been badly affected by a lack of planning at central level, little co-ordination between government departments and NGOs, limited funds and inconsistent supplies (187). Most healthcare is administered at district level and relies on public private partnerships, which are subject to regulations, but rarely held accountable (191). In the 2022 provincial Climate Action Plan, it is noted that there is a general lack of human resources within the health sector and that the current referral system is flawed (30). New initiatives to improve the management of health centres and the provision of resources often meet with success, but these are rarely continued once political interest has moved to other areas (191). Paramedics in the district of Khyber have even staged protests about political interference as this was seen to be damaging the competency of hospitals to deliver efficient healthcare (207). Local politicians often have a say in health service personnel decisions, which is said to have resulted in managers lasting an average of 7 months in their roles, not giving them the chance to build up an understanding of the inherent challenges of the job (191; 208). As these managers are mainly doctors with no experience in management and budgeting, they tend to be having to deal with problems reactively, rather than having time to plan for the future. At one hospital political interference even led to 56 senior doctors leaving, which resulted in those with little experience being put in charge and even the closure of the Cardiology Department (209). Lack of strategic planning in the healthcare sector has led to informal payments, high staff absenteeism, unqualified private health care providers and a massive loss of medical supplies (191). More than half of all healthcare posts in Khyber Pakhtunkhwa are currently unfilled, with fifteen and a half thousand more doctors already needed and even more nurses (191).

It is projected that by 2035 Khyber Pakhtunkhwa will have 3.1 million inpatient admissions per year, but will still only have provision for less than a million (191). More hospitals were planned in the province over the last five years and claimed by some to have been built, but this is a subject of some controversy (210). At the same time outpatient care is growing by 7.4% a year (191). The local government has now started the Sehat Sahulat Program into which 69% of households are enrolled (191). Under this initiative families will have free access to 83 hospitals, 59 of these being private (211).This is based on proxy means testing and includes limited tertiary cover and 100% cover for maternity, cancer and all illnesses requiring hospitalisation (191). However, there are already many other public-private programmes running in the province, so confusion over scope of each scheme leads to inefficient resource use and a lack of co-ordination in healthcare (191). There is also a need to co-ordinate federal and provincial health services in order to extend research on connections between climate change, disasters and health (30).

Disaster preparedness

The north of Khyber Pakhtunkhwa is a snowy, cold, mountainous region, bringing with it the potential for flash floods, GLOFs, avalanches and landslides (30). Twenty districts of Khyber Pakhtunkhwa are at risk from flash flooding (48). In addition, Chitral district is prone to both droughts and landslides, the latter also being a concern for Kohistan (48). Further south, the province contains good agricultural land in the central valley plains, which tend to be warm in the summer and mild in the winter (30). However, this region is now prone to riverine floods, given the increased frequency of extreme weather, ruining crops, demolishing infrastructure and potentially leading to mass migration (30; 31).

> "It costs less to prepare for a disaster than to undertake rescue and rehabilitation."
>
> Idrees Jahan, student at 'Master the Disaster' Hackathon in Khyber Paktunkhwa (214).

In the Chitral district, which is home to many of Pakistan's glaciers, warmer weather and more intense rain is melting glaciers faster than normal and the shorter spring season is preventing re-freezing, leading to both flash flooding in mountain areas and riverine flooding further downstream in the densely populated flood plains (30). Villagers in Gulabad and Shabara, where the north and south regions meet, perceived flooding to be the biggest climate risk they faced, with the Kabul River overflowing on an annual basis (52). Particularly in the areas that have more recently become part of Khyber Pakhtunkhwa, there is a lack of hydrometeorological stations and previous data, making an understanding of the region's climatology far harder (31). Flood early warning systems are needed at the Tarbela and Warsak Dams, especially with river flow rates increasing due to accelerated glacial melting (30). These would work in tandem with an improved river flow and flood warning system and snow and rain monitoring according to the Khyber Pakhtunkhwa Action Plan (30).

According to MA, in Khyber Pahtunkhwa, where one of the major sources of disasters is landslides, there has been major investment in tree planting. In spring 2022 almost 300000 trees were planted across the province, with a further 2.1 million being distributed (212). By involving local communities and even the Pakistan Boy Scout Association in this project, the tree planting targets are far more likely to be met and trees will be left to grow as people start to understand better why they are

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needed. Action to plant trees involving the Khyber Pakhtunkhwa Forest Department, The World Conservation Union (IUCN) Pakistan and the Embassy of the Republic of Korea happened in September 2022 (213). A total of 408 mass planting events were organized across urban and rural areas of the province (213). In creating this project the organisers listened to mountain communities and focused on involving women in the conservation initiative to strengthen their role in helping to combat the effects of climate change (213). Khyber Pakhtunkhwa was the only province in which investment was made in the 10 billion tree tsunami program (MA).

Given the wide-ranging climate events likely to happen in Khyber Pakhtunkhwa due to its unique geography, there is a need for multi-hazard vulnerability risk assessment at district level in order to plan emergency response (30). This includes mapping risks to infrastructure such as power stations, irrigation and agriculture as well as improving infrastructure resilience where this is possible (192). To cope with the increased risk of climate disasters, better co-ordination of groups of stakeholders is needed, including comprehensive emergency response training for NGOs and other volunteer organisations (30). Building capacity at a district level will make response to extreme weather events better fitted to the local context and should help to close the communication gap between the government and communities (192; 214).

Khyber Pakhtunkhwa risk chart

TABLE 7: RISK GRID FOR KHYBER PAKHTUNKHWA BASED ON RANKING WITHIN PROVINCE

District	2: Heat (100s)	3: Poverty (% of population)	4: River flood: Built-up (hectares)	5: River flood: Agriculture (hectares)	6: GLOF (31 year total)	7: Landslide (31 year total)	8: Flash flood (31 year total)	9: Riverine Flood (31 year total)	10: Storm (31 year total)	11: Population density (people/km^2)
Abbottabad	<50	0-13	0.1-2.5	5-20				1		678
Bajaur	50-200	39-52	0.1-2.5	5-20			1			848
Bannu	200-350	26-39	0.1-2.5	5-20			1			614
Batagram	<50	13-26	0.1-2.5	5-20			1	2		366
Buner	50-200	39-52	0.1-2.5	5-20				1		481
Charsadda	350-700	26-39	2.5-10	20-50			1	3		1623
Dera Ismail Khan	350-700	39-52	0.1-2.5	100-200			3	1		182
Hangu	50-200	39-52	0.1-2.5	5-20						473
Haripur	200-350	0-13	2.5-10	5-20			1			581
Karak	50-200	26-39	0.1-2.5	5-20			1	1	1	210
Khyber	200-350	39-52	0.1-2.5	20-50			1	1		383
Kohat	200-350	13-26	0.1-2.5	5-20			1		1	372
Kolai-Palas	<50	26-39	0.1-2.5	5-20						223
Kurram	<50	26-39	0.1-2.5	5-20					1	183
Lakki Marwat	200-350	39-52	0.1-2.5	5-20			1			274

Top 10%
20%
30%
40%
50%

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Lower Chitral	ND	13-26	10-17	5-20		3	2	4		43
Lower Dir	50-200	26-39	0.1-2.5	5-20			1	2	1	907
Lower Kohistan	<50	26-39	0.1-2.5	5-20		3	2	4		239
Malakand	50-200	13-26	0.1-2.5	5-20				2		757
Mansehra	50-200	13-26	10-17	5-20	1	2	1	3	1	377
Mardan	350-700	13-26	2.5-10	20-50			3	3		1454
Mohmand	50-200	52-65	0.1-2.5	5-20			1			203
North Waziristan	50-200	26-39	0.1-2.5	5-20				1	1	115
Nowshera	350-700	13-26	17-35	5-20			1	3		869
Orakzai	<50	39-52	0.1-2.5	5-20						165
Peshawar	>700	13-26	>35	20-50			4	4	1	2855
Shangla	<50	26-39	0.1-2.5	5-20			2	3	1	478
South Waziristan	50-200	65-78	0.1-2.5	5-20			1			102
Swabi	350-700	13-26	2.5-10	20-50			1	2		1053
Swat	50-200	26-39	10-17	5-20	1	2	3	5		433
Tank	<50	52-65	0.1-2.5	5-20			1			148
Torghar	<50	13-26	10-17	5-20	1	2	1	3		340
Upper Chitral	ND	13-26	10-17	5-20	1	3	2	4		20
Upper Dir	<50	26-39	0.1-2.5	5-20	1		2	2		256
Upper Kohistan	ND	26-39	0.1-2.5	5-20	1	3	2	4		74

5.3 Punjab

Punjab is Pakistan's most populous province, with 70% of this population living in rural areas (215). Overall it contributes over 50% of Pakistan's agricultural output, 56% of the land in the province being cultivated (74; 215). In terms of gross domestic product, this province is the richest of the four, with a total GDP of $173 billion in 2017 (216). However, Punjab sees the success of future adaptation projects as relying on foreign investment, rather than local funding (74).

The Government of Punjab is still working to produce a provincial adaptation plan (MA), although the MoCC in Islamabad created a draft document in 2021. The challenges faced by different districts of Punjab are very varied due to the diverse levels of development and different climates in evidence across the region (217). North Punjab is more developed and benefits from the August monsoon breaking the summer heat, whilst South Punjab, which relies on rain brought by the southwest winds, has larger, poorer households, lower literacy, high unemployment, poor access to markets and poor infrastructure (217; 215). The very low levels of education amongst farmers, most of whom are illiterate, are especially worrying as this leads to less understanding of the need to adapt to climate change, as well as a lower take-up of diversification strategies (217). Projections show that more intense monsoons, following droughts and extended heatwaves are expected in the future, which will necessitate alterations in the way food is produced in the region (215). Capacity building is starting to happen, though, with agriculture extension departments set up to discuss best practice with local farmers and public awareness campaigns providing information about climate change in local languages (74).

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Water resources

Punjab encompasses a widely changing geographical region which includes fertile plains, riverine regions prone to flooding and even deserts (39). There are five rivers in the province, as well as lakes, streams and springs, all feeding into Punjab's extensive irrigation network (217; 215). However, a lack of proper drainage has led to the IBIS being waterlogged, increasing the salinity of the water (215). As 95% of the province's water supplies are required by the agricultural sector, inefficient irrigation practices are leading to a need for groundwater extraction (215). Currently, Punjab uses 90% of all groundwater that is abstracted in Pakistan, with 85% of private tube wells being situated in the province (218). This has the dual effect of lowering the water table and increasing the salinity of available water resources, with over 50% of irrigated areas having groundwater levels below six metres and 21% being affected by salinity (215; 218).

Most rainwater, 50-75%, falls during the monsoon season leading to some seasonal problems with water shortages, whilst at other times there are floods (217). Where rain is particularly intense, this can result in nutrients being stripped from the rich alluvial soil in some cases, whilst in others the soil is washed away altogether (218). In the west of the province flash floods are becoming more frequent as the monsoon rains intensify, whilst downstream, riverine floods are more likely across the floodplains, where the majority of the population are housed (215).

In some areas of Punjab, people must travel a long way to reach a source of clean drinking water, which is becoming even more scarce due to increasingly frequent floods and droughts (217; 215). This is particularly impractical for female heads of household who do not have time to leave their farms to collect water (217). According to one study published in 2020, a lack of access to clean water in South Punjab is causing people to drink from ponds, steal from irrigation canals and use untreated rainwater (217).

Adaptation to reduce reliance on groundwater in the province is necessary, as currently 76% of cultivable land is dependent on this dwindling resource either directly or indirectly (218). Improvements in rainwater harvesting, water storage, crop irrigation techniques, irrigation canal linings and water management plans, will need to go hand in hand with research into drought resistant crops, flood warnings and wastewater treatment, if Punjab is to increase its resilience to projected changes in its climate (215). There are also plans to improve storm drainage, particularly in Punjab's five main cities, in which over fifty per cent of the population live (215).

Agriculture

As the climate changes, so does the agricultural productivity of the different regions of Punjab. In the central and southern areas of the province, where there has been limited rainfall, more drought and increased insect breeding due to warm, humid conditions, this has resulted in a reduced crop yield, whilst increased temperatures in the north have led to higher productivity (215).

Due to a shift to using tube wells, rather than relying on the irrigation canals in Punjab, water availability became better over the last few decades, leading farmers to plant more water intensive, but also more economically rewarding crops like rice and sugar cane (218). An enormous 97% of the rice and 63% of the sugar cane grown in Pakistan comes from Punjab (215). Along with wheat, these crops use 80% of Punjab's groundwater (218). However, 70% of the wells in Punjab extract saline-sodic water, which is degrading the soil (218). Salination is particularly dangerous for fruit crops, meaning that Punjab's production of the vast majority of Pakistan's mangoes, guavas and citrus fruits is being threatened by this change (215; 218). The PCRWR has been working with farmers in Punjab to monitor crop water requirements, in order to help farmers to reduce their water usage (61). Adaptation plans to expand research into more drought resilient crops, efficient irrigation and harvesting practices more aligned with projected changes to Punjab's climate, along with campaigns to raise awareness through newly developed farming centres with help to protect the agrarian sector (215).

FIGURE 37: CATTLE GRAZING IN THE WILD. (IMAGE: BILAL PHOTOS)

Climate change is also affecting those dependent on mixed crop-livestock production (217). Growing fodder is very water intensive, which means that as Punjab's groundwater resources are depleted with up to 15% of farmers likely to lose all access to groundwater by 2025, providing cattle with high quality feed will become increasingly more difficult and expensive (218). Livestock rearing provides livelihoods for three quarters of the rural population and is continuing to grow faster than industry and crop cultivation in the region (215). Although climate effects on crops are well researched, it is less well understood that a one degree increase in

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temperature can cause a 3-5% reduction in food intake by cattle making them more susceptible to pathogens and parasites (217). With veterinary resources still limited in the province, disease prevention is vitally important (215). A cow in Pakistan is likely to give only a quarter of the milk that a similar animal in a cooler climate will produce, so research into farm cooling systems and advisory weather data will be very important in maintaining and even improving yield as the climate continues to warm (219). This is particularly important in Punjab as it supplies two thirds of Pakistan's milk (215). There are currently no loan arrangements formalised for livestock keepers in the province, despite 64 large scale industries being dependent on the derivatives of livestock farming (215; 217). As lack of credit was found to be a critical financial constraint for farmers in Punjab, this is increasing their vulnerability (217). Larger farms will benefit from schemes helping all livestock raising in a district to adapt to changes in the climate, as this will prevent disease locally and increase the health of all cattle (219). By encouraging the co-ordination of livestock raising initiatives between corporate farms and smallholders, adaptation will become more universally accessible and research and development opportunities will be increased (220).

The Punjabi government is linked to 26 agricultural institutes who discuss their findings with the Ayub Agricultural Research Institute. From here new information is disseminated, which helps farmers to set targets (74). The Punjab Agriculture Policy mentions climate change adaptation measures, but a full policy on adaptation is still in progress (MA). From the draft action plan created by the MoCC in Islamabad, clear priorities include documentation on current land-use and soil types, crop modelling to demonstrate ways to increase productivity despite climate impacts, sustainable mechanisation and improved communication of agricultural research at local level, in appropriate languages (215).

Health

Climate change affects health in Punjab in a number of ways, from reducing access to food and clean water to promoting growth of viruses and bacteria (215). However, compared with the rest of Pakistan, health reforms in Punjab since 2014 seem to be improving the province's resilience, with routine immunisation coverage currently at 84% and the number of doctors having been doubled between 2014 and 2018 (221). Malaria cases are now so low in Punjab, that it is deemed to have entered the "elimination phase", with just 658 cases in 2018 (90). In 2019 Punjab launched a new ten year health sector strategy aimed at providing international standard healthcare to patients in public sector hospitals (222).

However, there are still many climate induced health challenges in the region. Food security can be affected by climate change through insect plagues, floods and droughts and this has led to a high rate of malnourishment in Punjab, although this is no longer increasing in the province (48; 215). During the recent extreme heat events in Punjab, people have suffered, not just from heatstroke, but also from dehydration, kidney stones and impaired immune systems (50).

In the three largest cities in Punjab, Lahore, Faisalabad and Gujranwala, smog is a regular event both at the start of autumn and winter (50). Although the main causes of the smog are crop burning, increasing use of road vehicles run on poor quality fuel and smoke from brick kilns, deforestation has also added to the problem (223). Whilst the effect of climate change on air pollutants such as particulate matter is still being researched, it is clear that the black carbon in smog contributes further to the warming of the climate (224). Higher temperatures and smog increase the amount of allergens and pollen in the air, which along with pollution of water sources can lead not just to more cases of respiratory diseases like asthma, but also to liver, breast and lung cancer (50).

As is true across all of Pakistan, health problems in Punjab are not limited to physical effects, but include mental disorders, depression and anxiety (225). In Rajanpur, after a decade of floods, farmers questioned were said to be despondent and many were suffering from extreme depression (50). Due to the low budget for mental health treatment in Pakistan, it is often difficult for people to find help, which is all the more alarming as issues like post-traumatic stress can cause reduced immunity to infections as well as leading to less resilience in the future (50; 225).

Although there are many health centres in Punjab, over-population has led to inadequate provision (215). For example in both the Rahim Yar Khan and Multan districts of Punjab, there is a lack of basic health facilities for both people and animals (217). The provincial government is currently trying to improve health centres and disease control programs, but in the meantime those living in poverty, who are unaware of facilities available at a distance, tend to self-medicate, often ineffectively (217; 215). In Punjab people are buying analgesics and antipyretics inspired by advertising, according to a 2018 study, with so-called "prescription only medicines" being available without prescription in the same way as over the counter medicines (226). In order to make both the urban and rural populations of Punjab less vulnerable to the health issues associated with climate change, the draft action plan suggests creating an emergency healthcare program to cope with the expected rises in vector borne diseases such as malaria and dengue, with better co-ordinated communication to prevent epidemics spreading, improved local medical storage facilities and mobile water purification plants on standby in case of climate change disasters (215).

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Disaster preparedness

As in much of the rest of Pakistan, Punjab is hit by heatwaves, earthquakes, storms, floods and droughts (215). In Punjab there are 15 districts at risk of riverine flooding, with government figures from 2019 placing Punjab and Sindh top of the list of regions most susceptible to floods (48). In addition to this Punjab also has 13 districts at risk of moderate to severe drought (48).

The PDMA of Punjab provides a proforma District Disaster Management Plan each year to each DDMA (227). These are then completed at district level to include important details of risks based on impacts and likelihoods for potential local hazards, as well as specific DDMA structure and a list of their strategic supplies (227). Full action plans are included in these documents, but do not necessarily take into account cascading disasters. For example, the district of Bhakkar is one of the most susceptible areas of Punjab to climate hazards, suffering regularly from floods, droughts and heavy rains, so that any effort to recover from one climate disaster is negated by the arrival of the next in a cycle of increasing vulnerability (217). The plans are more reactive than pro-active, so often miss important opportunities to reduce vulnerability. In both Dera Ghazi Khan and Rahim Yar Khan housing is an issue, with guidance on how to build flood proof housing desperately required (217). The disaster management plans consider the need for early warnings, but do not deal with general information about the changing climate, a point picked up by a 2020 survey of people in South Punjab, 89% of whom were not satisfied with the way that the local governments were sharing climate change information, upon which there was very limited focus (217; 227). In a study comparing disaster preparedness levels in Sialkot in the north of the province and Muzaffargarh in the south, it was found that there was a strong relationship between certain aspects of community life and success in preparing for disasters (111). For example, the southern district with trusted leadership, gender equality in disaster planning opportunities and a general sense of belonging to a community, were better prepared than the richer more qualified northern district, despite the latter having better supplies and more preventative infrastructure (111). Most importantly, although both districts were prepared at a household level, the majority of survey respondents, were unfamiliar with the DDMA emergency plans and did not know about stakeholders external to their districts (111).

In the 2021 Draft Climate Change Action Plan for Punjab, it is recognized that more research is needed on the health implications of climate change disasters in the future, but that current priorities must include better awareness campaigns, emergency training, hazard monitoring, provision of safe evacuation areas for both people and livestock and pre-planned rescue schemes (215).

Punjab risk chart

TABLE 8: RISK GRID FOR PUNJAB BASED ON RANKING WITHIN PROVINCE

District	2: Heat (100s)	3: Poverty (% of population)	4: River flood: Built-up (hectares)	5: River flood: Agriculture (hectares)	8: Flash flood (31 year total)	9: Riverine Flood (31 year total)	10: Storm (31 year total)	11: Population density (people/km^2)
Attock	350-700	0-13	2.5-10	<5		1		275
Bahawalnagar	>700	13-26	>35	>200			1	335
Bahawalpur	>700	13-26	17-35	>200		2		148
Bhakkar	350-700	13-26	2.5-10	20-50				202
Chakwal	350-700	0-13	0.1-2.5	5-20		1		229
Chiniot	>700	13-26	2.5-10	20-50				518
Dera Ghazi Khan	>700	26-39	>35	100-200		2		241
Faisalabad	>700	0-13	17-35	100-200		1	1	1346

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Gujranwala	350-700	13-26	17-35	50-100		2	1	1384
Gujrat	>700	0-13	17-35	20-50		1		864
Hafizabad	350-700	13-26	2.5-10	5-20		1		489
Jhang	>700	13-26	17-35	>200	1	3		445
Jhelum	350-700	0-13	2.5-10	50-100		1		341
Kasur	>700	13-26	>35	>200		1	1	865
Khanewal	>700	13-26	17-35	100-200		1		671
Khushab	350-700	0-13	2.5-10	50-100	1			197
Kot Addu	>700	26-39	17-35	>200	1	1		426
Lahore	>700	0-13	17-35	20-50		4	3	6275
Layyah	350-700	26-39	2.5-10	50-100	1	1		290
Lodhran	350-700	26-39	17-35	100-200			1	612
Mandi Bahauddin	350-700	13-26	17-35	50-100		2		586
Mianwali	350-700	13-26	2.5-10	50-100	1	1		264
Multan	>700	13-26	>35	100-200		1	2	1276
Murree	>700	0-13	2.5-10	5-20	2	3	1	609
Muzaffargarh	>700	26-39	17-35	>200	1	1		525
Nankana Sahib	350-700	0-13	10-17	100-200				611
Narowal	350-700	13-26	2.5-10	50-100		3		731
Okara	>700	0-13	>35	>200		1	1	695
Pakpattan	350-700	0-13	>35	>200				670
Rahin Yar Khan	>700	13-26	10-17	100-200		1		405
Rajanpur	350-700	26-39	>35	>200	1	3	2	162
Rawalpindi	>700	0-13	2.5-10	5-20	2	2	1	1022
Sahiwal	>700	0-13	>35	50-100		1	1	785
Sargodha	>700	0-13	>35	>200		1		631
Sheikhupura	>700	0-13	17-35	100-200		1	1	924
Sialkot	>700	13-26	>35	100-200		6	1	1291
Talagang	350-700	0-13	0.1-2.5	5-20		1		180
Taunsa	>700	26-39	>35	100-200		2		245
Toba Tek Singh	>700	13-26	17-35	50-100		1	1	674
Vehari	>700	13-26	>35	100-200		1		665
Wazirabad	350-700	13-26	17-35	50-100		2	1	690

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5.4 Sindh

The province of Sindh is home to just under 48 million people, with almost half of those living in urban areas (17). The economy of the province contributes a third of Pakistan's GDP, 20% of which is derived from the agricultural sector (228). Climate change is already causing shorter winters and longer summers, as well as intensifying monsoon rains, lengthening heatwaves and droughts and increasing coastal intrusion (17). The cabinet of the Sindh Provincial Government has approved this province's adaptation policy, but implementation has not started as yet (MA). Along with Balochistan, Sindh suffers from very high multidimensional poverty, particularly in rural areas increasing the vulnerability of the population to climate change (48).

The most highly populous area of the province, providing homes to 23 million people, is the mega-city of Karachi, which is made of 5 city district municipal corporations (229). It is the financial capital of Pakistan, housing the headquarters of both the stock exchange and many banks and financial institutions (230). The Karachi Development Authority oversees all city planning, with the result that this is done on a provincial rather than local level (231). The city has two seaports and an airport, making it the centre of Pakistan's export industry (230). However, it is a city of contrasts with investment going on encouraging more international links, rather than focusing on alleviating poverty in the city's 600 slum areas (232). This is further widening the gap between socio-economic groups. As a coastal city, Karachi is particularly vulnerable to climate change and projections show that increasing sea levels, cyclones, tropical storms and intense rainfall all pose flooding risks to the city (17). Given the urban heat island effect, in which the dense concentrations of pavements and buildings in a city absorb and retain heat and thus make the city hotter than the surrounding non-urban areas, residents are also particularly at risk during periods of intense heat such as happened in 2015 (50; 20).

Water resources

Water scarcity is a real problem for Sindh, lying as it does at the south of Pakistan, downstream from Punjab (228). The River Indus flows through the middle of the province, flooding the land during strong monsoon seasons, whereas in weak monsoon years upstream areas often use the water before it reaches Sindh, leading to poor crop yields (30). This province has 5 million hectares of irrigated agriculture and has the second largest allocation of irrigation water in Pakistan, just behind Punjab (233). Despite this, water resources are limited, not least by the fact that 65% of irrigation water is lost due to the inefficiency of the canal system (228). In the future more droughts are projected for the region, with floods materializing only when upstream areas receive more intense precipitation, leading to floods on the downstream plains of Sindh (17). Outside of the IBIS water is extremely scarce, so people in Sindh rely almost completely on their system of three barrages and 14 canals fed by the River Indus (233; 228). The PCRWR is helping provincial adaptation by using water metering technology to work out crop water requirements to allow farmers to use this valuable resource more efficiently (61). However, the practice of groundwater extraction via tube wells is increasing, with insufficient recharge leading to saline intrusion in coastal aquifers and a lowering of the water table (17; 228). At the moment Sindh uses 16% of Pakistan's extracted groundwater (228).

Sindh's growing population and the effects of climate change are the two main reasons for the accelerating water demand in the province (228). Over the next three decades, water use in the region is projected to rise by between 16 and 25%, depending on whether temperatures rise by 1 or 3^{o}C (228). This is split between the domestic, agricultural and industrial sectors. However, environmental water is also needed, as if there is not enough escapage at the Indus Delta, with a continuous flow at the Kotri barrage, then the sea will intrude further upstream, threatening the finely balanced ecosystem of the mangroves and resulting in further hardship for the fishing community (228).

Sindh's Tharparkar region was classified as a drought calamity area in 2015 with Dadu, Sukkur, Achhro Thar, Nara Kohistan, Kachh and the coastal belt all suffering from droughts (17). With higher levels of evapotranspiration due to the increasing temperatures in the region and damming upstream, Sindh has not been able to meet irrigation water demands (17). Given projections for a 0.5 to 2 degree increase in temperature in the future, an 8-10% decrease in crop productivity by 2040 is expected if better water storage is not prioritised (17). However, if the water course efficiency is improved, there could be a 9% improvement in agricultural GDP even in the face of climate change (228). There are currently 1247 water supply schemes across Sindh, but only 529 of these are functional, giving an average daily water supply duration of 5 hours (97).

Domestic water is a particular problem in the region, with 33% of households still hand pumping their water, a figure which grows to 63% in rural areas (228). In a 2015 survey, households were found to be willing to pay up to three times more in water tariffs, just to receive good quality piped water (234). Money raised in this way could be used to ensure proper maintenance of the water delivery infrastructure (228). In the city of Karachi, which is home to 29% of the residents of Sindh, water is particularly scarce with at best availability for 4 hours a day and at worst

> "Running water is now an anomaly for many of us and the only way to access water is through buying it from the tanker mafia."
>
> Faisal Riaz, office worker in Orangi Town, Karachi (304).

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access reduced to 2 hours every other day (48; 68). 93% of the water piped to residences in Karachi is unsafe, due to the proximity of damaged pipes carrying sewage to those supplying drinking water (234). Local mafia groups offer water at exorbitant rates in the city, adding to the tensions caused by resource limitiations (48). In autumn of 2022, some areas of Karachi were without piped water for between 15 and 30 days, with the system pressure so low that the water was not reaching many areas (235). Further investigation showed that the land mafia had taken control of pumping stations in some areas, which explained how the water tankers selling water were still able to function (68). Key priorities for the provincial government must now include creating a new distribution flow for water resources, so that both supply and drainage can be improved and the 40% of water that is currently being stolen is safeguarded (97; 68; 235).

By June 2023 the feasibility study for a barrage on the Indus River at Thatta, 45km upstream from the Arabian Sea, should have been completed (236; 50). This scheme aims to provide clean drinking water to Sindh, particularly to Karachi and Thar by means of a 2.5-4 billion cubic metre reservoir of stored water, with the knock-on effect of reclaiming 80000 acres of land (236). In the meantime, projects to encourage more efficient water use and in particular water harvesting, could help to remove some of the strain from the system (228). Tariffs for water in Karachi are currently based on building size, rather than water being metered, so there is no incentive for people to use water sparingly when it is available (234). This shows that any improvements in water supply must be complemented by changes in lifestyle of local communities, which could be instigated by education about water availability, sanitation and pollution (97).

Agriculture

The economy of the province is based on agriculture and grazing, making Sindh particularly vulnerable to climate events (17; 237). Altered precipitation patterns and changes to river flow volumes, causing both droughts and floods in Sindh, are not just affecting short term crop yields, but are resulting in long term degradation of both rangeland and cultivated land, due to erosion, waterlogging and salinity (17). For example, in the 2022 floods, Sindh lost large proportions of its cotton, chilli, onion and rice harvests (48). As those in poverty are reliant on the natural environment for their livelihoods, changes in temperature and precipitation, causing a decrease in agricultural productivity, have a direct impact on household income (17; 237). Before increases to temperature, Sindh was well placed to grow early crops of mangoes and tomatoes, thus benefitting from early season prices, but more variability in climate has made this practice too risky (237). Temperature changes are also making wheat grains mature too early leading to smaller grains at harvest, whilst the early pollination of banana crops is increasing their vulnerability to heat stress, leading to poor quality fruit (17). The Government of Sindh has actually had to ban rice growing in some parts of the province due to the massive water intensity of production, which is not only exhausting a limited resource, but also leads to water logging and land degradation (237).

FIGURE 38: CULTIVATION OF RICE IN FLOODED FIELD. (IMAGE: BILAL PHOTOS)

Although Sindh has 6.8 million hectares of agricultural land, 1.6 million of these cannot be cultivated due to a lack of water (228). However, research shows that if water resources used by the agricultural sector, currently 95% of all water available to Sindh, were applied more effectively and farming techniques were improved by the use of adaptive technologies, then agricultural GDP in the province could actually grow by as much as 26% (228). Crop cycles have been shortened by the changes to the climate, reducing productivity, but by sowing crops early and intercropping there could be increased productivity of 9% for cotton and 12% for rice (17; 237). Rice harvests, in areas where the crop will not cause damage to the land, could increase by 3%, by moving to more heat resistant strains (237). Equally spreading inorganic and organic matter on the soil, known as “mulching” could reduce erosion, retain moisture and improve filtration in cultivated land (237). Ideas such as these could be disseminated by agricultural extension centres across the province, supplying advice tailored to local needs (237).

High poverty levels in Sindh often lead to unsustainable use of resources, like burning of trees for fuel, so if the province wishes to reduce its vulnerability to climate change, it is imperative that improving the living standards of all people, particularly those in the south and southeast, is a priority (17). If the government supply resources for disaster relief and rehabilitation, then a d**o**wnward spiral of vulnerability could be avoided (237).

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FIGURE 39: FISHING BOAT PARKED AT REHRI GOTH, KARACHI (IMAGE: AMEER_GREAT)

Fishing has been affected by higher winds, stronger water currents, more intense rainfall and temperature changes, with degradation of the mangrove forests exacerbating the problems by decreasing available fish and shrimp stocks (17). In the Badin District of Sindh, 65% of the population depend on catching and drying fish (53). With increasing temperatures the Indus Delta has become drier and saltier, which along with the cutting down of the mangroves, has led to fish species decreasing, meaning that the men are now having to go deep sea fishing (53; 237). This leaves the women needing to travel long distances for freshwater, as saltwater intrusion up to 85 km up freshwater channels has destroyed local drinking water sources (53). Aquatic life upstream has also suffered, unable to cope with the increasingly brackish water (237). Previously fishermen had supplemented their income by keeping livestock, but waterlogging of more than half a million hectares of farmland, has removed this option, as well as reducing available planting areas for food crops (53). For many the environmental changes have removed livelihoods, necessitating migration to urban areas (237).

Health

Climate induced disasters have been shown to have wide ranging and varied health impacts in the province of Sindh, where both extremes of drought and flooding are frequently experienced. The hot and humid weather in Sindh worsens effects of heatwaves, leading to heatstroke, increased vector borne diseases and reduces access to clean drinking water (17). When there are floods, direct contact with the water, which comprises both sewage and rainwater, increases cases of malaria, dengue, Hepatitits A, leptospirosis, typhoid, cholera and diarrhea (238).

Like Punjab and Balochistan, Sindh's main health issue is malnourishment, predominantly in urban areas, although rates are starting to drop (48). Moderate to severe under-nutrition has been recorded in 42% of the province's children and 62% of pregnant women (17). Food insecurity is at 33% in Sindh and is most notable in rural areas, which also see the most significant stunting and wasting in children (48). According to figures from 2021 over 45% of children in Sindh suffer from stunting, over 23% from wasting and 73% from childhood anaemia (48; 17). It has been shown that stunting makes children more vulnerable to infectious diseases as it compromises the immune function (50).

Waterborne diseases are rife across the province, with typhoid, diarrhea and cholera cases all rising (97). Only 20% of Sindh's population having access to clean drinking water, as 78% of piped water is contaminated with pathogens, chemicals and other toxic materials (97). In Karachi, urban flooding has led to cholera outbreaks; most recently 234 cases were confirmed between January and May, 2022 (238). This is exacerbated by the fact that 42% of Karachi residents have no access to proper toilets and appropriate sanitation (97). In coastal areas 30-35% of people are suffering from viral hepatitis (97). Education about floods is also needed if cases of waterborne diseases are to be limited, as currently many families are unaware of the dangers of eating food that has come into contact with floodwater (238).

Sindh has the highest provincial rates of both malaria and Chikungunya virus and since the 2022 floods, malaria cases in the province have exhibited an almost 250% increase between August 2022 and the previous year (90; 239). In 2018, 2088 cases of dengue fever were recorded in Sindh, with the highest dengue transmission region situated along Its border with Balochistan (90; 97). The 2022 floods have made the people of Sindh still more vulnerable to vector borne diseases, with 7452 dengue cases registered in September, 2022 (240). This is in some part due to flood hit families being housed in flimsy shelters with little protection against mosquitoes (241). Although international aid agencies are now mobilizing testing kits, mosquito nets and antimalarial medicines to Sindh, the provincial government needs to be ready for future occurrences, with improved emergency healthcare planning (239; 240).

Increasing temperatures and high humidity, in an area where 50°C mid-summer maximum temperatures were already a regular occurrence, has led to unbearable levels of heat intensity (228). In built up areas, particularly the city of Karachi, intense heat is amplified by the urban heat island effect, which has resulted in severe health issues, such as in 2015 when more than 65000 people were hospitalized due to heatstroke, 1200 of them later dying (50; 20). However, this severe heatwave did result in the city creating a heatwave plan to alert people of impending high temperatures (242). This also includes provision for "cooling centres", such as mosques and public buildings to be opened to ensure access to daytime shade and temporary night shelters with a prioritized supply of electricity and water for those without reliable access to these resources (243). Such measures are yet to be rolled out to other vulnerable areas of the province, but reports of impending high temperatures and lists of

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preventative actions that can be taken by individuals are now publicised by the Pakistan Meteorological Department (PMD) via the press (244). In 2022 in Jacobabad, temperatures reached 51°C, with a 51 day run of temperatures over 38 °C bringing heatstroke and severe dehydration (242). Extremely hot weather can also cause kidney stones (50). Although basic preventative measures, like staying indoors and using air conditioning can go some way to combatting this extreme heat, this is not always possible in a region where electricity is unreliable and people need to be outside working in order to earn enough to eat (242). Healthcare infrastructure across Sindh is not prepared to cope with prolonged heatwaves (242).

Mental health is an area not often considered in Pakistan, but in Tharparkar, which has been heavily hit by droughts this millenium, the suicide rate has increased by 75% and 31% of respondents to a 2020 survey said they were suffering from extreme depression (50). This is particularly worrying in a country where mental health treatment is practically non-existent and reduced immunity due to stress could prove fatal (50).

Measures proposed for better future adaptation as the climate continues to warm include a more even sharing of healthcare resources between urban and rural areas, improved access to food and clean water and widespread health insurance (17). There is also a huge need to educate people about health and hygiene in the province and to provide basic hygiene kits in the case of floods, particularly for those with children under 5 who are at increased risk from dehydration caused by diarrhea (238). An assessment of current healthcare facilities is urgently needed, but this should not be prioritised ahead of pro-active policies, such as a drive for early diagnosis and treatment of conditions, hospital-based crisis management teams and more training for hospital staff (17; 238). A lack of disease prevention measures in Sindh has already resulted in a sharp rise in serious cases (238).

Disaster preparedness

Sindh is one of the two provinces most prone to flooding, with eight districts at risk from riverine flooding (48). The Indus River changes course every quarter century, so the extent of any flooding is dependent on its position at the time of heavy rains (17). The five types of flood which affect Sindh are monsoon floods, flash floods, river breeches, urban floods and coastal floods (17; 245). Five districts of Sindh are at risk from the last of these, which involves hurricanes and cyclones producing heavy rains and driving ocean water onto the land (17; 48). If tropical cyclones wipe out the coastal infrastructure of Sindh, there would be severe repercussions for the whole of Pakistan, as the country's export industry depends on Sindh's ports (17).

> "Sindh's overall needs assessment for post-flood recovery and reconstruction stands at $7.9 billion, which is highest of all provinces."
>
> The World Bank, from a factsheet assessing the 2022 floods (306).

Drought from moderate to severe level threatens 12 of Sindh's districts (48). The provincial government has recognized the need for better drought monitoring in the future, so that early warnings can be communicated to the population (17). Although predicting drought is very difficult, using data from droughts over the last half century, academics from the National Drought Monitoring Centre have developed a drought hazard map of Sindh based on climatological datasets of rainfall and soil moisture (246). Dissemination of important information during any such event would be via the PDMA's Provincial Emergency Operation Centre or for more localized threats by the relevant DDMAs (245).

Karachi, Sindh's megacity, is at risk from urban flooding, sea level rise and increasing salinity (48). Urban areas have insufficient drainage to absorb heavy rainfall, so floods result, submerging 80% of the city's commercial areas (247). In the future, it is hoped that better urban planning will reduce this risk, but the city's huge area of 600 crowded slums will also need to be considered (17; 238). In some flooded areas of the city in 2022, even the ambulance services could not provide help to the residents (247). Already the city services and resources are being overwhelmed by large numbers of migrants, but with the Indus River Delta now almost at sea level, there is also the problem of increasing salinity in streams further inland, reducing freshwater supplies (48). The removal of the coastal mangrove forests has led to the Arabian Sea submerging parts of the city, with others destined to follow, an effect likely to be accelerated by the increased numbers of tsunamis and cyclones projected for the future (48; 17). The district of Badin has also been badly affected by coastal intrusion, with water resources, land and livelihoods, all having been destroyed or degraded (53). In view of this the provincial government is planning to construct and strengthen coastal defences to reduce the impact of sea intrusion (17). In Badin a project to construct a protective embankment has already been undertaken through co-operation between the local community and Oxfam, but this did not prevent severe flooding in the 2022 disaster, in which Badin was the country's worst affected area (53; 248).

The rescue events needed due to the 2010-11 floods, were considered as "poorly prepared and planned" (17). Despite private sector involvement, the unco-ordinated efforts of those involved led to a "lack of effective action" (17). To combat these deficiencies Sindh's provincial climate change action plan includes the creation of multipurpose, climate resilient centres to be used as shelters and storage points for essential supplies, proper evacuation plans, with priority for children, the elderly, women and those with disabilities and better urban planning to provide disaster safe buildings (17). However, it will need massive investment to give everyone an equal chance of adapting to climate change as currently poverty levels in Sindh

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exacerbate vulnerability, with the poor living in mud houses in low lying areas, whilst the rich have brick built dwellings on higher land (48).

Research into climate hazards in Sindh was until recently quite limited, but the provincial government recognized in their 2022 action plan that in a province with such varied terrain it is vital that localised studies of projected climate change impacts are undertaken, so that along with detailed socio-economic data at district level, climate induced risk maps can be created and policies made based on these (17). In 2015 Islamic Relief prepared a roadmap for disaster risk reduction in Sindh to help communities move away from institutionally provided reactive disaster aid to pro-active local initiatives (249). This has been followed by more in-depth information on the Sindh PDMA website detailing district and provincial level risks as well as new "Informed Disaster Management Plan 2023-2032" documents, produced based on multi-hazard vulnerability risk assessment informed by the provincial disaster management plan (245; 250). Created by the PDMA and the Space and Upper Atmosphere Research Commission (SUPARCO) and funded by the provincial government and WB, these new documents include detailed risk analysis based on weather data, responsibilities of DDMAs and even more localized groups such as the Union Council Disaster Committees and priority disaster risk management projects (250).

Sindh risk chart

TABLE 9: RISK GRID FOR SINDH BASED ON RANKING WITHIN PROVINCE

District	1: Drought (1000s)	2: Heat (100s)	3: Poverty (% of population)	4: River flood: Built-up (hectares)	5: River flood: Agriculture (hectares)	7: Landslide (31-year total)	8: Flash flood (31-year total)	9: Riverine Flood (31-year total)	10: Storm (31-year total)	11: Population density (people/km^2)
Badin	200-700	350-700	39-52	2.5-10	50-100			2	1	268
Dadu	200-700	350-700	26-39	2.5-10	100-200		1	6		81
Ghotki		350-700	26-39	17-35	100-200			4		270
Hyderabad		350-700	0-13	>35	20-50	1		3	2	398
Jacobabad		200-350	26-39	17-35	100-200			4		191
Jamshoro	200-700	200-350	26-39	2.5-10	20-50					88
Karachi		>700	0-13	0.1-2.5	<5	1	2	8	2	2795
Kashmore		200-350	13-26	>35	100-200					420
Khaipur		350-700	26-39	2.5-10	50-100			3		151

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Larkana		350-700	13-26	10-17	50-100			4		205
Matiari		200-350	26-39	>35	50-100					543
Mirpur Khas		350-700	26-39	10-17	50-100			2		515
Naushamro Feroze		350-700	26-39	2.5-10	20-50			2		548
Qambar Shahdadkot	100-200	350-700	13-26	2.5-10	100-200					244
Sanghar	50-100	350-700	26-39	>35	>200			1		192
Shaheed Benazirabad		350-700	39-52	2.5-10	50-100			3		358
Shikarpur		350-700	26-39	10-17	100-200			4		490
Sujawal		200-350	39-52	0.1-2.5	50-100					89
Sukkur		350-700	13-26	10-17	100-200	1		3		592
Tando Allahyar		200-350	26-39	2.5-10	20-50					162
Tando Muhammad Khan		50-200	39-52	0.1-2.5	20-50					293
Tharparkar	>1600	350-700	52-65	2.5-10	5-20			2	1	84
Thatta	<50	200-350	26-39	2.5-10	20-50			3	2	56
Umer Kot	100-200	200-350	39-52	0.1-2.5	20-50			1	1	191

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SECTION 6: STORYLINES AND INFOGRAPHICS

Based on all of the quantitative and qualitative data given in the last five sections, we can start to form storylines. As the climate projections given in Section 4 are from the mean of an ensemble of model data, they do not incorporate the full range of uncertainty that should be used when this process is repeated using downscaled data from RCMs. The finer tuned approach will allow data points within provinces to be considered, whereas here the narratives are based on much less focused information.

Climate change projections are scenario based and depend on a range of different climate models, so it is important to acknowledge that they do include uncertainties (24). Just as storylines present plausible descriptions of future scenarios that allow policy makers to make decisions despite the inherent uncertainty in climate change projections, so infographics provide a way to communicate these key issues to all stakeholders so that bottom-up adaptation action can be taken. The next layer of research would involve localized risk assessment based on a synergy of meteorological and socio-economic data to create a range of causal networks, showing what actions would reduce vulnerability and increase resilience.

6.1: Balochistan summary storyline

- Monsoon shift to later.
- Heavy rains in March.
- Less rain in November.
- Longer dry spells in spring.
- More dangerously hot days.

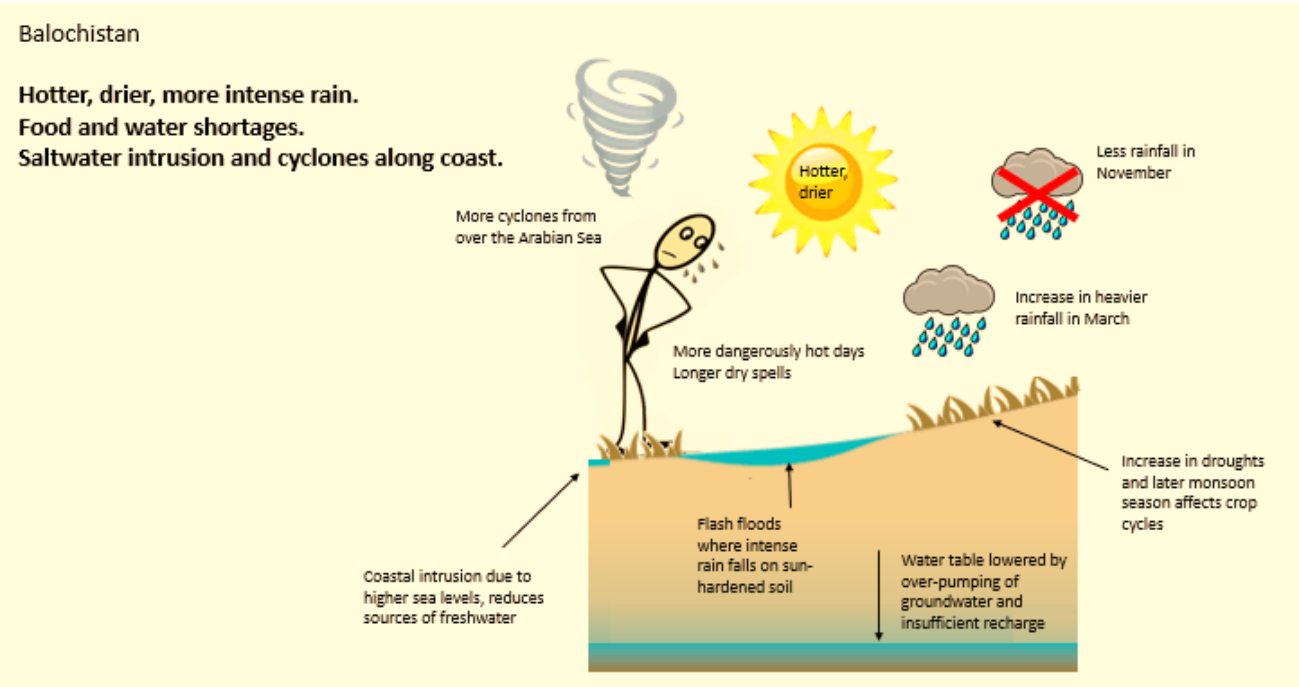

FIGURE 40: INFOGRAPHIC SHOWING POSSIBLE FUTURE SCENARIO FOR BALOCHISTAN

Matching these points up with the historical list of climate hazards encountered in Balochistan, this is likely to increase the risk of heatwaves leading to droughts. It could also cause food and water shortages without adequate forward planning. Equally flash floods due to sun hardened soil and lack of proper irrigation infrastructure could occur in the late spring and summer.

The correct crops should be planted to exploit the extra heat, but planting cycles need to be carefully considered to ensure that the likelihood of sudden heavy rains are taken into account. Livestock needs will also require forward planning to ensure water and fodder are available.

The number of cyclones over the Arabian Sea is projected to increase, so storm defences on the coast will need to be strengthened to cope with sudden heavy rainfall and strong winds, as well as higher sea levels leading to coastal intrusion. Mangrove restoration and proliferation could help to reduce vulnerability.

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The short term socio-economic implications would be a need for support from extension services to assist farmers adapt their farming strategies such as:

- introducing mixed cropping to provide a fall back if one crop fails;
- increasing ground cover to protect the soil
- focusing on wheat and maize varieties that can withstand higher temperatures
- adopting production of fast maturing vegetables

Climate related tolerances of these crops should be examined to establish sustainability of adaptation approaches under different climate futures.

Ways in which outdoor workers in the construction and agricultural sectors can be protected from increased temperatures should be explored including education, changes to working hours and labour regulation.

Investment in mangrove restoration and proliferation is necessary. Possibilities for value addition in the seafood sector generating local employment would also be useful. The potential 'lifespan' of these investments under different climate futures must, however, be considered.

6.2: Khyber Pakhtunkhwa summary storyline

- Warmer winters with many fewer ice days.
- More rain in winter and spring.
- Greater intensity of rain in the spring.
- Less intense rainfall in summer.
- Possibly more or less intense rain in the winter.

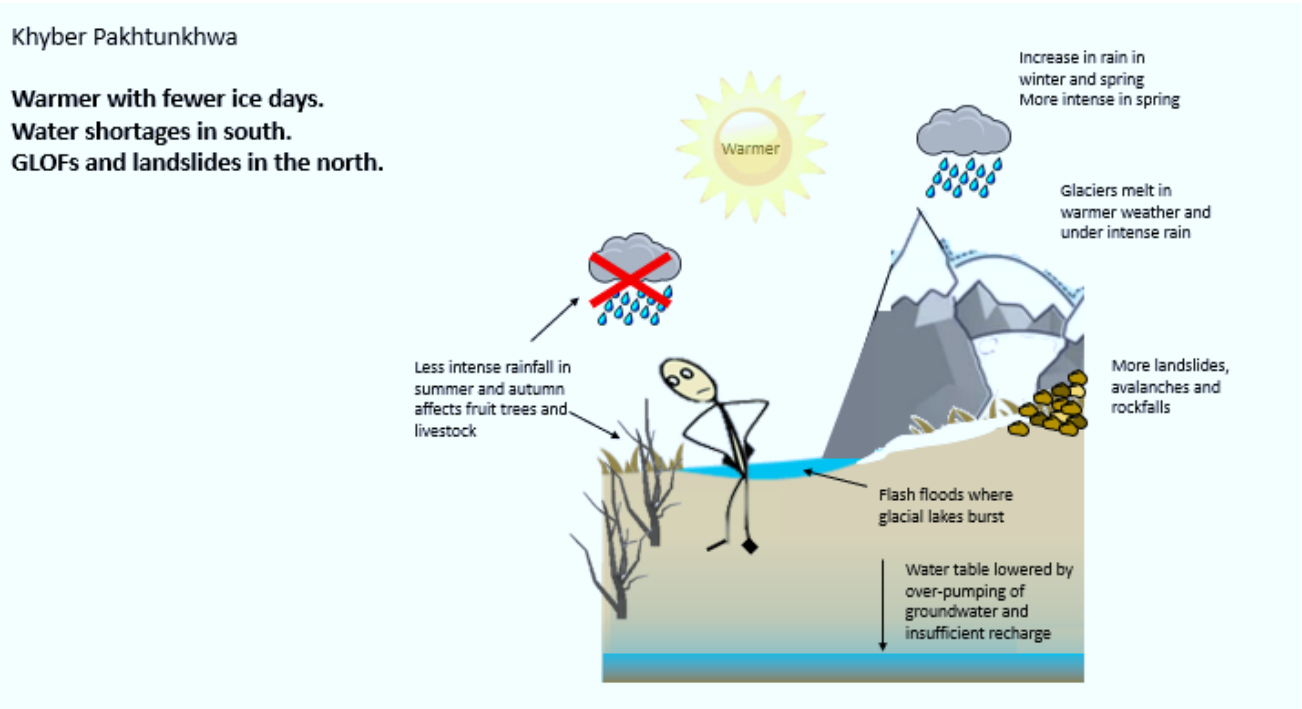

FIGURE 41: INFOGRAPHIC SHOWING POSSIBLE FUTURE SCENARIO FOR KHYBER PAKHTUNKHWA

Fewer ice days and generally increased temperatures are likely to lead to accelerated glacial melt. This will bring with it the threat of GLOFs. With careful district led water monitoring schemes in place, lake water depth can be lowered artificially to prevent these events (43).

More intense rain is likely to lead to more landslides. To reduce vulnerability to such events it will be important to look at land-use across the province. Maintenance of slope vegetation and reforestation could reduce risks greatly.

Reductions in summer rainfall will need to be planned for, especially in terms of orchard areas and livestock rearing. Education and communication about the climate changes that are projected and possible methods of adaptation should be disseminated directly to local communities.

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There is a need to explore capacity for adapting farming practices particularly among poorer tenant farmers. Appropriate support and inputs are required where production is falling, for example in fruits and cereals in some areas. Based on future climate projections, scope to introduce alternative crops should be explored as conditions become warmer with less intense rainfall in summer. Out migration of the poor, landless population is likely to increase, putting pressure on urban areas if provision is not made to support adaptation.

6.3: Punjab summary storyline

- Cooler, wetter summer.
- Shorter dry spells, but more intense heat days in the spring and autumn.
- More intense rain in spring with an earlier start to the monsoon.

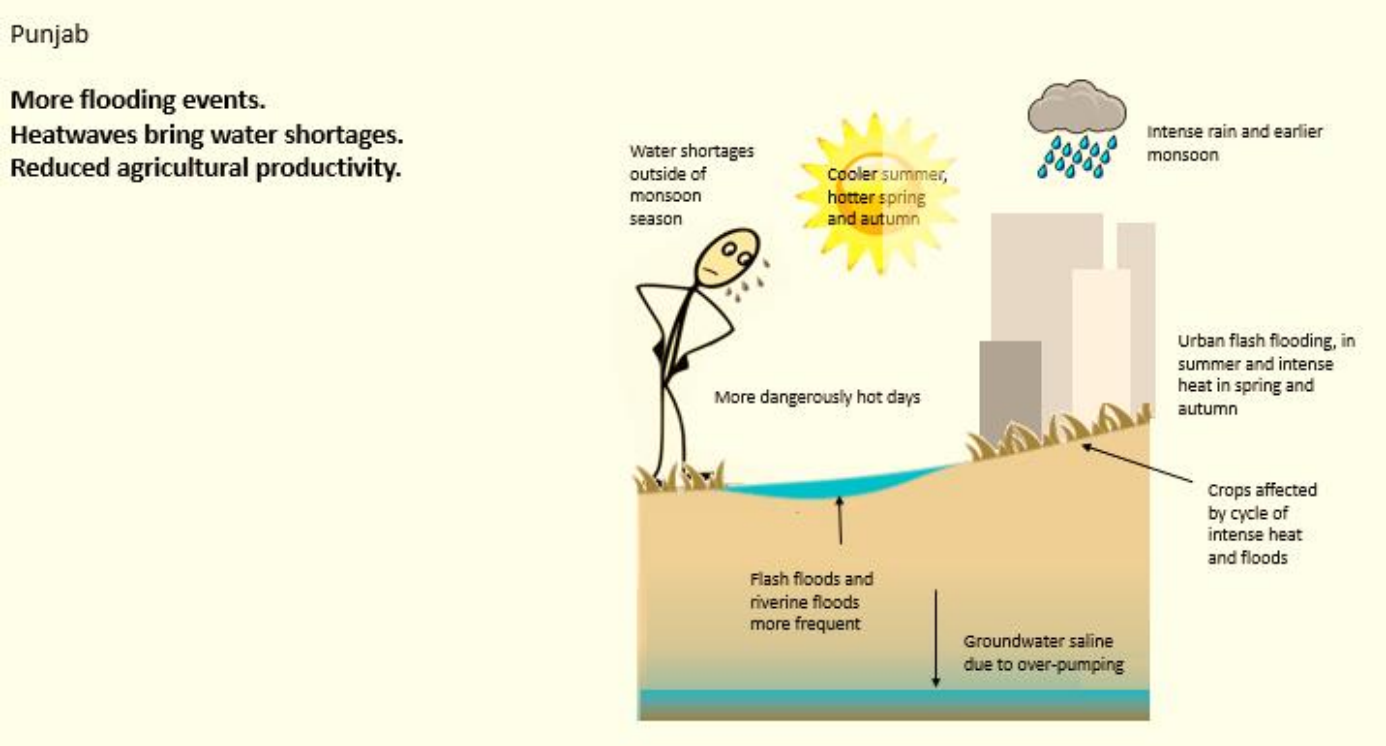

FIGURE 42: INFOGRAPHIC SHOWING POSSIBLE FUTURE SCENARIO FOR PUNJAB

Punjab is likely to encounter more flooding events in the future, with increases of instances of both riverine flooding and flash flooding, particularly in strong La Niña years. Irrigation systems will need improving and regulating better to ensure that water is fairly distributed across Pakistan.

Given a greater chance of more intense rain in spring, drainage in urban areas must be carefully monitored and improved. Water harvesting to cope at times with intense heat will need to be a priority. Public information about the best ways to stay cool in a heatwave is needed, to avoid inefficient use of air conditioning that could lead to power outages.

Punjab produces 74% of Pakistan's food crops (mainly wheat, rice, maize) and is a major source of revenue from cash crops (sugarcane and cotton). Investment in new cereal varieties that are adapted to cooler, wetter summers with more intense heat days and potential flash flooding is critical. Similarly, work is needed to establish whether cotton and sugar cane production will remain viable under defined future climate projections. The possibility of alternative cash crops must also be explored, should these reach the climatic limits of profitable exploitation.

Investment in flood early warning systems and local flood protection infrastructure would reduce the economic impact of extreme climate events. Future climate projections should inform decisions on the specification for these flood defences, in both rural and urban areas. This would be best implemented using a Dynamic Adaptive Policy Pathway (DAPP), so that short-term actions could be planned with trigger points identified showing when a different action would need to start. This form of adaptation has already been used to great effect in the long-term management of the Rhine Delta in the Netherlands, as it takes into account uncertainties arising from social, political, technological, economic and climate changes (251).

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6.4: Sindh summary storyline

- Shorter dry spells, but more days of dangerously high heat index.
- More intense rain from July to September.
- Also a possible shift to June to August rains, depending on SSP and time window.
- Less intense rain by end of September.

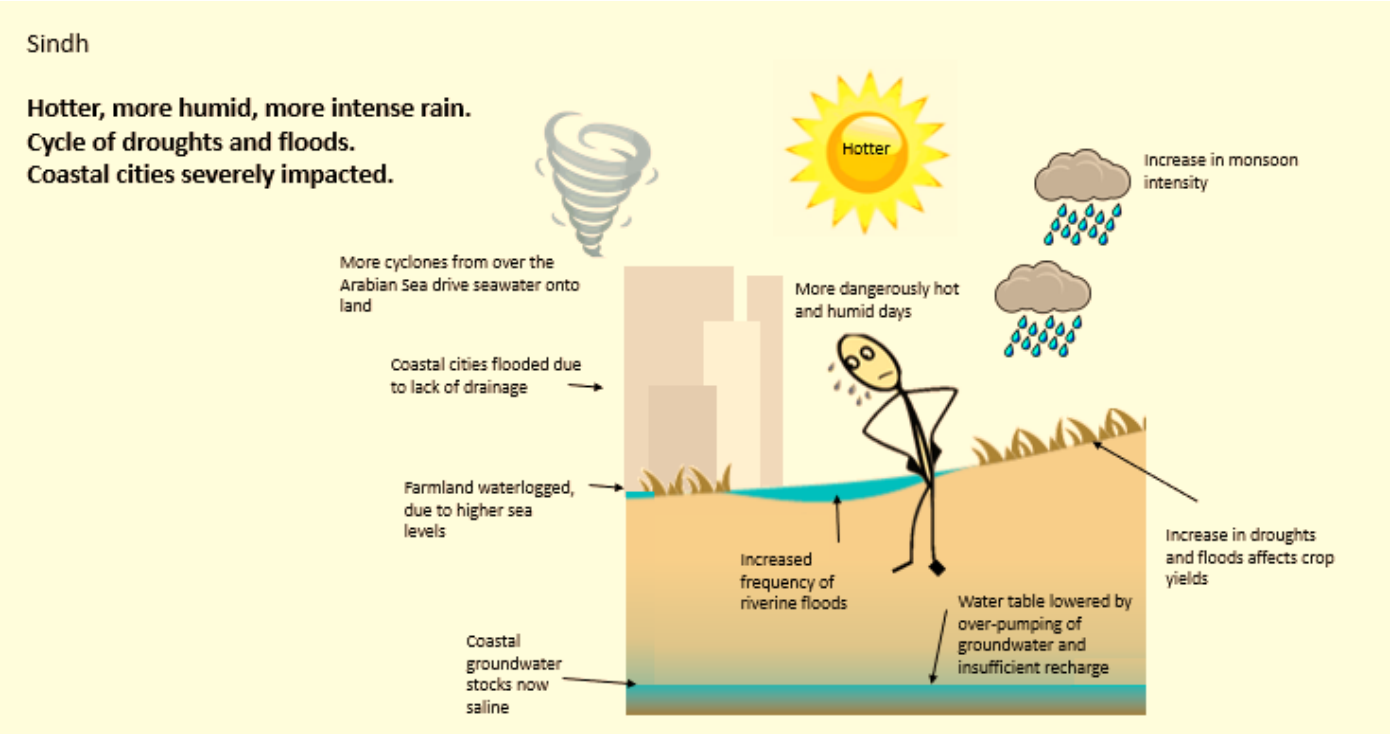

FIGURE 43: INFOGRAPHIC SHOWING POSSIBLE FUTURE SCENARIO FOR SINDH

Like Balochistan, Sindh must be prepared for both climate hazards associated with more intense rainfall and dangerous heat. Irrigation methods should be made as efficient as possible to reduce the risk of both a lack of enough water in the drier, hotter periods of the year and avoidable inundations during the monsoon season. The increased frequency of drought and floods on such a major crop producing region, where rice, cotton, wheat and sugar cane are all particularly important, will need to be addressed by way of a comprehensive set of measures to include both flood protection and proliferation of drought resistant crops. Irrigation systems upgrades are vital for the higher value crops such as tomatoes and chillies. Such investment in water management will result in better resilience and lead to a better living standard in the future. Equally farmers with livestock need to have their livelihoods safeguarded as temperatures rise. Measures as simple as distribution of fodder during drought conditions and more provision of shelter to protect animals from heat stress will pay dividends in maintained productivity.

Education is needed at district level, to help farmers to adjust to changes in the monsoon season and to plant the most appropriate crops. Poverty reduction via properly regulated loans and grants would reduce the vulnerability of the poorest agricultural workers. This would also reduce the rate of migration to cities, particularly Karachi, which will become more vulnerable to floods, cyclones and sea water intrusion as sea levels rise. With coastal storms becoming more severe, early warning systems to protect the fishing community should be improved. Continuing to redevelop the mangroves in the coastal region will reduce coastal climate induced hazards, but man-made defences will still need to be strengthened. Climate friendly urban development is also essential if urban drainage issues are to be reduced.

With rates of malnutrition very high in Pakistan, improving access to food could reduce the vulnerability of the population, so that the increased death toll associated with the aftermath of climate events, rather than the hazard itself, can be reduced. Equally more education and resources are needed to improve sanitation and hygiene. Diseases associated with overcrowding and poor sanitation, have a higher mortality rate than drowning and other direct causes of death due to climate disasters (92; 95; 96).

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SECTION 7: ADAPTATION EMPHASIS TO LIMIT VULNERABILITY

This section summarises the most important issues highlighted in the stakeholder survey and in current literature that must be addressed to ensure adequate climate change adaptation in Pakistan.

The diagrams are based on the Enabling Framework for Action, to empower users to see quickly where important information, resources, funding, research, regulation and communication may be missing. In this instance the diagrams have been produced to summarise all concerns raised up to national level. However, the same technique can be used at provincial and local level to provide the required focus for the relevant policy makers. By using this framework, it is instantly clear where increased investment and more research will have the greatest effect.

In Figure 45 the diagram structure is shown. This is then repeated for the four sectors examined in Section 5: Water Resources, Agriculture, Health and Disaster Preparedness, along with a more general look at Climate Change Preparedness.

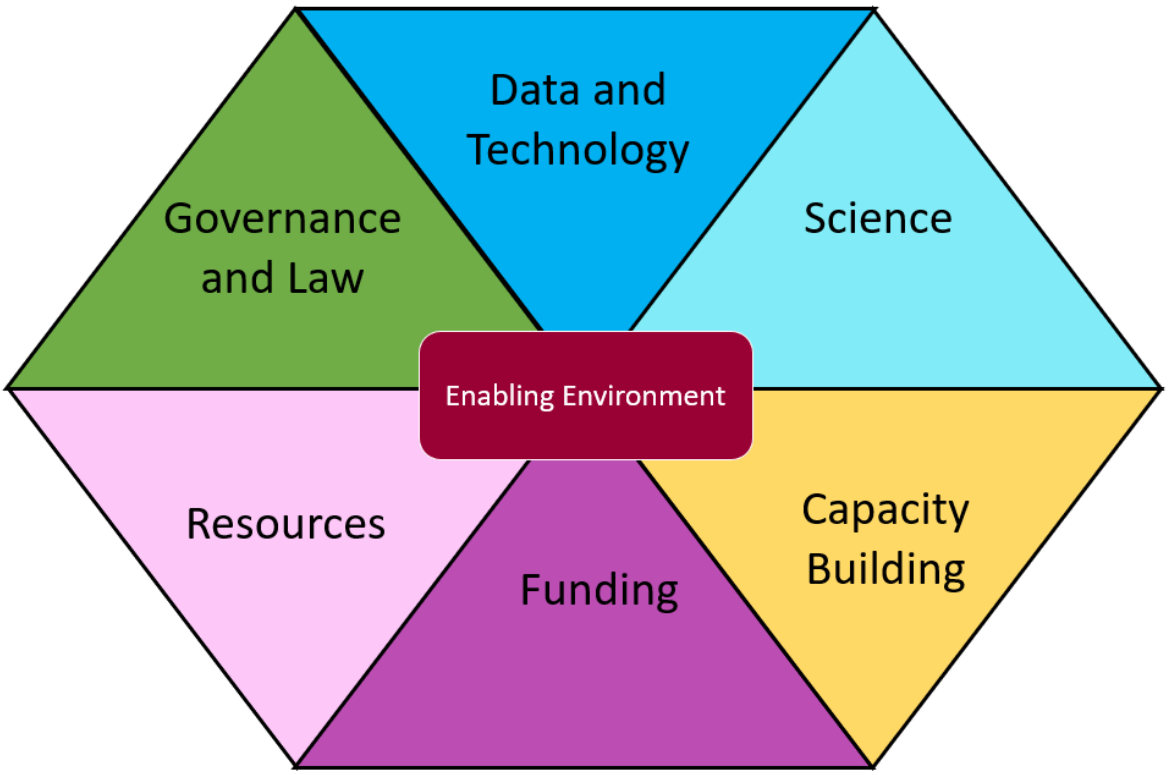

FIGURE 44: THE ENABLING ENVIRONMENT DIAGRAM STRUCTURE

There is some overlap between the diagrams, as clearly some changes may have a positive effect on more than one sector. It is also true that some of the suggestions for research are already underway in particular establishments. By highlighting the necessity of such studies here, it is hoped that other regions will be able to collaborate or add to this research and that it will continue to be updated. One key point about all of these suggestions is that they will need to evolve as more becomes known about how the climate is changing. Long-term planning is vital, but within this it is important to understand that it must include different adaptation paths, to be switched to once particular trigger points are reached (251).

In Section 8 all findings based on these areas and the rest of the research will be reviewed.

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Climate Change Preparedness

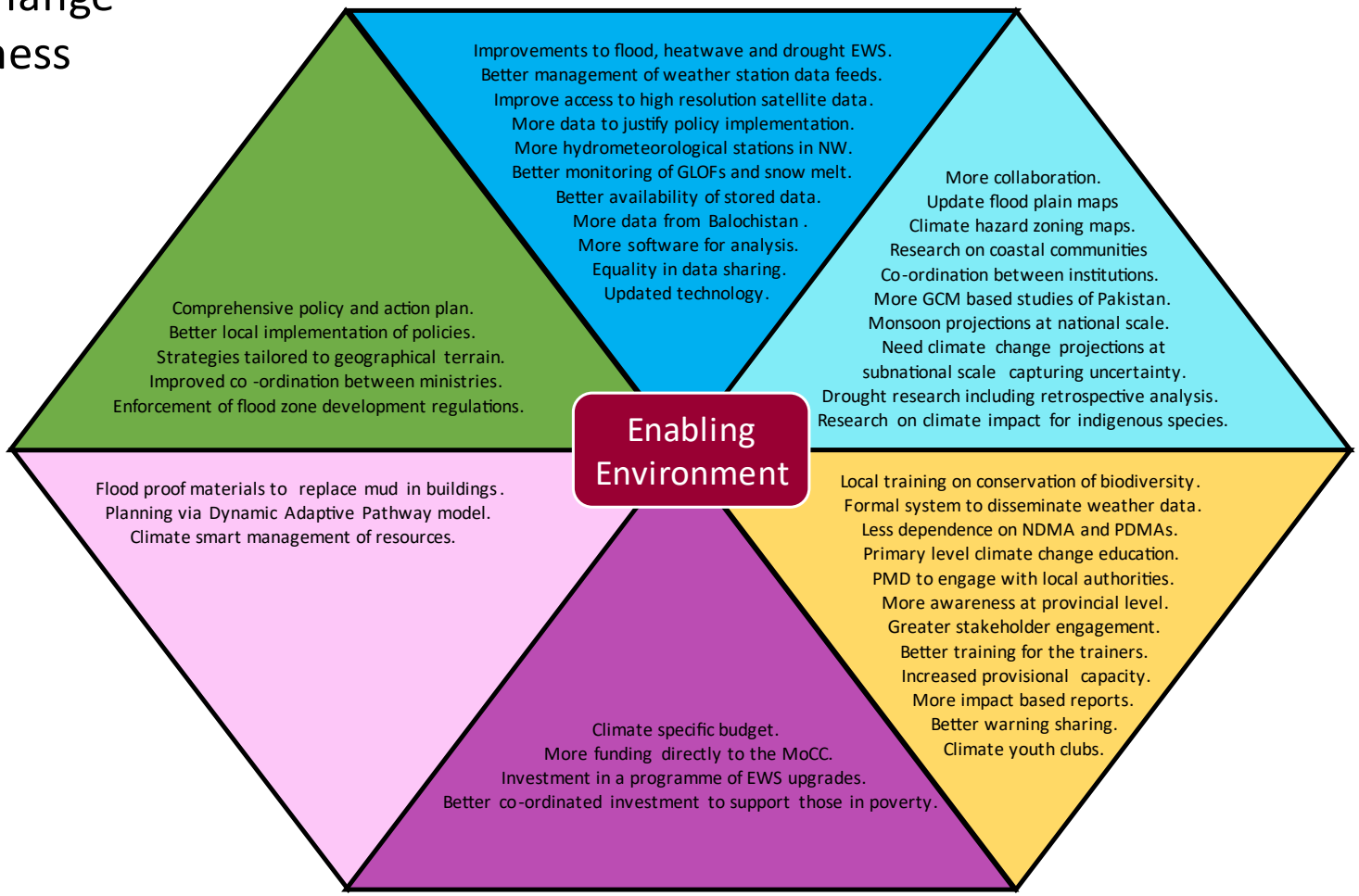

FIGURE 45: ENABLING ENVIRONMENT FOR CLIMATE CHANGE PREPAREDNESS

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Water Resources

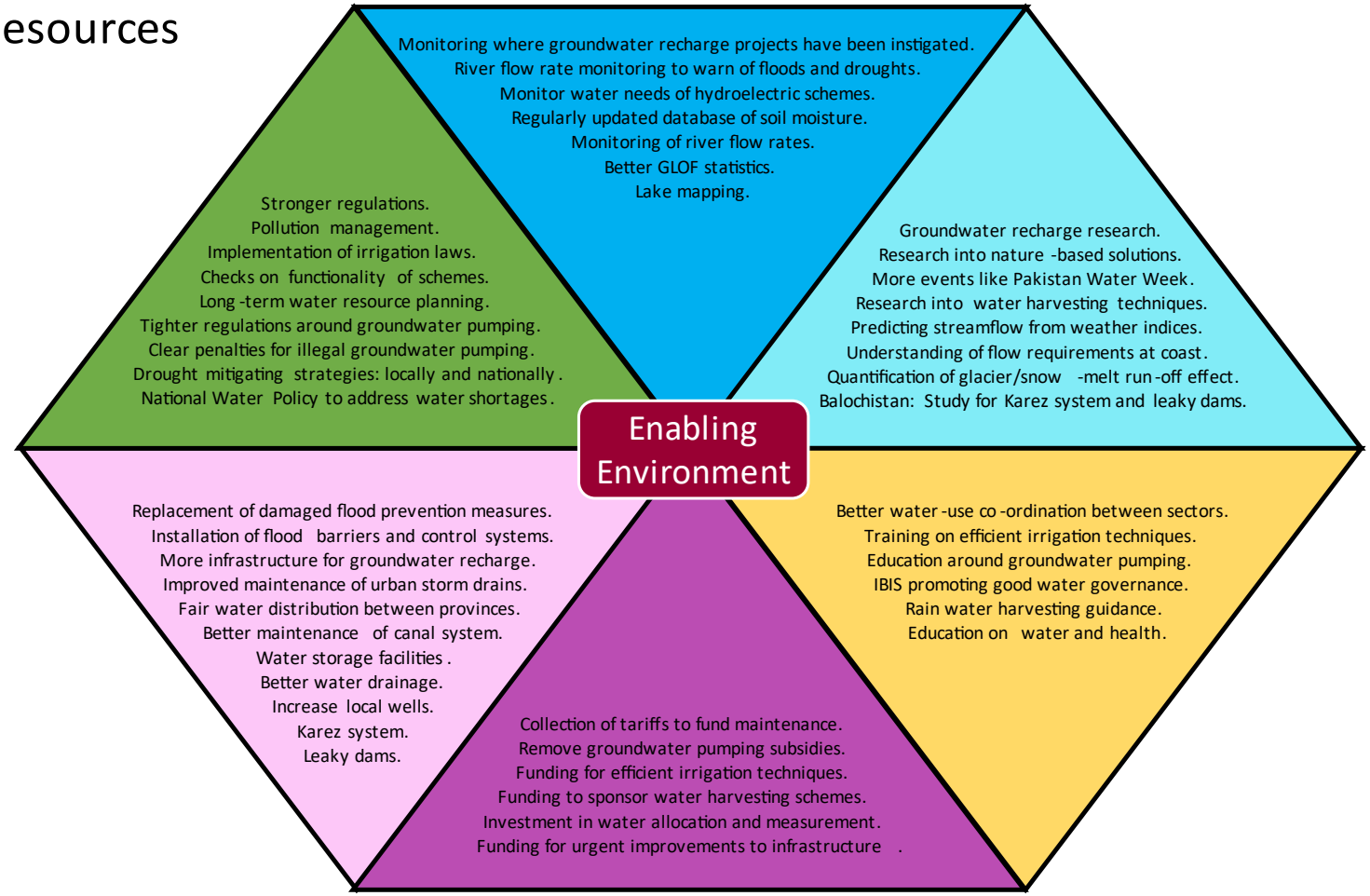

FIGURE 46: ENABLING ENVIRONMENT FOR WATER RESOURCES

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Agriculture and Land-Use

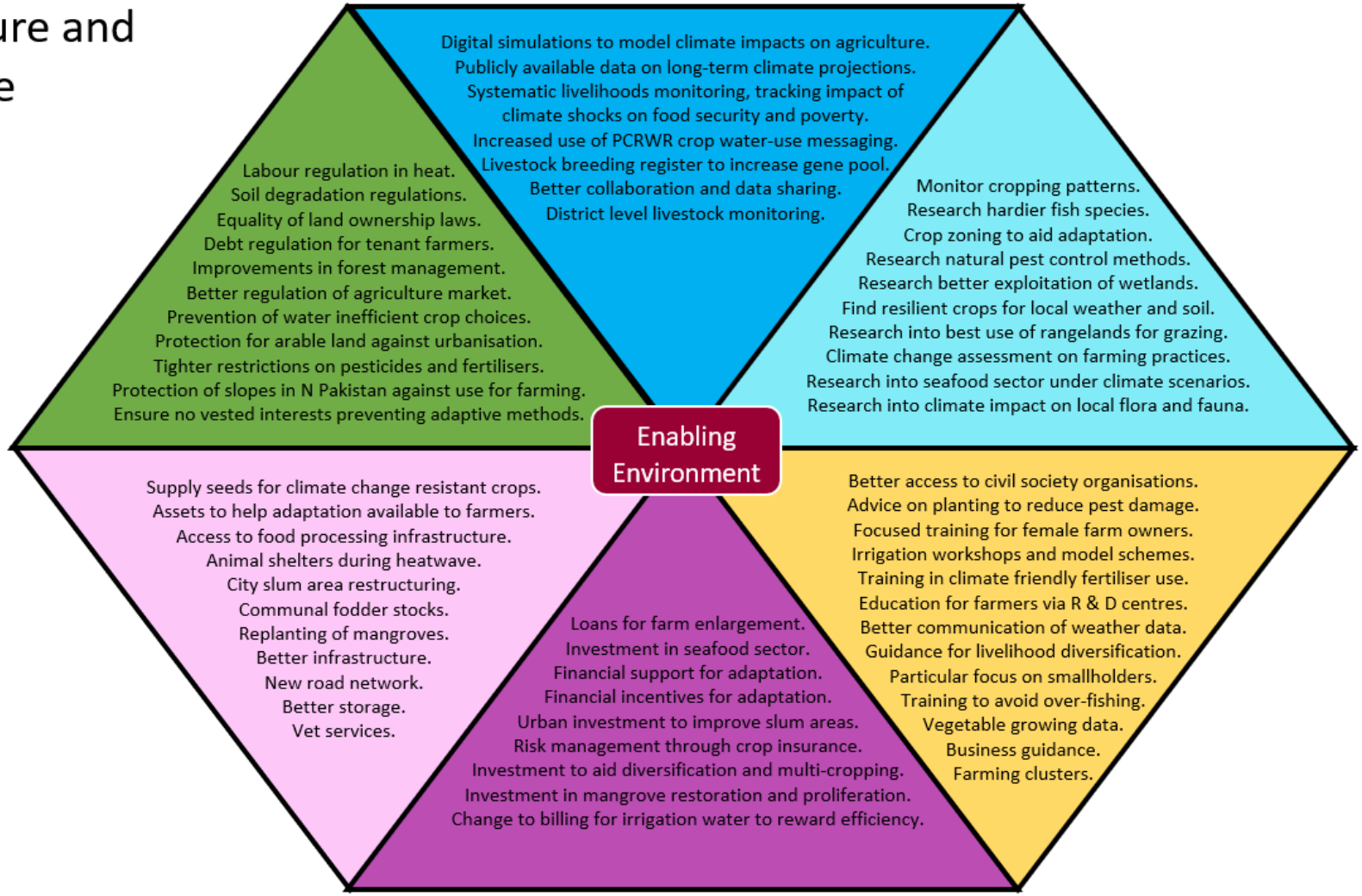

FIGURE 47: ENABLING ENVIRONMENT FOR AGRICULTURE AND LAND-USE

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Health

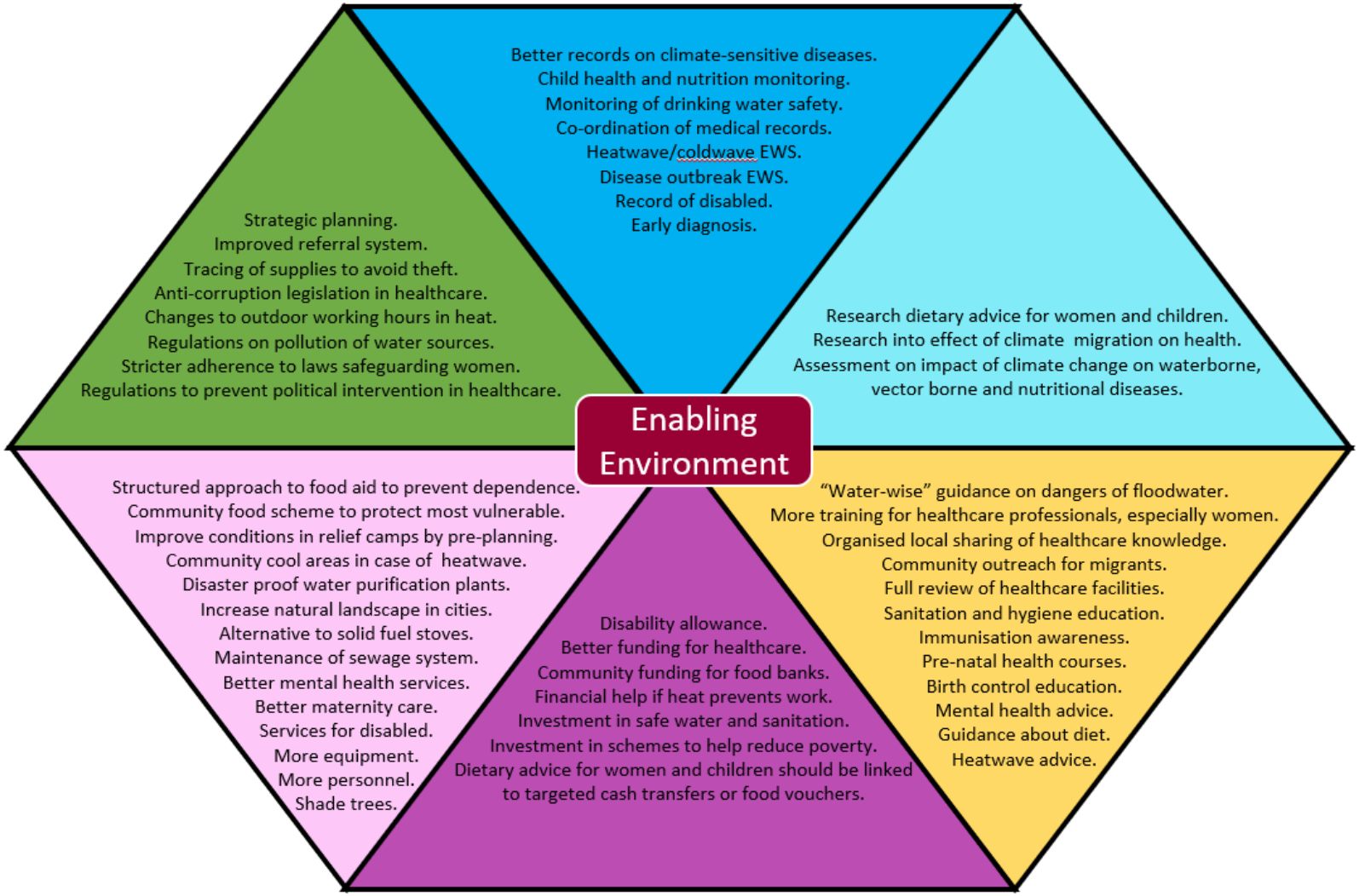

FIGURE 48: ENABLING ENVIRONMENT FOR HEALTH

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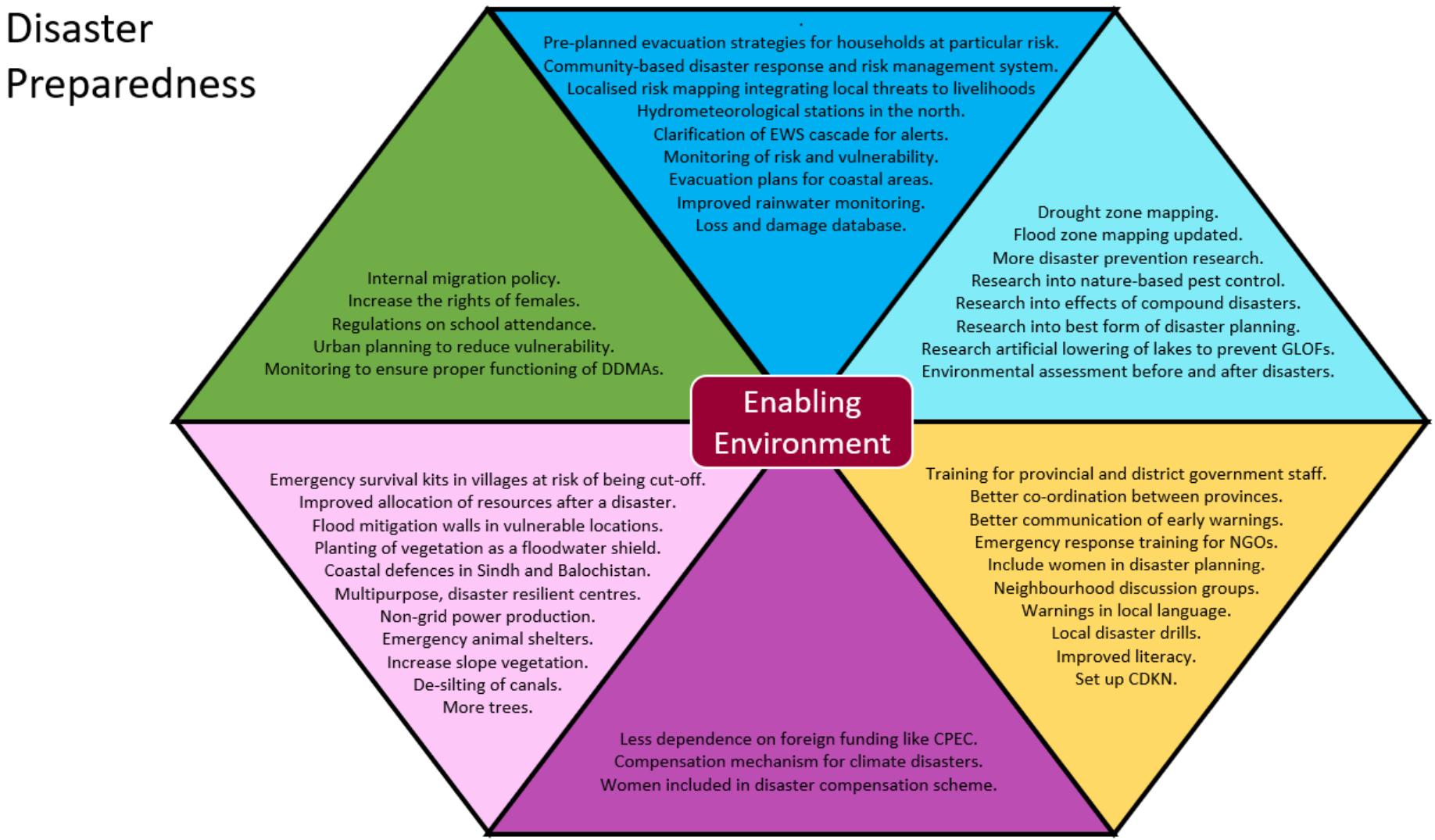

FIGURE 49: ENABLING ENVIRONMENT FOR DISASTER PREPAREDNESS

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SECTION 8: CONCLUSIONS

This report has been constructed to both show the process used to develop impact storylines and to create potential storylines relevant to each province of Pakistan. Where stakeholder information has been available this has been incorporated into the text, but in its absence, a comprehensive review of peer reviewed and grey literature has been used to inform findings. It is hoped that by including such a wide range of sources, the synthesis of information on vulnerabilities and climate change risk will add value to the ongoing evolution of Pakistan's NAP.

Research has incorporated a focus on the past, present and future. Historic climate events and their impacts have been assessed, along with the effectiveness of any pre-emptive and reactive measures taken. The current data has been used to see what climate changes are already in evidence and research has been undertaken into the vulnerability of various sectors to potential future climate events on a national scale. Projections looking until the end of the century have been used to create provincial storylines and representative infographics, with short summaries of possible socio-economic affects, that can be expanded upon by those with local expertise. This has led to a deeper examination of four sectors at provincial level: water resources, agriculture, health and disaster preparedness, from whence, along with the material in the previous sections of the report, the enabling environment for each of these areas could be mapped, in addition to a more general mapping of climate change preparedness. These sections work together to provide a comprehensive review of where Pakistan's policy priorities should lie as it works to develop in an environmentally aware way, whilst coping with the extreme challenges that the changing climate is likely to bring.

In Section 1 an overview of Pakistan's history as well as the challenges it faces under a warming climate are summarized, along with a description of this report's aims and contents. From the review of available literature and discussion with stakeholders, Pakistan is not lacking reports on how it will be affected by climate change or even adaptation action policies. What seems to be missing is implementation. One barrier is a lack of capacity at provincial and district levels, along with the apparent almost non-existent co-ordination of efforts between provinces. Much of the variety in emphasis being afforded to climate change adaptation seems to stem from the political economy in each province, rather than an in-depth assessment of local risks and vulnerabilities.

> "Many beautiful policies exist, but without funding, extra technology and capacity building these are very hard to implement."
>
> Afsar Khan, Deputy Director for Climate Change at the Environmental Protection Agency, Khyber Pakhtunkhwa (AK).

In Section 2 climatic changes that have already been observed are noted. These include:

- rising temperatures
- higher rates of evapotranspiration
- changing monsoon patterns
- increased precipitation intensity
- more frequent droughts
- accelerated melting of glaciers
- rising sea levels.

These areas are then re-explored through the lens of future climate projections, which all agree that temperatures and sea levels will continue to rise, but give different interpretations of how rain patterns may evolve. This is true for differences in models used, for example taking data from projections based on

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the CMIP5 or CMIP6 generations of models, differences in chosen scenarios, in this case use of a variety of RCPs or SSPs and differences in considered time periods.

Vulnerability to climate change is the central theme for Section 3, providing as it does a comprehensive guide to national level issues which are making the people of Pakistan more at risk from the projected climatic changes. Flood risk is shown to be increasing, as rain intensity becomes greater, for potentially shorter periods of time. However, at the same time the very opposite problem, that of water scarcity, is also a major issue. This is being exacerbated by an outdated irrigation system, inadequate drainage schemes particularly in urban areas, little local education on efficient water use and water harvesting, poor maintenance of freshwater and sewage pipes to homes and a general lack of joined up thinking when it comes to water provision and use across the country. For example, regulations on groundwater pumping and recharge are desperately in need of proper implementation, but how can these be achieved, when subsidies are still available for this damaging and short-term approach to water resources? Equally, in coastal regions whole areas are being lost to coastal erosion and salination, where proper planning of sea defences and land-use have not been undertaken. The effects of this situation and lack of sufficient focus on water resources in Pakistan, are wide ranging, affecting the health and welfare of vast swathes of the population.

Agriculture is highly dependent on atmospheric conditions and as Pakistan's climate changes, it is likely that productivity will be reduced, bringing food shortages and additional suffering to many, but particularly to those already enduring poverty, malnutrition and loss of livelihood. By using the dual approach of building capacity locally, whilst applying research to crop choices, planting patterns, seed types, fertilizer use and pest control, the agriculture sector can adapt, so that productivity does not suffer, but instead increases. This is possible, if farmers are not only given better information on what rainfall and temperatures to expect, but also on the best crops to grow and the most efficient way to use the resources they have, including, of course, water. Equally, new crop and seed varieties must be available in local markets and farmers will need to have the means to purchase these so that they can act on the expert advice given. Livestock rearing and fisheries are also at risk. There is an urgent need for the research that has been completed into how these sectors can adapt to be used practically through more widespread dissemination of findings and investment to enable changes to be made. Changing land-use is becoming a source of tension in Pakistan, with areas previously used for agriculture being urbanized and wild wooded areas that were allowing good water drainage and preventing landslides being transformed into farmland. It is immensely important that unregulated changes to land-use are stopped, so that Pakistan's development does not render it more vulnerable to climate change. The way that this development is funded must also be examined carefully. Where investment is being channeled towards drawing international companies into the country's large cities, leaving the poorer slum areas and rural regions unaided, the large divide between those with and without food security is growing.

To help people to understand the future risks that climate change entails, it is imperative that there is a renewed focus on education, including tackling poor literacy rates among adult women and men, as well as girls and boys. The poor literacy rates across the provinces are increasing vulnerability, as early warnings may not be understood and limiting the ability for the long-term adaptation. Education on climate change itself is also necessary at a level before university, so that the younger generation can become more environmentally aware and help the previous generations to grasp the scope of the changes to come. Being part of farming organisations and climate youth clubs, joining local discussion groups and taking part in disaster drills, will all help to bring the community together as they learn to adapt.

The warming climate is likely to bring with it more health challenges, which, for a country with already inadequate healthcare, could be devastating. The hotter days will bring heatstroke and dehydration, particularly to those working outdoors and the flooding is likely to increase vector born and waterborne diseases as well as respiratory problems. It is important that health centres are prepared for this, with

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well trained staff and medical supplies housed in floodproof buildings. Early warning systems for potential epidemics would also reduce risk. Special provision must be made to protect those with disabilities, particularly during adverse climate events. It is also worrying that Pakistan does not have resources to treat those with mental health issues, which are becoming more prevalent.

Across each of these issues, certain social groups are feeling these effects more than others due to the extra vulnerability caused culturally. Women, the poor and climate migrants are all marginalized in different ways, with those falling into all categories having these effects multiplied. It has been recognized that adaptation to climate change works best when everyone is involved, so it is vital that women are given the freedom to make decisions and receive the same information on climate to which their male counterparts have access. They need to be included in education, in funding mechanisms and in agricultural extension groups. Whilst some climate migrants see their fortunes improving, often having areas of migrants leads to less of a community response to cope with the impacts of climate change. The flow of migrants from rural to urban settings is putting food supply further at risk and increasing the pressure on already overcrowded cities. There are also many who find their freedom reduced by the demands of their employers, so that moving away becomes impossible. Those living in poverty need to be given a means to find more diverse livelihoods, so that they can cope better when productivity changes affect their food security. Currently informal loan agreements are seen as the only way to survive, opening the poorest up to a never-ending cycle of debt and deprivation. With better structured funding to help those most in need, migration could be slowed and a better quality of life accessed by more in the rural areas of Pakistan.

Section 4.1 of the report looks first at some of the climate disasters recorded over the last three decades, to show the different issues faced by Pakistan. It also traces patterns in numbers of events through time and between provinces. It is shown that strong La Niña events seem to be linked with particularly intense monsoon seasons that have resulted in the worst floods. It is also evident that many disasters affect more than one province and so preventative action needs to be looked at in a co-operative way between the provinces. A full list of all disasters by type over the last thirty years is provided so approximate judgements of return periods can be made. However, full analysis of return periods is outside of the scope of this report.

Climate analysis based on data from the World Bank Climate Change Knowledge Portal follows in Section 4.2, with data averaged across 31 CMIP6 models. The change in the 5-day maximum precipitation was examined using a 1995-2014 baseline set, as the monsoon rains are crucial to Pakistan's agricultural sector and also key in disaster preparedness. This showed that changes in monsoon length and timing are likely. For Punjab, Balochistan and Sindh consecutive dry days and high heat index days were considered, as these provinces are most likely to suffer from heatwaves and droughts. Interestingly the length of dry periods appears to be reducing, but the number of dangerously hot days is likely to rise. For Khyber Pakhtunkhwa changes in ice days and precipitation were more relevant and showed that there will be very little opportunity for glacial refreezing in the future, meaning that the water from melting glaciers will have a finite availability. Different time periods, SSP scenarios and seasons were considered to help to show some of the uncertainty inherent in the projections. However, the fact that data was from an ensemble mean limits access to uncertainties in climate projections between models. A more comprehensive review of data that could be properly downscaled was not available in the research timeframe. Therefore, conclusions drawn have been combined with previous findings from the literature in order to produce provincial climate storylines.

Section 5 concentrates on Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh, referring to both stakeholder views and literature to summarise each province's position with regard to water resources, agriculture, health and disaster preparedness. This snapshot of current resources and projects can be

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used in conjunction with the storylines to help to assess gaps between planning and implementation that can lead to inaction.

In Balochistan the key issues are reducing water resource losses, improving infrastructure to limit post-harvest food loss, increasing livelihood diversity, reducing malnutrition, improving healthcare services and raising public awareness of health and climate change issues. There is also an urgent need for earlier action to prevent increased impacts of climate disasters.

In Khyber Pakhtunkhwa, adaptation needs include continued reforesting of slopes to help prevent landslides, improved water storage and irrigation methods, improved regulation in water and health provision, increased training of healthcare staff, continued agricultural adaptation to exploit warmer weather and an improved cascade of early warning information so that this can be acted upon at a local level.

Punjab already has a better health record and lower poverty rates than other provinces. However, the over-use of groundwater is a real issue in the province, with agricultural water inefficiency reducing resources at an alarming rate and little focus on climate change adaptation policies. There is involvement in agricultural research, but this is not always backed up by the necessary funding to make adaptation universally accessible. In terms of healthcare, the province has been at the forefront of immunization programmes and disease reduction, but now the smog caused by crop burning, road vehicles and brick kilns is threatening to increase cases of respiratory diseases across Punjab.

Sindh's biggest issues are water scarcity, particularly drinking water in the mega-city of Karachi and water logging along the coastal areas, as sea levels rise. Increasing salination of water sources and agricultural soil is reducing productivity, but with better water harvesting and storage this could be reversed. The mangroves around the coast need to be replanted to prevent further coastal erosion and improve conditions for the fishing communities living in the province. However, this alone will not be enough to counter sea level rises and so action to build defensive infrastructure should also be a priority. Sindh's healthcare needs to be improved, especially in terms of education about sanitation and hygiene to help to prevent large disease outbreaks, particularly following flooding events. Better urban drainage and improved access to heatwave shelter also needs to be carefully planned to reduce climate impacts.

Risk grids for the separate districts of each province based on results from literature are also included, giving an idea of which districts are in most need of adaptation funding to reduce risk. This ranking was created by looking at the top 5 deciles for eleven different indices such as poverty, population density and flood hazard. To improve these grids and ensure that all information considered is completely relevant to a particular region, at a provincial level, the key risk indices can be chosen by stakeholder consultation. Then a standard table can be created for the province and information collected across each district. This does not quantify risk, but gives a view of where key problems lie and how funding can be used to best effect.

In Section 6 all of the research, including both qualitative and quantitative evidence, is drawn together to produce climate storylines and corresponding infographics for each province. These are intended to stimulate discussion in workshops, where expert stakeholders can assess the implications of the projected changes in climate and from here start to make policy decisions. Due to the disparate climate and geography of Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh, a national storyline would not allow adequate detail for effective adaptation planning. It is hoped that the methods used can be repeated in future at an even finer focus, so that the combination of previous events, localised climate projections and socio-economic risk factors can be incorporated into district level storylines.

Barriers to climate change policy implementation are considered in Section 7. The stakeholder surveys and thorough review of hundreds of reports, articles and academic papers providing information on national

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climate change issues and vulnerability at a provincial level have been used to assess the gaps between plans and implementation, in order to produce hexagonal enabling environment reviews, showing the key changes that could result in the urgent action that is needed. These cover the sectors of governance and law, data and technology, science, capacity building, funding and resources. In Section 7 separate diagrams have been provided for each focus sector examined in Section 5 and also a more general diagram on climate change preparedness. This method can be translated to provincial and even district level needs in the future, but would require local expert information and full engagement with all stakeholders.

From all of the information reviewed it seems that there is a tendency for changes to happen very slowly, if at all in Pakistan, despite the many excellent adaptation plans that already exist (74). For example, the Pakistan Climate Change Act of 2017 set up the mandate for a Pakistan Climate Change Council whose duties include preparing and implementing climate change policies and adaptation plans, but this group only met for the first time in October 2022 a full five years later (42; 252). The council, with its 26 members drawn from provincial governments, environmental experts, lawyers and members of the civil society is now in place with the remit to advise the federal government on strategies involving finance, adaptation, loss and damage (42). Chaired by the Prime Minister of Pakistan, the council will oversee the NCCPIC, who in turn will work with the PCCPICs (192). A cascade of information, policy guidance and adaptation implementation cannot stop here, however. Just as in disaster management where the NDMA oversees the PDMAs who organize DDMAs in each district, district level climate change policy implementation councils are also needed (253). Up until now each provincial government met quarterly with the MoCC to discuss their adaptation planning, but this federal government group cannot become directly involved with implementation due to the 18th constitutional amendment which devolved power to the provinces. This has led to weak co-ordination between provinces and a lack of local evaluation and monitoring (74). With the implementation of the PCCIC and the extension of this idea to district level, sharing good practice and co-ordinating projects across district and provincial boundaries should be more straightforward. This is critical, as where communities interact with policy makers this has been shown to be the most effective way of increasing adaptive capacity (74).

The other serious hurdle to implementing climate action plans seems, from both literature and stakeholder information, to be not just a lack of funds, but also a lack of knowledge about the longevity of any funding source. Relying heavily on foreign aid reduces the amount of autonomy that Pakistan has in respect to its own climate action policies, a fact noted in some of the anxiety surrounding the CPEC projects (254). Stakeholders recorded a level of unease about how much influence outside powers may exert over Pakistan as part of their projects to help the country. This is illustrated by the environmental damage done during the CPEC Port Qasim Power Project (48). Another area which worried stakeholders was that projects involving international aid groups are often limited to localized studies, with no scope for rolling schemes out across more regions. As isolated efforts, these can soon become lost as other issues need more drastic action. Long-term, high-profile, internally led campaigns are both more popular and more likely to have a real effect on Pakistan's ability to adapt to climate change. The difficulty is how to administer and fund such projects given the disparate political economies of each province.

In conclusion, it should not be forgotten that the most important justification for adaptation and disaster preparedness is that climate events will only become disasters, if the impacts are not reduced by limiting vulnerability and boosting resilience.

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ANNEX 1: STAKEHOLDER INFORMATION SUMMARY

Extra information from stakeholders is included here.

A1.1: Subnational Adaptation Planning

According to stakeholders subnational adaptation planning in Pakistan involves the following groups:

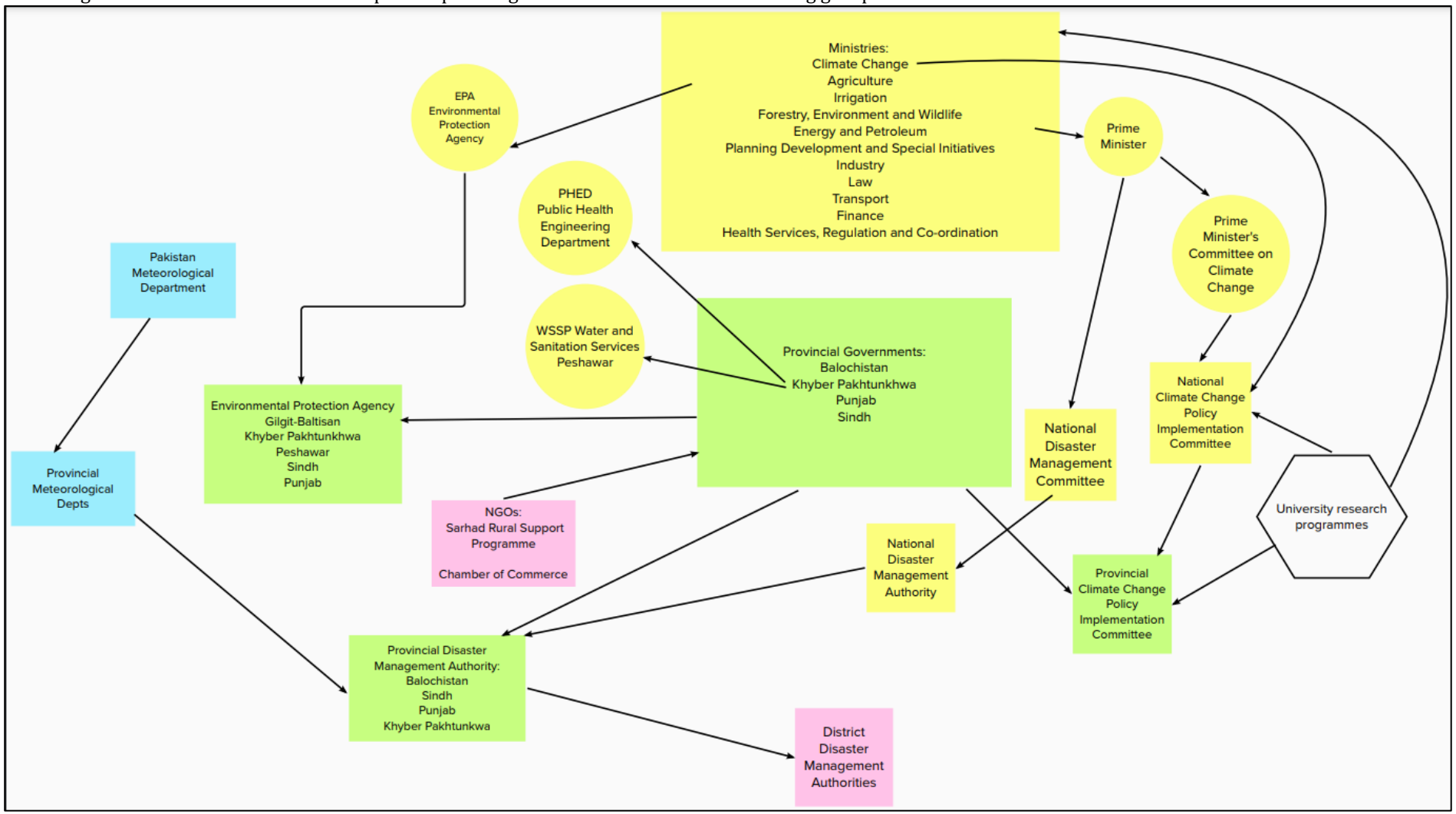

FIGURE 50: STAKEHOLDER VIEW OF SUBNATIONAL ADAPTATION PLANNING

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A1.2: Climate risk, vulnerability assessments produced in Pakistan

Stakeholders identified the following reports and information gathering exercises:

- Assessments covering drought, heat, flood, glacier melting, flash flooding, excessive rainfall
- Provincial Climate Change Policies
- PCRWR report on water bodies with good quality of freshwater
- Representative Agricultural Pathways: used to look at climatic uncertainties and adverse impacts under GCM and RCM projections
- Document giving key interventions necessary for the ecological restoration of the River Indus
- GLOF Risk and Potential Role of Concerned Departments
- EPA sent questionnaires to all Departments so that stakeholder information could be incorporated into Provincial Climate Change Policies
- IPCC AR6 data and local data are used in the Climate Change vulnerability assessment

It was commented that all available sources of information about climate are being used, but more data is needed.

A1.3: Who are the most vulnerable groups to Climate Change in Pakistan?

This diagram represents all of the groups noted as being vulnerable by the stakeholders and particularly highlights intersections of these groups. The outer dashed ring signifies that within these groups, being female increases vulnerability. See Section 3.7 for more details on gender-based vulnerability.

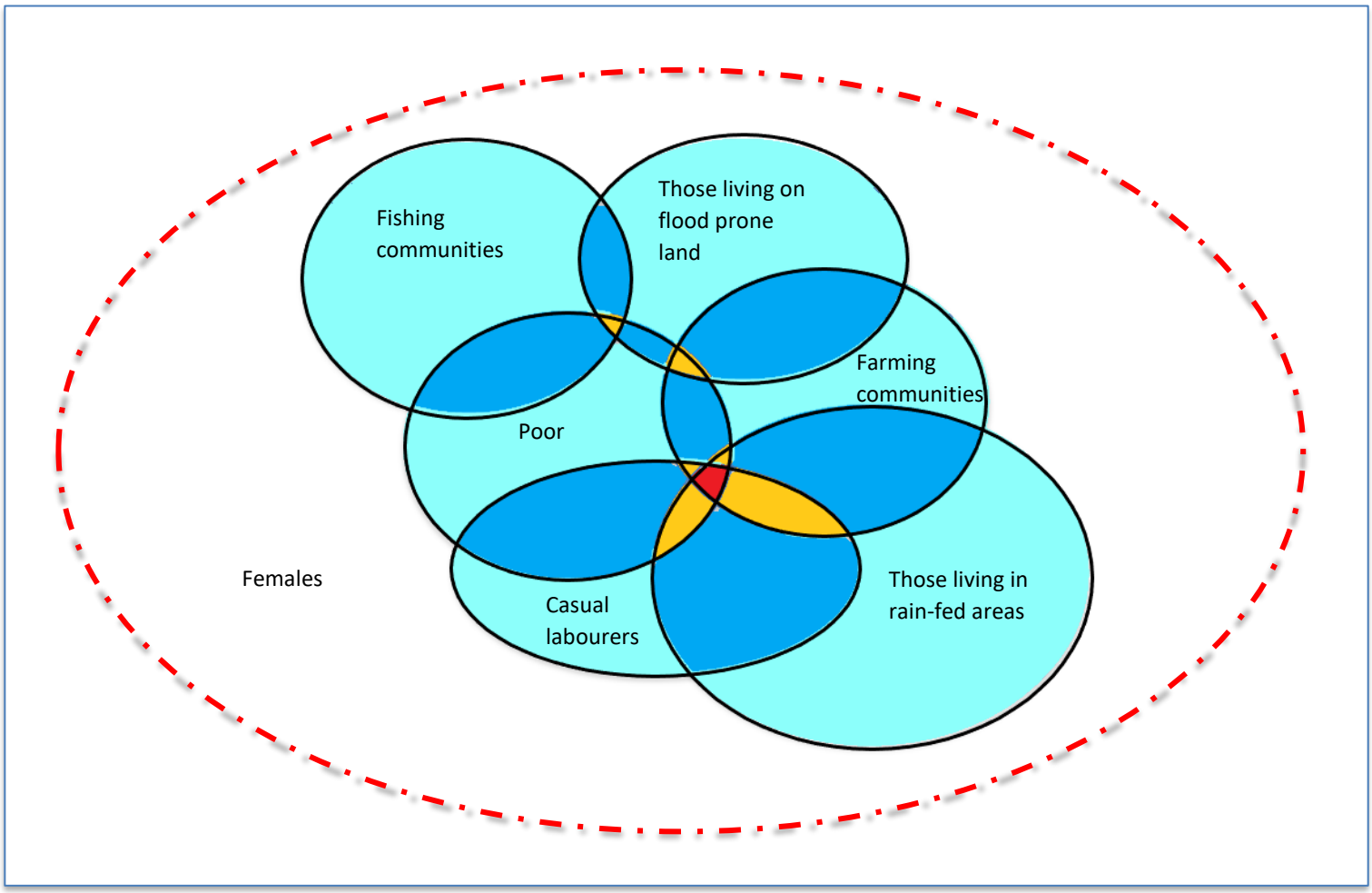

FIGURE 51: STAKEHOLDER VIEWS ON MOST VULNERABLE GROUPS IN PAKISTAN

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A1.4: Who helps the vulnerable?

According to stakeholders these are the key organisations helping the vulnerable of Pakistan. Shading shows where live activity is taking place.

Organisation	Health	Agriculture	Funding	Disasters
NGOs				
NDMA				
Charities				
Municipal Corporations				
Self-help				
Federal government	Food subsidies for poor.	Subsidies for farmers. Hospital dispensaries for livestock.		
National Institute for Biotechnology and Genetic Engineering		Research into drought and heat tolerant cereal crops mainly.		
National Institute of Agricultural Botany, UK				
Ayub Agriculture Research Institute				
Rice Research Institute, Kala Shah Kaku				
Agricultural Banks				
SRSP			Microloans for the most vulnerable.	
International Support			Funding based on vulnerability of local areas.	
Deutsche Gesellschaft für Internationale Zusammenarbeit			Funding limited to single small scope projects.	
United Nations Development Programme				
Japanese International Co-operation Agency				
WB			Promotion of adaptation at pilot levels	
ADB				
GCF			This is not being used enough currently.	

TABLE A 1: ORGANISATIONS HELPING THE VULNERABLE IN PAKISTAN

Areas which do not obtain ring-fenced climate specific funding, but should according to stakeholders:

Water resources, renewable energy sources and research into water logging of cotton fields and submergence of rice.

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To contact the authors

Dr Cathie Wells, cathie.wells@reading.ac.uk

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Walker Institute
University of Reading
Earley Gate
Reading
RG6 6AR
UK

Email: info@walker.ac.uk
Tel: +44 (0)118 378 4651
Web: www.walker.ac.uk
Twitter: @WalkerInst