Federal Ministry
for Economic Cooperation
and Development

giz

Climate Risk Profile for Pakistan

Summary

This profile provides an **overview of projected climate parameters and related impacts** on different sectors in Pakistan until 2080 **under different climate change scenarios** (called Representative Concentration Pathways, RCPs). RCP2.6 represents the low-emissions scenario, which aims to keep global warming likely below 2 °C compared to pre-industrial temperatures, and RCP6.0 represents a medium/high emissions scenario. RCP6.0 was selected to follow a middle-of-the-road pathway, while RCP2.6 was added as the best-case scenario. We avoid to add the worst-case scenario RCP8.5, as the energy behaviour leading to such emissions has been deemed not realistic. **Model projections do not account for effects of future socioeconomic impacts.**

Water, agriculture, infrastructure, ecosystems and health are highly vulnerable to climate change. The **need for adaptation in these sectors has been stressed in Pakistan's INDCs**, which highlight agriculture and energy as two key emissions-generating sectors. These sectors as well as their interdependencies should be **represented in the German development cooperation portfolio** in Pakistan. This climate risk profile serves to complement the climate risk country profile by the World Bank and the Asian Development Bank, by taking a stronger geospatial approach as well as providing a comprehensive analysis of climatic changes and associated impacts, all based on the same database.

Depending on the scenario, **temperature** in Pakistan is projected to **rise by between 2.0** (RCP2.6) **and 4.1 °C** (RCP6.0) **by 2080**, compared to pre-industrial levels, with highest temperature increases in northern Pakistan and highest absolute temperatures projected for eastern Sindh.

Precipitation trends are uncertain and vary across Pakistan, with projections indicating an overall **increase in annual precipitation of up to 9 mm by 2080**. Future dry and wet periods are likely to become **more extreme**.

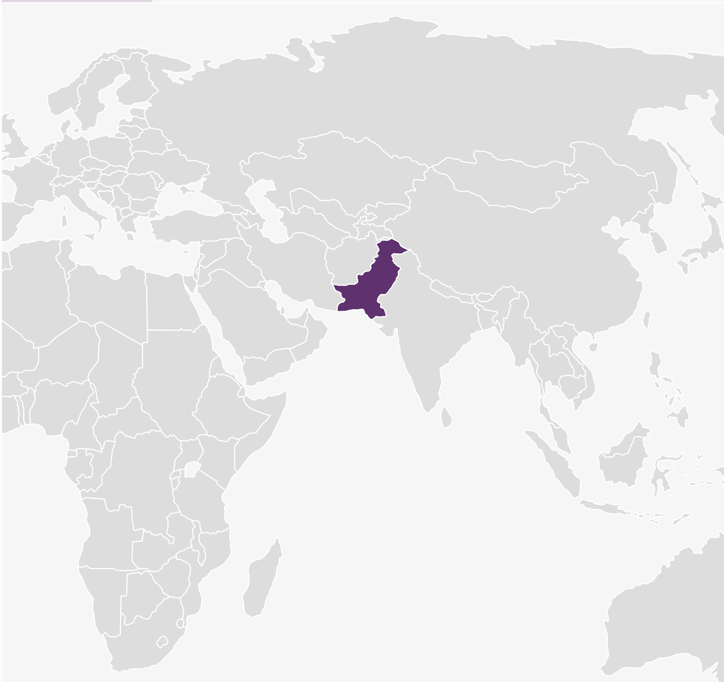
Under RCP6.0, the **sea level** is expected to **rise by 40 cm** until 2080.[1] This threatens Pakistan's coastal communities and may cause saline intrusion in coastal waterways and groundwater reservoirs.

Climate change is likely to cause **severe damage to the infrastructure sector** in Pakistan including roads and bridges. As roads are the backbone of the country's transportation network, investments will need to be made into building climate-resilient roads and other infrastructure.

Climate change will have regional impacts on crop yields, with most parts of Pakistan experiencing **declining yields of wheat, rice and maize.** Farmers will need to adapt to these changing conditions.

Per capita water availability will decline by 2080 mostly due to population growth. Model projections indicate that **water saving measures are expected to become more important all over Pakistan after 2030**.

The **population share affected** by at least one **heatwave** per year is projected to **rise** from 7.8 % in 2000 to 45.4 % in 2080. This is related to an average of 39 more very hot days per year over this period. As a consequence, **heat-related mortality** is estimated to **increase by a factor of 3.5** by 2080.



[1] Unless stated otherwise, the numbers in this summary refer to RCP6.0.

Published in June 2022

Country context

Pakistan is a South Asian country with direct access to the Arabian Sea and **1,046 km of coastline** [1]. The population is estimated to exceed **225 million** in 2021, making it the fifth-most populous country in the world [2]. Despite having the **highest mortality rate of children under the age of five** on the Asian continent (67.2 per 1,000 live births in 2019), Pakistan's population continues to grow at an annual **population growth** rate of 2 % [2]. Furthermore, Pakistan is the **second-youngest country in the South Asian region**, since 35 % of the population are below the age of 15 [2]. The majority of the population lives in rural areas along the Indus River and its tributaries. The largest **urban centres** include **Karachi** in the south and **Lahore** in the east, with around 16.5 and 13.1 million inhabitants, respectively [1]. Pakistan's capital Islamabad is located further north in the foothills of the Himalayas, counting around 1.2 million inhabitants [1].

With a real **GDP per capita of 1,168 USD** (11 % of the world average), Pakistan counts as a **lower middle-income country (LMIC)** [2]. The economy recovered after the global financial crisis of 2007–2008, reaching an annual GDP growth rate of 5.8 % in 2018, however, the COVID-19 pandemic caused substantial growth downgrades with an annual **GDP growth rate** of only **0.5 %** in 2020 [2]. Pakistan's economy is dominated by the services sector, contributing 53.9 % to the country's GDP in 2019, followed by the agricultural sector (including forestry and fishing) with 22.0 % and the industrial sector (including construction) with 18.3 % [3]. Pakistan is the **fifth-largest producer of cotton** worldwide with an annual production quantity of 4.5 million tons [4]. The importance of this commodity is also reflected in Pakistan's exports, where textiles prevail at 55.3 % of the total export value in 2019 [5]. Textiles are, by a long margin, followed by rice (8.5 %) with major destinations being China and Kenya [5]. Other agricultural exports include citrus and tropical fruits, wheat flour and potatoes [5].

In Pakistan, **agriculture is the most important sector** in terms of livelihoods, providing employment to the majority of the population [2]. According to ILO data, 37 % of total employment is in the agricultural sector [2]. However, **63 % of the population live in rural areas**, which suggests a much higher share of people who depend on agricultural livelihoods [2]. Therefore, concerns are rising over the **effects of climate change**, including rising temperatures, reduced precipitation and the occurrence of extreme weather events, such as floods and droughts. Agricultural production in Pakistan is primarily **subsistence-based and irrigated**, with an average farm size of 2.6 hectares [6]. Wheat is by far the most important staple crop, followed by rice, maize, sugar cane and chickpeas [7]. Pakistan has an irrigation potential of 21.3 million hectares, of which around 90 % are under full control irrigation [8]. However, **adaptive capacity in the agricultural sector is limited**, due to limited access to formal credit, agricultural inputs, markets or support services, underlining the sector's vulnerability to climate change [9]. Hence, especially smallholder farmers are directly affected by the impacts of climate variability, which can reduce their food supply and increase the **risk of hunger and poverty**.

Pakistan serves as a **destination for approximately 3.3 million migrants**, especially **from Afghanistan** and **India** with 1.6 million migrants from each of these countries [10]. It is expected, however, that after the Taliban takeover in August 2021, the **Afghan diaspora will further grow** with many Afghans seeking refuge in Pakistan, which has the longest border with Afghanistan. In turn, many Pakistanis migrate abroad with the **largest Pakistani communities in the Gulf States** (3.3 million), especially Saudi Arabia, the United Arab Emirates and Kuwait, as well as India (1.1 million) and the United Kingdom (610,000) [10]. Pakistani migration to the Gulf States tends to be short-term or seasonal, with the **majority being low-skilled workers** [11]. Overall, migration is of great importance to Pakistan's economy: Inflow **remittances make up 9.9 % of the country's GDP** [12].

Quality of life indicators [2], [13]–[15]

Human Development Index (HDI) 2019	ND-GAIN Vulnerability Index 2019	Gini Index 2018	Real GDP per capita 2020	Poverty headcount ratio 2018	Prevalence of undernourishment 2017–2019
0.557 **154 out of 189** (0 = low, 1 = high)	**38.3** **153 out of 181** (0 = low, 100 = high)	**31.6** (0–100; 100 = perfect inequality)	**1,168 USD** (constant 2010 USD)	**4.4 %** (at 1.9 USD per day, 2011 PPP)[2]	**12.3 %** (of total population)

[2] Poverty headcount ratio for the year 2012 adjusted to 2011 levels of Purchasing Power Parity (PPP). PPP is used to compare different currencies by taking into account national differences in cost of living and inflation.

Topography and environment

Pakistan's topography is very diverse, including the **Himalaya and Karakoram mountain ranges** in the north, various **plateaus** in the centre and west, the **Indus River Plain**, which spans from north to south, and **smaller desert areas** in various parts of the country. Pakistan's highest – and the world's second-highest – peak is the **K2**, which is located in the Karakoram Range, reaching **8,611 m**.

Pakistan has a **mostly hot desert climate** in the southern two thirds of the country. Further north, the climate becomes more temperate with distinct seasons, while the high **mountain ranges** in the far north are characterised by a complex **combination of arid, cold and polar climatic features** [16]. Each of these topographies is characterised by different agro-ecological conditions with specific temperature and moisture regimes and, consequently, specific patterns of crop production and pastoral activities.

Several important rivers originate from or flow through the northern mountain ranges, including the Indus, Sutlej, Chenab and Jhelum, of which the latter three are all tributaries of the Indus.

The Indus is **fed by melting snow and glacial meltwater** from the Himalayas and runs southward, ultimately discharging into the Arabian Sea. At a total length of 3,180 km, the **Indus** is considered **the lifeline of the country**. The water and fertile banks of the Indus Basin provide agricultural and other livelihoods to an estimated 180–300 million people in Pakistan, India, China and Afghanistan [17]–[19]. Overall, however, and in light of the country's growing population, Pakistan's **water resources are scarce**, unequally distributed and threatened by reduced precipitation amounts and rising temperatures.

Unsustainable farming and grazing practices, **deforestation** and inadequate reforestation techniques as well as poor watershed protection and **excessive water** abstraction for irrigation have resulted in major environmental issues, including **soil erosion** and **desertification** [20], [21]. Extreme weather events, including heavy precipitation and droughts, are expected to intensify in the context of climate change, highlighting the **need for adaptation measures** to protect biodiversity and maintain fragile ecosystems and their services.

Present climate [16]

Pakistan has a diverse climate largely influenced by elevation. Mean annual temperatures range from −4 °C to 28 °C with lower values in the north-eastern mountains and higher values in the south-east of the country.

Annual precipitation sums range from as little as 40 mm in western Pakistan, which has – like most parts of the country – an arid climate, to 1,460 mm in the northern mountains, which are characterised by a cold and polar climate.

Pakistan is characterised mostly by a bimodal precipitation regime with two rainy seasons from February to April and from June to October. Only a number of regions in western Pakistan have one rainy season from June to October or no rainy season at all.

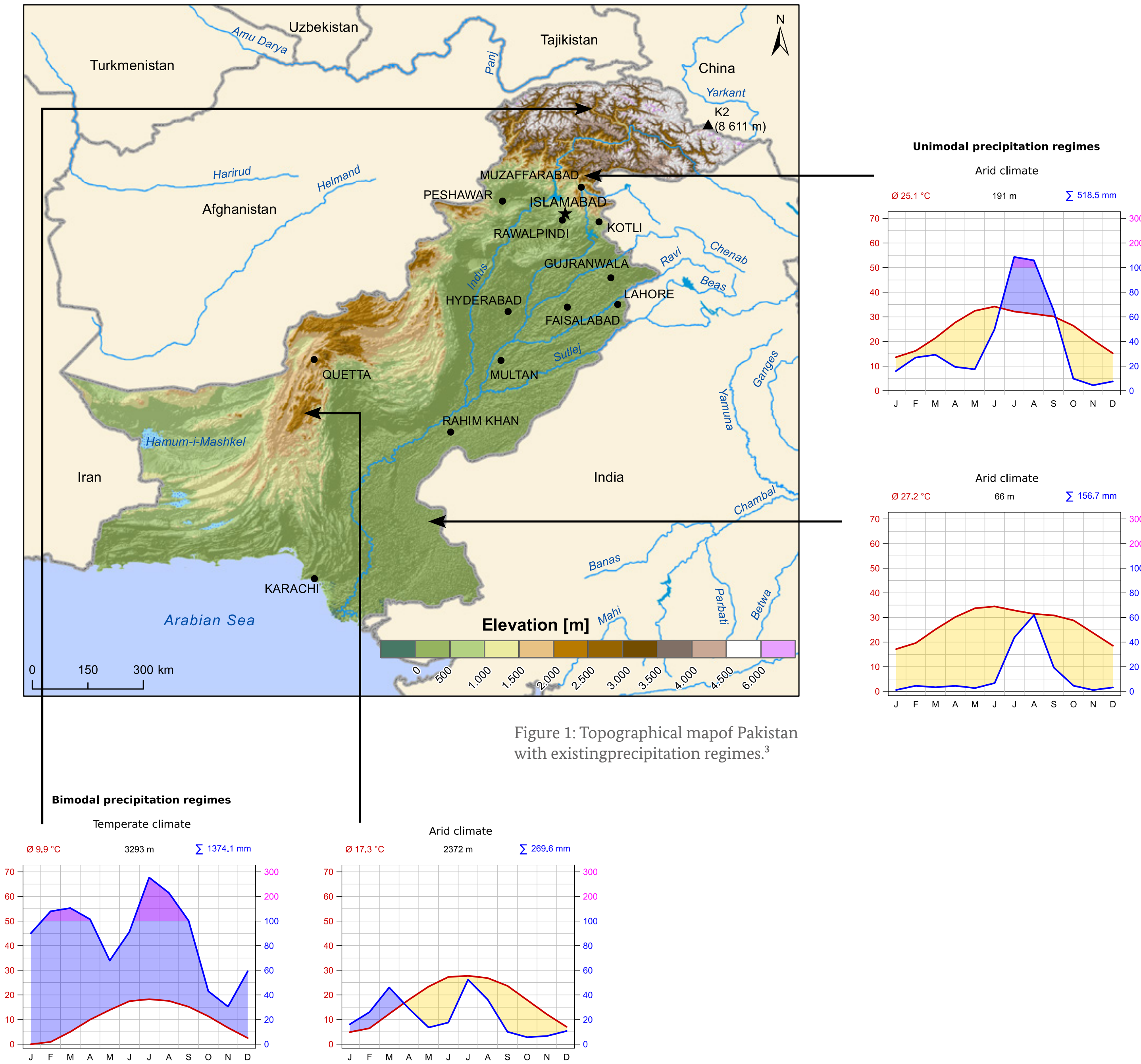


Figure 1: Topographical mapof Pakistan with existingprecipitation regimes.[3]

[3] The climate diagrams display temperature and precipitation values which are averaged over an area of approximately 50 km × 50 km. Especially in areas with larger differences in elevation, the climate within this grid might vary.

Projected climate changes

How to read the line plots

historical — best estimate
RCP2.6 — likely range
RCP6.0 — very likely range

Lines and shaded areas show multi-model percentiles of 31-year running mean values under RCP2.6 (blue) and RCP6.0 (red). In particular, lines represent the best estimate (multi-model median) and shaded areas the likely range (central 66 %) and the very likely range (central 90 %) of all model projections.

How to read the map plots

Colours show multi-model medians of 31-year mean values under RCP2.6 (top row) and RCP6.0 (bottom row) for different 31-year periods (central year indicated above each column). Colours in the leftmost column show these values for a baseline period (colour bar on the left). Colours in the other columns show differences relative to this baseline period (colour bar on the right). The presence (absence) of a dot in the other columns indicates that at least (less than) 75 % of all models agree on the sign of the difference.
For further guidance and background information about the figures and analyses presented in this profile kindly refer to the supplemental information on how to read the climate risk profile.

Temperature

In response to increasing greenhouse gas (GHG) concentrations, **air temperature over Pakistan is projected to rise**. Depending on the future GHG emissions scenario, the average temperature of Pakistan will rise by 2.0–2.6 °C under the strong-mitigation scenario RCP2.6 and **by 3.4–4.1 °C under the more realistic RCP6.0 scenario** (very likely range) by 2080, relative to the year 1876 (Figure 2). Temperature is expected to rise everywhere in Pakistan, but the degree differs regionally. While the regional differences in warming are only in the range of 1 °C by 2030, they become more distinct throughout the 21st century. Compared to the year 2000[4], simulated **temperatures increase strongest in the cool regions of northern Pakistan**: Under RCP2.6, northern Pakistan will be up to 2 °C warmer from the middle of the 21st century on and stabilise, while temperatures continuously increase under the medium/high emissions scenario RCP6.0 by up to 3.9 °C by 2080 (Figure 3). The southern coast, which is already experiencing the highest temperatures today, is projected to experience the lowest increases, with local temperature increases of less than 2 °C by 2080 under RCP6.0.

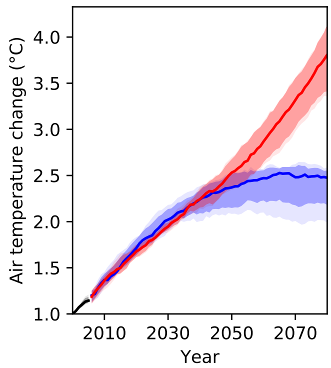


Figure 2: Projections of air temperature for all of Pakistan for different GHG emissions scenarios.

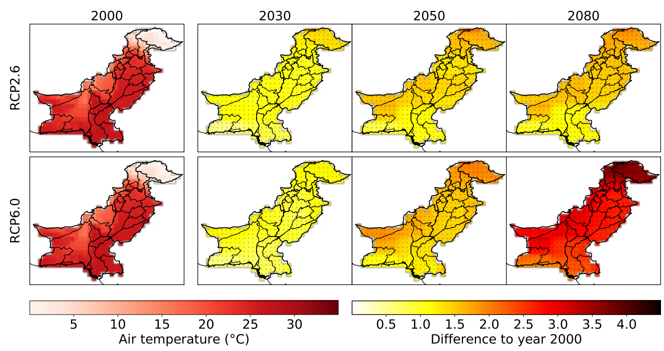


Figure 3: Regional projections of air temperature for Pakistan for different GHG emissions scenarios, relative to the year 2000.

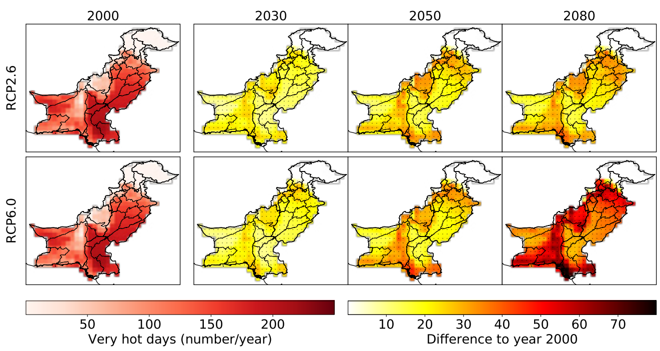


Figure 4: Regional projections of the annual number of very hot days (daily maximum temperature above 35 °C) for Pakistan for different GHG emissions scenarios, relative to the year 2000.

[4] Note that the baseline for Figure 3 is the year 2000, while for Figure 2, this is the year 1876. Hence, the projected differences are lower for Figure 3 than for Figure 2.

Very hot days

In line with rising temperatures, the number of very hot days, which are days with a daily **maximum temperature above 35 °C**, is projected to rise dramatically and with high certainty all over Pakistan, in particular in the north and centre of the country and along the coastline in the south (Figure 4). While the smaller differences in the western and eastern parts of Pakistan may be counterintuitive, in fact, they highlight the amount of very hot days in the present: Some parts of Pakistan, such as southern Sindh, already experience 223 very hot days per year. Hence, in these regions, further temperature increases could amount to **a total of 256 very hot days per year** in 2080 under RCP6.0. Temperatures above the threshold of 35 °C present a threat to human health as well as to animal health and productivity, and crop production [25], [26].

Sea level rise

In response to globally increasing temperatures, the sea level off the coast of Pakistan is projected to rise (Figure 5). In accordance with temperature changes, sea level changes are very similar under both emissions scenarios until 2050. Compared to the year 2000, the model ensemble projects a **sea level rise of 10 cm by 2030, 20 cm by 2050 and 30 (40) by 2080 cm under RCP2.6 (RCP6.0)**, respectively. Rising sea levels may cause saline intrusion in coastal waterways and groundwater reservoirs [22], [23]. In many coastal communities in Pakistan, this is already the case with serious consequences: Large areas of **agricultural land** have either been **drowned by the sea** or have **turned saline** [24]. The process of salinisation is further exacerbated by reduced amounts of water and sediment from the Indus and its tributaries, which is held back by increasing numbers of dams. This has resulted in an overall **sinking of the delta**, causing people to give up agricultural production and migrate out of the region, often to bigger cities.

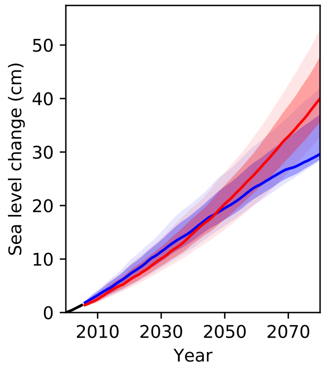


Figure 5: Projections of sea level rise off the coast of Pakistan for different GHG emissions scenarios, relative to the year 2000.

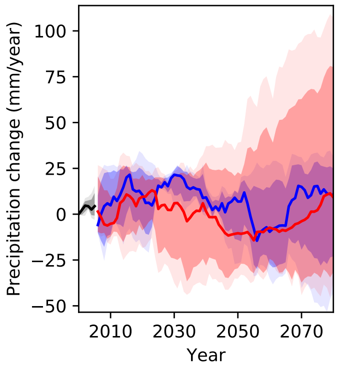


Figure 6: Projections of annual mean precipitation for all of Pakistan for different GHG emissions scenarios, relative to the year 2000.

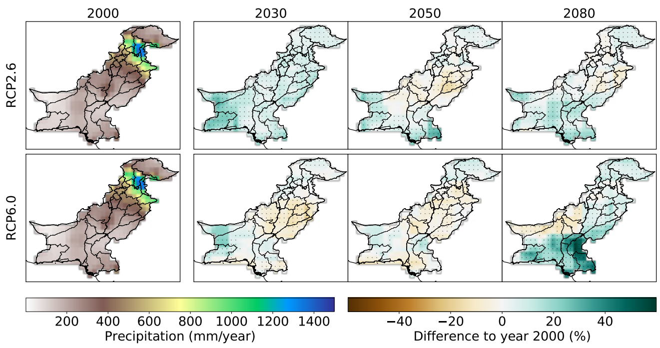


Figure 7: Regional projections of annual mean precipitation for Pakistan for different GHG emissions scenarios, relative to the year 2000.

Precipitation

Future **projections of precipitation are less certain** than projections of temperature due to high internal variability and model uncertainty (Figure 6). This finding is in line with previous modelling exercises conducted for Pakistan [27], [28]. Out of the four climate models underlying this analysis, two models project a decrease in mean annual precipitation over Pakistan, one model projects a moderate increase and one a strong increase (not shown in Figure 6). The resulting model ensemble projections show **increases** of 10 % (RCP2.6) and **9 % (RCP6.0)** and **no clear long-term trend** under either RCP. Also, there are regional differences in both the direction and magnitude of change (Figure 7). For example, **in northern Balochistan, precipitation is projected to decrease** by up to 15 % until the end of the century. This projected trend is in agreement with observed data: Ashraf and Routray found a negative trend in precipitation for Balochistan with more than 70 % of the rain gauge stations in their study showing decreases from 137.2 to 283.4 mm over the time period 1975–2010 [29]. Their findings also point to a greater severity of drought in north-western Balochistan, compared to the southern part of the province. At the same time, other parts of Pakistan are expected to see **increases in precipitation**, such as **north-eastern Sindh** with increases of up to 57 %. Samo et al. observed the time period 1996–2014 and found a rapid increase in precipitation [30].

Frequency of heavy precipitation events

In response to global warming, heavy precipitation events are expected to become more intense in many parts of the world due to the increased water vapour holding capacity of a warmer atmosphere. At the same time, **the number of days** with heavy precipitation events is expected to increase. This tendency is also reflected in climate projections for Pakistan (Figure 8). Nationally aggregated climate projections show **a slight increase in the number of days with heavy precipitation events**, from 7 days per year in 2000 to 8 days per year in 2080 under both RCPs. On a regional scale, however, the picture is more complex. For example, under RCP6.0, northern Pakistan and parts of south-eastern Pakistan will see an increase by up to 3.5 days per year, while parts of Balochistan will see a decrease by up to 1.5 days (Figure 9).

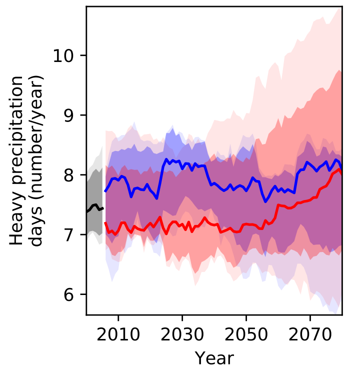


Figure 8: Projections of the number of days with heavy precipitation for all of Pakistan for different GHG emissions scenarios.

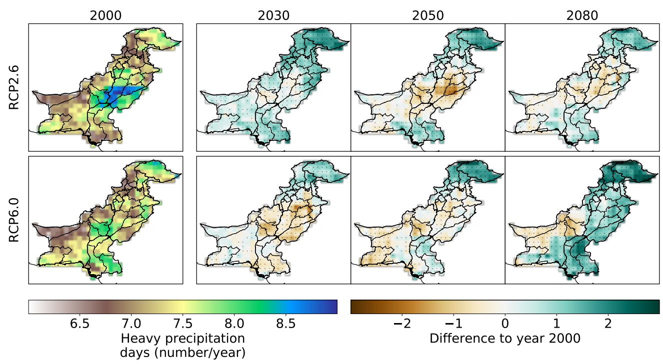


Figure 9: Regional projections of the number of days with heavy precipitation for Pakistan for different GHG emissions scenarios, relative to the year 2000.

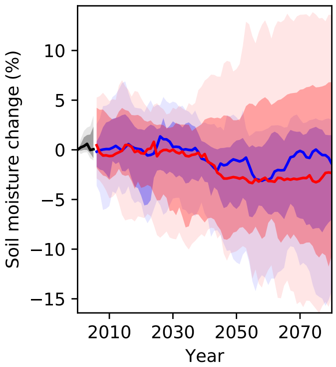


Figure 10: Projections of soil moisture for all of Pakistan for different GHG emissions scenarios, relative to the year 2000.

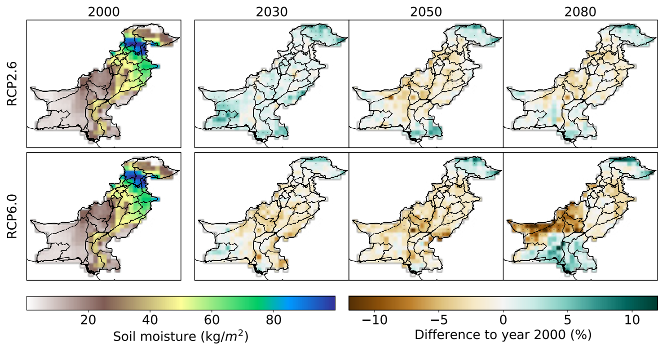


Figure 11: Regional projections of soil moisture for Pakistan for different GHG emissions scenarios, relative to the year 2000.

Soil moisture

Soil moisture is an important indicator for drought conditions. In addition to soil parameters and management, it depends on both precipitation and temperature, as higher temperatures translate to higher potential evapotranspiration. Projections for annual mean soil moisture for a soil depth of up to 1 metre **show a slight decrease under either RCP** by 2080, compared to the year 2000 (Figure 10). However, looking at the different models underlying this analysis, there is large year-to-year variability and modelling uncertainty, with some models projecting increases and others projecting decreases. With regards to regional differences, models only agree on decreases of up to 14 % in northern Balochistan under RCP6.0 by the end of the century (Figure 11).

Potential evapotranspiration

Potential evapotranspiration is the amount of water that would be evaporated and transpired if sufficient water was available at and below land surface. Since warmer air can hold more water vapour, **it is expected that global warming will increase potential evapotranspiration in most regions of the world.** Higher evapotranspiration affects the water supply and the amount of surface water available for agriculture. It can shift the fraction of precipitation that flows over land and into streams and rivers. Long-term shifts in recharge patterns can change groundwater levels and subsequently interactions between groundwater and surface water as well as soil moisture.

Indeed, hydrological projections for Pakistan indicate a stronger rise of potential evapotranspiration under RCP6.0 than under RCP2.6 (Figure 12). Under RCP6.0, **potential evapotranspiration is projected to increase by 3.0 % in 2030, 4.8 % in 2050 and 9.1 % in 2080**, compared to the year 2000. While RCP6.0 shows a steadily increasing trend, which will likely continue beyond the year 2080, the curve flattens under RCP2.6 after the year 2050, with increases of in 2.1 % 2030, 4.0 % in 2050 and 4.9 % in 2080. Figure 13 shows the countrywide increase in potential evapotranspiration, with the highest increases in northern Pakistan. Regions, which already experience high rates of potential evapotranspiration, such as south-eastern Sindh, will see some of the lowest percentage increases, however, these regions will arrive at the highest absolute rates of potential evapotranspiration by the end of the century.

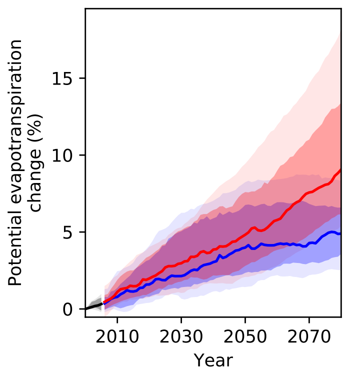


Figure 12: Projections of potential evapotranspiration for all of Pakistan for different GHG emissions scenarios, relative to the year 2000.

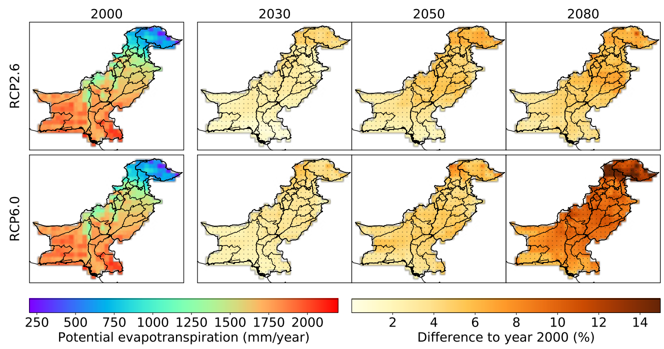


Figure 13: Regional projections of potential evapotranspiration for Pakistan for different GHG emissions scenarios, relative to the year 2000.

© Khalid nawaz / istockphoto

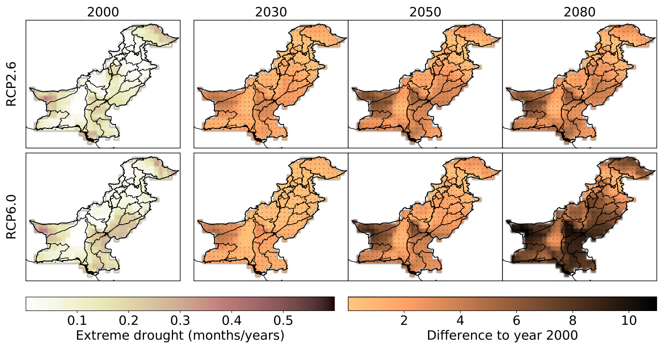


Figure 14: Regional projections of extreme drought for Pakistan for different GHG emissions scenarios, relative to the year 2000.

Drought conditions

Extremely dry months are projected to increase all over Pakistan. Defined by a very negative SPEI (Standardized Precipitation Evapotranspiration Index), extremely dry months describe months with a strong imbalance between precipitation and evapotranspiration, which is of great importance for soil conditions and water reservoirs. Therefore, increased numbers in **extremely dry months are particularly relevant for the planning of agricultural activities and water storage**. Already by 2030, projections show strong model agreement on a positive trend in the number of extremely dry months in most of Pakistan under both RCPs with the strongest increase in western Pakistan by up to 5 more extremely dry months (Figure 14). While maximum local increases under strong mitigation are limited to less than 8 more months per year in western Pakistan, under the more realistic medium/high emissions scenario, the majority of the country displays a stronger change than that by 2080. Regionally, up to 11 more months per year are found under RCP6.0, which translates to **almost constant drought conditions** according to present-day definitions.

Sector-specific climate change risk assessment

Water resources

Current projections of water availability in Pakistan display high uncertainty under both GHG emissions scenarios. Assuming a constant population level, multi-model median projections suggest an increase from 455 m³ per capita per year in 2000 to 457 m³ under RCP2.6 and 629 m³ under RCP6.0 by the end of the century (Figure 15A). Yet, when accounting for population growth according to SSP2 projections[5], **per capita water availability for Pakistan is projected to decline**, i.e. from 482 m³ in 2000 to 204 m³ under RCP2.6 and 282 m³ under RCP6.0 by 2080 (Figure 15B). This comparison points to the fact that a growing population will lead to increased water abstraction for irrigation, drinking water supply and domestic use, which will ultimately lead to reduced water availability [31]. The decline in water availability highlights the urgency to invest in water saving measures and technologies for future water consumption after 2030.

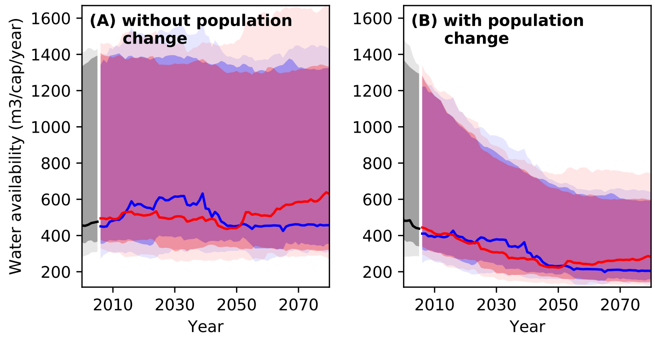


Figure 15: Projections of water availability from precipitation per capita and year with (A) national population held constant at year 2000 level and (B) changing population in line with SSP2 projections for different GHG emissions scenarios.

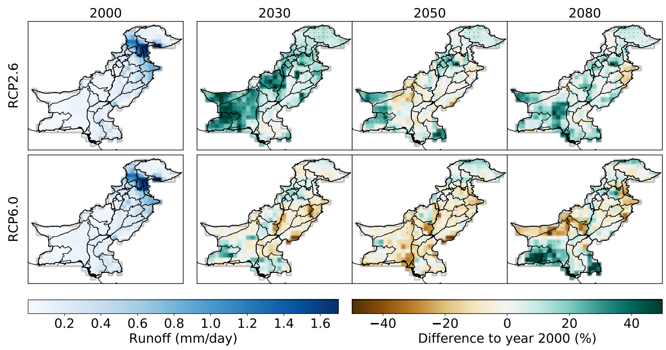


Figure 16: Regional projections of water availability from precipitation (runoff) for Pakistan for different GHG emissions scenarios.

Projections of future water availability from precipitation vary depending on the region and scenario (Figure 16). Water availability is projected to mostly increase under RCP2.6, with the highest increases in parts of Balochistan and Sindh in the early 21st century. Under RCP6.0, only the very south experiences stronger increases in precipitation of up to 77 %. At the same time, other regions, such as northern Balochistan and eastern Punjab, are projected to experience decreases in water availability of up to 50 % under RCP6.0. However, projections are subject to **high modelling uncertainty**, with models agreeing only on changes in northern Balochistan.

Water resources in Pakistan are unevenly distributed. Some regions in Pakistan are, at least for parts of the year, abundant in water resources, most importantly from the **Indus Basin**. This **complex, transboundary water system** is characterised by **seasonal snow** and **glacial melt** from the mountains, which makes up 50–80 % of the Indus water flow, and which is mostly fed by tributaries outside of Pakistan [19]. Other important water resources include **monsoon precipitation** in the period from July to September and **groundwater resources** [19]. In particular water resources from the Indus River allowed for the development of the **Indus Basin Irrigation System (IBIS)**, the largest irrigation system in the world. However, available water resources are under great pressure from Pakistan's **growing population**, which renders per capita water availability relatively low [32]. Further pressures include **inter-sectoral water demands** (e.g. agricultural, industrial, hydropower and household uses), which lead to degradation of water resources, which are already scarce in some regions [19]. Water scarcity is likely to exacerbate in the face of climate change, with **droughts becoming more and more common**: Jamro et al. evaluated meteorological data from the period 1902–2015 and found that southern Pakistan, including Sindh and southern Balochistan, showed a drying trend, pointing to a likely increase of dry spells and droughts in the future [33]. In particular Balochistan is prone to droughts: The province is characterised by a mostly arid climate with annual precipitation sums as low as 39 mm [16]. Unlike other provinces, Balochistan is not part of the Indus Basin, which increases its reliance on smaller, seasonal rivers and groundwater resources, which in many parts of Balochistan are poor in quality, due to **contamination with coliform, toxic metals and pesticides** [34], [35]. Along with water scarcity, **water excess** is likely to increase as a result of rising temperatures and increasing volumes of snow and glacial melt, but also due to more frequent and more intense extreme weather events, such as **heavy precipitation** and **flooding**, particularly during the monsoon. In the Global Climate Risk Index 2020, Pakistan ranked among the five most affected countries in the world when it comes to extreme events in the period 1999–2018, highlighting the urgency for more effective adaptation strategies to protect vulnerable communities [36].

[5] Shared Socio-economic Pathways (SSPs) outline a narrative of potential global futures, including estimates of broad characteristics such as country level population, GDP or rate of urbanisation. Five different SSPs outline future realities according to a combination of high and low future socio-economic challenges for mitigation and adaptation. SSP2 represents the "middle of the road"-pathway.

Agriculture

Smallholder farmers in Pakistan are increasingly challenged by the uncertainty and variability of weather that climate change causes [37], [38]. **Crops are predominantly irrigated** and depend on water availability from melting snow and glacial meltwater. However, **irregular melting of snow and glaciers** on the one hand and **flooding** on the other hand pose challenges to farmers through low discharge and drought on the one hand and flood damages to irrigation channels and cropland on the other hand [39]. For example, the monsoon rains in August 2020 caused severe flooding in Sindh, which led to **widespread crop damages**, particularly to cotton and chili, but also to onions and tomatoes [40]. Although Pakistan has the **largest contiguous irrigation system in the world**, the majority of irrigation facilities remain in poor condition, due to inadequate maintenance and limited storage capacity [32]. In addition, **poor water governance leads to unequal access** between upstream and downstream users with water theft at the top of irrigation canals being increasingly more common, leaving farmers at the bottom of irrigation canals without sufficient water for their crops [41]. What further complicates agricultural production in Pakistan is **soil erosion** [20]. Snow and glacial melting, along with heavy precipitation in summer expedite soil erosion in mountainous and slopy areas, leading to high levels of sedimentation in the plains, which in turn affects the life span and efficiency of water reservoirs [20].

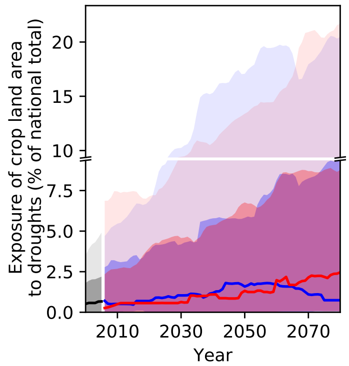


Figure 17: Projections of crop land area exposed to drought at least once a year for all of Pakistan for different GHG emissions scenarios.

Currently, the high uncertainty of projections regarding water availability (Figure 16) translates into high uncertainty of river drought projections, which are defined by low runoff and soil moisture [42] (Figure 17). According to the median over all models employed for this analysis, the **national crop land area exposed to at least one drought per year will increase from 0.52 % in 2000 to 0.74 % (RCP2.6) and 2.46 % (RCP6.0) in 2080.**

© GIZ Pakistan

[6] Projections show the combination of irrigated and non-irrigated crops. For irrigated crops, which outweigh non-irrigated crops, unlimited water availability is assumed.

Under RCP6.0, the likely range of drought exposure of the national crop land area per year widens from 0.01–1.80 % in 2000 to 0.05–8.76 % in 2080. The very likely range widens from 0.00–3.52 % in 2000 to 0.03–21.72 % in 2080. This means that **some models project a six-fold increase of drought exposure over this time period.**

Nationally aggregated data of crop yields[6] show that **climate change will have a negative impact on yields of wheat, rice and maize**, with decreases of 6.0 %, 2.6 % and 12.4 %, respectively, under RCP6.0 (Figure 18). The lower rice yield decrease for RCP6.0, compared to RCP2.6, can be most likely explained by the CO_2 fertilisation effect: Rice is a so-called C3 plant, which follows a different metabolic pathway than maize, which is a C4 plant, and benefits more from higher concentration pathways. While nationally aggregated data of crop yields show a decreasing trend, there are **regional differences in crop yield changes** across different parts of Pakistan.

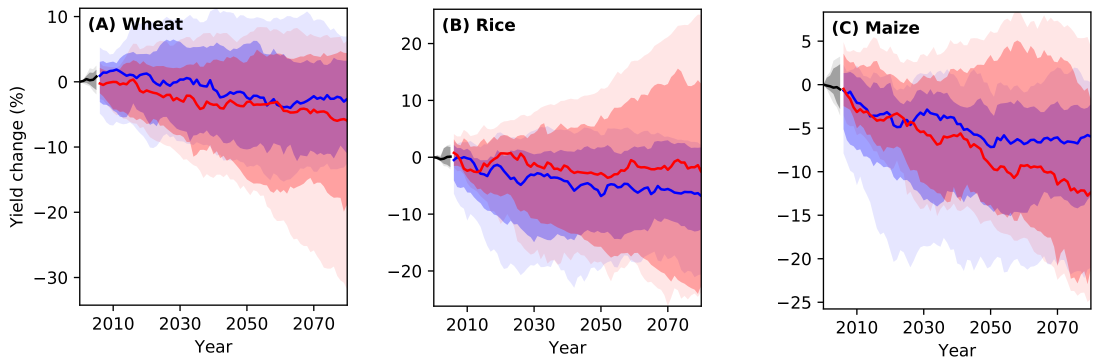


Figure 18: Projections of crop yield changes for wheat, rice and maize for all of Pakistan for different GHG emissions scenarios, assuming constant land use and agricultural management, relative to the year 2000.

Wheat is sensitive to high temperatures above 30 °C, growing best at 25 °C [43], [44]. In Pakistan, it is, therefore, known as a rabi crop, a cool season crop, which is **sown between October and December** and **harvested between March and May** [44]. These characteristics are also reflected in regional yield projections for wheat (Figure 19): Regions, such as Sindh and southern Punjab, which already have annual average temperatures of 27 °C, will be too hot by the end of the century and under RCP6.0 in order to grow wheat. These regions will experience decreases of up to 79 %. However, in other regions, where annual average temperatures are lower today, future temperature increases will provide a more favourable climate for growing wheat and thus lead to average increases of, for example, 10 % in northern Balochistan by the end of the century.

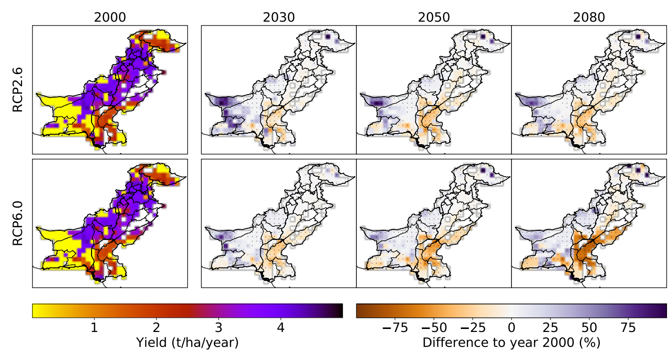


Figure 19: Regional projections of yield changes of wheat for Pakistan for different GHG emissions scenarios, assuming constant land use and agricultural management, relative to the year 2000.

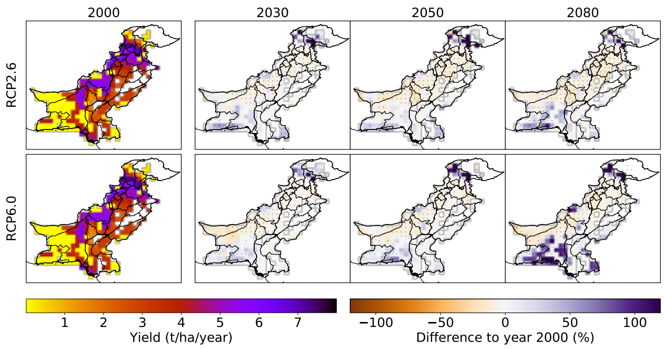


Figure 20: Regional projections of yield changes of rice for Pakistan for different GHG emissions scenarios, assuming constant land use and agricultural management, relative to the year 2000.

The picture is different for **rice**, which **tolerates high temperatures better** than wheat [45]. However, rice is also **a water-intensive crop** [46]. Under RCP6.0, northern **Balochistan and parts of KP and Punjab will experience decreases of up to 39 %** (Figure 20). For these regions models project **decreasing amounts of precipitation and soil moisture** (see Figures 8 and 12). Other regions, however, will see increases in rice yields: In southern Balochistan, these increases will amount to up to 126 % under RCP6.0 by the end of the century.

The regional distribution of climate impacts for maize is similar to that of rice. Maize is projected to increase in northern and southern Pakistan, with increases of up to 106 % in southern Balochistan (Figure 21). It should be noted that these areas will see increases in suitability, however, in absolute terms, yields will remain low. Furthermore, most remaining regions of the country are projected to experience **decreases in maize yields**. The highest decreases are projected for northern Balochistan at 36 % under RCP6.0 by the end of the century. Maize is usually planted at the onset of the monsoon season in July and harvested at the end of the monsoon season in September and is, therefore, referred to as a kharif crop, a warm-season crop [47]. Being **highly sensitive to variability in precipitation**, maize **needs sufficient soil moisture**, particularly for the seed germination process, yet, it **does not tolerate excessive amounts of water** and stagnant water, which blocks the pores of the soil and can lead to yield decreases [47].

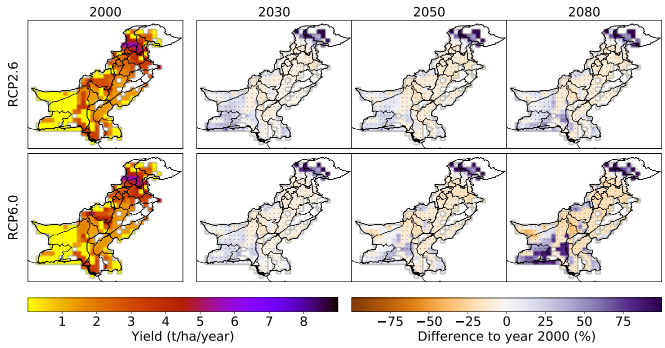


Figure 21: Regional projections of yield changes of maize for Pakistan for different GHG emissions scenarios, assuming constant land use and agricultural management, relative to the year 2000.

Infrastructure

Climate change is expected to affect the infrastructure of Pakistan through extreme weather events. High precipitation amounts can lead to the **flooding of roads**, while high temperatures can cause **roads, bridges and coastal infrastructures to develop cracks and degrade more quickly**. Despite a well-established railway network, road transport remains the backbone of Pakistan's transport system. The spatial distribution and condition of Pakistan's roads, however, is highly unequal: While the segment east of the Indus River is historically well developed, with a relatively dense road network, the **western segment is less developed**, with only few major roads [48]. Furthermore, many roads, in particular in rural areas, become **inaccessible during the monsoon season**, limiting connectivity between agricultural production areas and markets. Hence, investments will have to be made in order to expand and strengthen Pakistan's road network, particularly in the face of likely climate impacts on Pakistan's roads and urban areas (Figure 22 and 23).

Extreme weather events also have **devastating effects on human settlements**, especially in urban areas with high population densities like Karachi or Lahore. **Informal settlements are particularly vulnerable to extreme weather events**: Makeshift homes are often built at unstable geographical locations, including steep slopes or river banks, where strong winds and flooding can lead to loss of housing, contamination of water, injury or death. Dwellers usually have low adaptive capacity to respond to such events due to high levels of poverty and lack of risk-reducing infrastructures. For example, during the **2020 monsoon season**, eastern Karachi recorded a **monthly precipitation record** of 588 mm, where 68 mm would be the norm [49]. This water excess resulted in severe flooding, causing disruptions to energy and water supply and damages to transport links and buildings, particularly in low-lying informal settlements, which lack drainage [50]. Flooding and droughts will also have an impact on hydropower generation: Pakistan draws **32 %** (2020) of its energy **from hydropower** with a total installed capacity of **9,389 MW** (2019) [51], [52]. However, variability in precipitation and **climatic conditions could severely disrupt hydropower generation**.

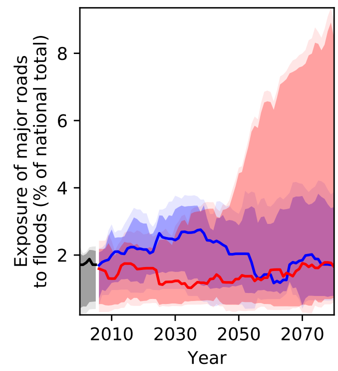


Figure 22: Projections of major roads exposed to river floods at least once a year for all of Pakistan for different GHG emissions scenarios.

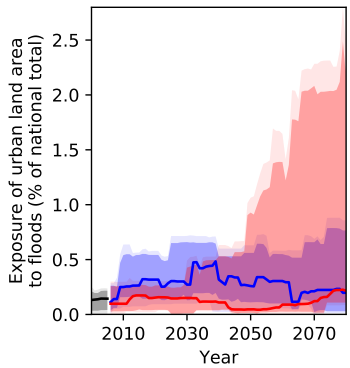


Figure 23: Projections of urban land area exposed to river floods at least once a year for all of Pakistan for different GHG emissions scenarios.

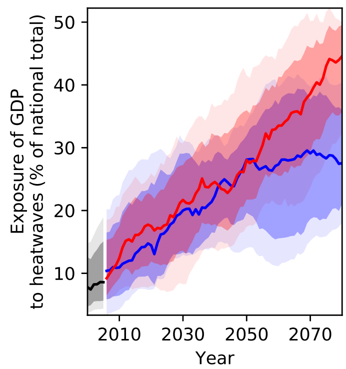


Figure 24: Projections of the exposure of GDP to heatwaves for all of Pakistan for different GHG emissions scenarios.

Despite the risk of infrastructure damage being likely to increase, precise predictions of the location and the extent of exposure are difficult to make. For example, projections of river flood events are subject to substantial modelling uncertainty, largely due to the uncertainty of future projections of precipitation amounts and their spatial distribution (see also Figure 8). In the case of Pakistan, median projections show **little change in national road exposure to river floods** (Figure 22). In the year 2000, 1.71 % of major roads were exposed to river floods at least once a year. By 2080, this value is projected to not change under RCP2.6 and to decrease to 1.65 % under RCP6.0. The **exposure of urban land area to river floods** is projected to also **change only slightly** from 0.13 % in 2000 to 0.20 % under RCP2.6 and 0.22 % under RCP6.0 by the year 2080 (Figure 23). However, model uncertainty is large, and at least one model projects an exposure up to 2.8 % under RCP6.0.

With the **exposure of the GDP to heatwaves projected to increase** from around 7.8 % in 2000 to 27.6 % (RCP2.6) and 44.6 % (RCP6.0) by 2080 (Figure 24), it is recommended that policy planners start identifying heat-sensitive economic production sites and activities, and integrating climate adaptation strategies such as improved solar-powered cooling systems, "cool roof" isolation materials or switching the operating hours from day to night [53].

Ecosystems

Climate change is expected to have a significant influence on the ecology and distribution of tropical ecosystems, though the magnitude, rate and direction of these changes are uncertain [54]. With rising temperatures and increased frequency and intensity of droughts, wetlands and riverine systems are increasingly at risk of being disrupted and altered, with structural changes in plant and animal populations. Increased temperatures and droughts can also impact succession in forest systems while concurrently increasing the risk of invasive species, all of which affect ecosystems. In addition to these climate drivers, low agricultural productivity and population growth might motivate unsustainable agricultural practices resulting in increased deforestation, fires and soil erosion. In turn, soil erosion, along with heavy precipitation and storms, facilitate the occurrence of landslides, threatening human lives, infrastructures and natural resources [55], [56].

Model projections of species richness (including amphibians, birds and mammals) and tree cover for Pakistan are shown in Figure 25 and 26, respectively[7]. The models applied for this analysis show particularly strong agreement on the development of species richness: Under RCP6.0, species richness is expected to increase in most parts of Pakistan, in particular in north-western Punjab and along the border of Punjab with KP and Balochistan, where increases amount to 80 %, compared to 2010 (Figure 25). Only western and southern Balochistan as well as northern Pakistan will see decreases in species richness of up to 19 %. With regard to tree cover, model results are more uncertain and almost no changes are projected under both RCPs (Figure 26). Hence, no clear trend regarding tree cover can be identified.

It is important to keep in mind that the **model projections exclude any impacts on biodiversity loss from human activities, such as land use**, which have been responsible for significant losses of global biodiversity in the past, and are expected to remain its main driver in the future [57]. These impacts can also be observed in the case of Pakistan, where deforestation is a major issue: The country has **lost 1.2 million ha of tree cover** between 1991 and 2020, which is equivalent to a **25 % decrease** of national forest area [58]. Ullah et al. studied the socio-economic factors behind deforestation in Gilgit Baltistan in northern Pakistan and found that population pressure, increasing demand for firewood, lack of education and poor forest management were prominent drivers of deforestation [59].

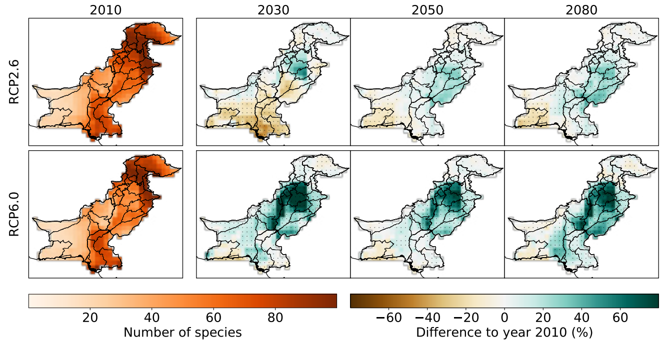


Figure 25: Regional projections of the aggregate number of amphibian, bird and mammal species for Pakistan for different GHG emissions scenarios.

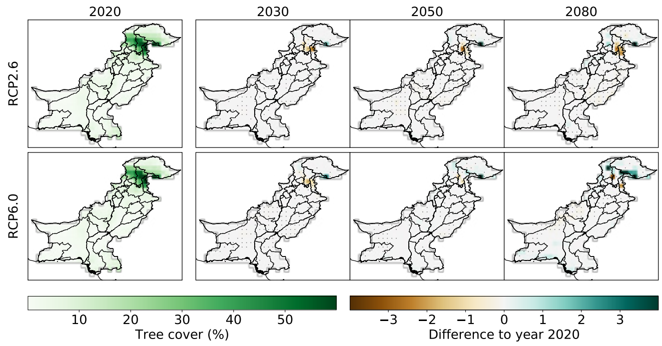


Figure 26: Regional projections of tree cover for Pakistan for different GHG emissions scenarios.

[7] Note that the baseline year for Figure 25 is 2010 due to pre-averaged output of the Global Vegetation Models. For Figure 26, the baseline year is 2020 to avoid the effect of changing land use in the historical simulations.

Health

Among the **key health challenges** in Pakistan are morbidity and mortality through vector-borne diseases, such as malaria or dengue, and water-borne diseases related to extreme weather events [60], [61]. For example, flooding increases prevalence of diarrhoea. Furthermore, respiratory diseases, tuberculosis, hepatitis B and C, and HIV are widespread. Many of these challenges are **expected to become more severe under climate change**, which poses a threat to the health and sanitation sector through more frequent incidences of heatwaves, droughts, storms and floods.

Climate change is likely to have an **impact on the occurrence and geographic range of vector-borne diseases**: Heavy monsoon precipitation, along with poor flood control and water disposal facilities, have led to repeated **dengue fever** outbreaks in the city of Karachi, most recently in 2020 [62], [63]. In a similar way, **malaria** outbreaks continue to be reported during the summer months, when temperatures and humidity are the highest [64]. Temperature increases could provide more favourable conditions for mosquito habitats and their reproduction and thus help to expand malaria occurrence to higher-lying areas, which have previously been free of malaria [65], [66].

Climate change also increases the frequency and severity of droughts and poses thereby a **threat to agricultural production and food security**, increasing the **risk of hunger and malnutrition**, particularly for subsistence farmers [67]. A study of Thatta and Sujawal districts in Sindh found that malnutrition among children under the age of five was widespread: Stunting was prevalent in 48.2 % of children under the age of five and underweight in 39.5 % [68]. Malnutrition has further exacerbated due to the consequences of the **COVID-19 pandemic**, including through **higher food prices** and **reduced purchasing power** [69]: A study found that the pandemic affects dietary diversity and nutritional security, leading to declines in daily nutrients and in the share of daily meat consumption [70]. This was particularly true for female-led households. The pandemic has also increased the pressure on the healthcare system, access to which is unequal in Pakistan. This is particularly true for **healthcare in rural areas**, which is characterised by staff absenteeism and long distances to health facilities; and even more so for women, who often have limited autonomy in household decision-making as well as in unassisted travel [71], [72].

© Mike Abrahams / Alamy Stock

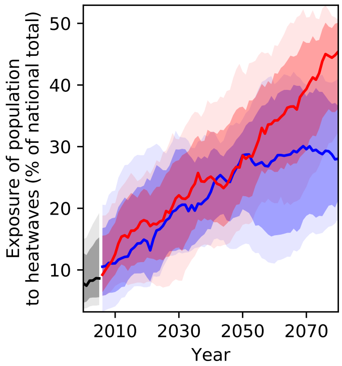


Figure 27: Projections of population exposure to heatwaves at least once a year for all of Pakistan for different GHG emissions scenarios.

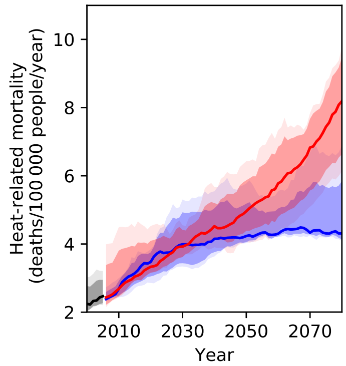


Figure 28: Projections of heat-related mortality for all of Pakistan for different GHG emissions scenarios assuming no adaptation to increased heat.

Rising temperatures will result in **more frequent heatwaves** in Pakistan, leading to **increased exposure to heatwaves and increased heat-related mortality.** Under RCP6.0, the **population affected by at least one heatwave per year is projected to increase from 7.8 % in 2000 to 45.4 % in 2080** (Figure 27). Heatwaves particularly affect the elderly, children, the chronically ill and occupational groups, who spend a lot of time outdoors, such as farmers or pastoralists. Furthermore, under RCP6.0, **heat-related mortality will increase from 2.3 to 8.2 deaths per 100,000 people per year by 2080**, which translates to an increase by a factor of more than 3.5 towards the end of the century, compared to year 2000 levels and provided that no adaptation to hotter conditions will take place (Figure 28). Under RCP2.6, heat-related mortality is projected to increase to 4.3 deaths per 100 000 people per year in 2080, however, with a flattening trend already after 2030, highlighting the effect of strong mitigation under this low-emissions scenario.

References

[1] CIA World Factbook, “Pakistan,” 2021. https://www.cia.gov/the-world-factbook/countries/pakistan/ (accessed Jun. 14, 2021).

[2] World Bank, “World Bank Open Data,” 2019. https://data.worldbank.org/ (accessed Jan. 31, 2020).

[3] World Bank, “World Bank Development Indicators,” 2019. https://databank.worldbank.org/source/world-development-indicators (accessed Sep. 22, 2020).

[4] FAOSTAT, “Crops in Pakistan,” 2019. http://www.fao.org/faostat/en/#data/QC (accessed Jun. 21, 2021).

[5] Observatory of Economic Complexity, “Pakistan,” 2017. https://legacy.oec.world/en/profile/country/pak (accessed Jun. 14, 2021).

[6] Ministry of National Food Security and Research of Pakistan, “Agricultural Statistics of Pakistan 2017–18,” Islamabad, Pakistan, 2019.

[7] FAO, “FAOSTAT Database.” http://www.fao.org/faostat/en/#data/QC (accessed Dec. 07, 2020).

[8] AQUASTAT, “Irrigation and Drainage Development in Pakistan,” 2017. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en (accessed Jul. 05, 2021).

[9] IFAD, “Pakistan,” 2021. https://www.ifad.org/en/web/operations/w/country/pakistan (accessed Jun. 21, 2021).

[10] UNDESA, “Trends in International Migrant Stock: Migrants by Destination and Origin,” New York, 2019.

[11] IOM, “Pakistan Migration Snapshot: August 2019,” Bangkok, Thailand, 2019.

[12] World Bank, “Migrant Remittance Inflows (US$ Millions),” Washington, D.C., 2021.

[13] UNDP, “Human Development Index,” 2018. http://hdr.undp.org/en/indicators/137506# (accessed Oct. 08, 2019).

[14] Notre Dame Global Adaptation Initiative, “ND-Gain Ranking Since 1995 Pakistan,” 2019. https://gain-new.crc.nd.edu/country/pakistan (accessed Oct. 04, 2021).

[15] FAO, IFAD, UNICEF, WFP, and WHO, “The State of Food Security and Nutrition in the World,” Rome, Italy, 2020.

[16] S. Lange, “EartH2Observe, WFDEI and ERA-Interim Data Merged and Bias-Corrected for ISIMIP (EWEMBI).” GFZ Data Service, Potsdam, Germany, 2016, doi: 10.5880/pik.2016.004.

[17] PreventienWeb, “International Conference on Climate and Environmental Change Impacts on the Indus Basin Waters,” 2016. https://www.preventionweb.net/events/view/47646?id=47646 (accessed Jun. 23, 2021).

[18] Y. Wada et al., “Co-Designing Indus Water-Energy-Land Futures,” One Earth, vol. 1, no. 2, pp. 185–194, 2019, doi: 10.1016/j.oneear.2019.10.006.

[19] M. A. Watto, M. Mitchell, and T. Akhtar, “Pakistan’s Water Resources: Overview and Challenges,” in Water Resources of Pakistan: Issues and Impacts, M. A. Watto, M. Mitchell, and S. Bashir, Eds. Cham, Switzerland: Springer Nature, 2021.

[20] S. Bashir, A. Javed, I. Bibi, and N. Ahmad, “Soil and Water Conservation,” in Soil Science: Concepts and Applications, I. A. Khan and M. Farooq, Eds. Faisalabad, Pakistan: University of Agriculture Faisalabad, 2017.

[21] A. N. Khan and A. Ali, “Desertification Risk Reduction Approaches in Pakistan,” in Disaster Risk Reduction Approaches in Pakistan, A.-U. Rahman, A. N. Khan, and R. Shaw, Eds. Tokyo, Japan: Springer Japan, 2015.

[22] S. Baloch, F. K. Chang, H.-R. Mangio, M. Sana, and M. I. Kumbhar, “Deterioration of Ground Water Quality through Seawater Intrusion in Coastal Area of,” Int. J. Environ. Sci. Nat. Resour., vol. 20, no. 5, pp. 0149–0157, 2019, doi: 10.19080/IJESNR.2019.20.556048.

[23] H. Magsi and M. J. Sheikh, “Seawater Intrusion: Land Degradation and Food Insecurity Among Coastal Communities of Sindh, Pakistan,” in Regional Cooperation in South Asia, S. Bandyopadhyay, A. Torre, P. Casaca, and T. Ponce Dentinho, Eds. Heidelberg, Germany: Springer International Publishing, 2017.

[24] S. Shah, “Pakistan’s Indus Delta Becoming No Man’s Land,” 2019. https://www.thethirdpole.net/en/climate/pakistans-indus-delta (accessed Jul. 08, 2021).

[25] T. A. Carleton and S. M. Hsiang, “Social and economic impacts of climate,” Science (80-.)., vol. 353, 2016, doi: 10.1126/science.aad9837.

[26] N. Christidis, D. Mitchell, and P. A. Stott, “Anthropogenic climate change and heat effects on health,” Int. J. Climatol., vol. 39, no. 12, pp. 4751–4768, 2019, doi: 10.1002/joc.6104.

[27] A. Amin et al., “Regional climate assessment of precipitation and temperature in Southern Punjab (Pakistan) using SimCLIM climate model for different temporal scales,” Theor. Appl. Climatol., vol. 131, no. 1–2, pp. 121–131, 2018, doi: 10.1007/s00704-016-1960-1.

[28] K. Ahmed et al., “Quantitative assessment of precipitation changes under CMIP5 RCP scenarios over the northern sub-Himalayan region of Pakistan,” Environ. Dev. Sustain., vol. 22, no. 8, pp. 7831–7845, 2020, doi: 10.1007/s10668-019-00548-5.

[29] M. Ashraf and J. K. Routray, “Spatio-Temporal Characteristics of Precipitation and Drought in Balochistan Province, Pakistan,” Nat. Hazards, vol. 77, pp. 229–254, 2015, doi: 10.1007/s11069-015-1593-1.

[30] S. R. Samo, N.-K. Bhatti, A. Saand, M. A. Keerio, and D. K. Bangwar, “Temporal Analysis of Temperature and Precipitation Trends in Shaheed Benazir Abad Sindh, Pakistan,” Eng. Technol. Appl. Sci. Res., vol. 7, no. 6, pp. 2171–2176, 2017.

[31] M. Kerres et al., “Stop Floating, Start Swimming: Water and Climate Change - Interlinkages and Prospects for Future Action,” Bonn, Germany, 2020.

[32] W. J. Young et al., “Pakistan: Getting More from Water,” Washington, D.C., 2019.

[33] S. Jamro, G. H. Dars, K. Ansari, and N. Y. Krakauer, “Spatio-temporal variability of drought in Pakistan using standardized precipitation evapotranspiration index,” Appl. Sci., vol. 9, no. 21, 2019, doi: 10.3390/app9214588.

[34] M. M. Akhtar, A. D. Mohammad, M. Ehsan, R. Akhtar, J. ur Rehman, and Z. Manzoor, “Water resources of Balochistan, Pakistan — a review,” Arab. J. Geosci., vol. 14, no. 4, 2021, doi: 10.1007/s12517-021-06502-y.

[35] S. Kanwa, M. K. Taj, I. Taj, F. Abbas, Z. Samreen, and T. M. Hassani, “Water Pollution in Balochistan Province of Pakistan,” Int. J. Eng. Appl. Sci., vol. 2, no. 6, 2015.

[36] D. Eckstein, V. Künzel, L. Schäfer, and M. Winges, “Briefing Paper: Global Climate Risk Index 2020,” Berlin, Germany, 2019.

[37] M. Waseem et al., “Spatiotemporal dynamics of precipitation in southwest arid-agriculture zones of Pakistan,” Sustainability, vol. 12, no. 6, 2020, doi: 10.3390/su12062305.

[38] S. Fahad and J. Wang, “Farmers’ risk perception, vulnerability and adaptation to climate change in rural Pakistan,” Land use policy, vol. 79, no. April, pp. 301–309, 2018, doi: 10.1016/j.landusepol.2018.08.018.

[39] M. Z. Khan, H. Abbas, and A. Khalid, “Climate vulnerability of irrigation systems in the Upper Indus Basin: Insights from three Karakoram villages in northern Pakistan,” Clim. Dev., pp. 1–13, 2021, doi: 10.1080/17565529.2021.1944839.

[40] M. H. Khan, “Rain spells disaster for Sindh’s agriculture sector,” Dawn, Sep. 07, 2020.

[41] Z. Ebrahim, “Irrigation in Pakistan: Water theft drains Indus canals dry,” The Third Pole, 2019.

[42] S. Lange et al., “Projecting Exposure to Extreme Climate Impact Events Across Six Event Categories and Three Spatial Scales,” Earth’s Futur., vol. 8, no. 12, pp. 1–22, 2020, doi: 10.1029/2020EF001616.

[43] S. Narayanan, “Effects of high temperature stress and traits associated with tolerance in wheat,” Open Access J. Sci., vol. 2, no. 3, pp. 177–186, 2018, doi: 10.15406/oajs.2018.02.00067.

[44] National Agromet Centre, “Weather & Wheat Crop Development in Central Punjab (Faisalabad) (2014 – 2015),” Islamabad, Pakistan, 2015.

[45] S. Abbas and Z. A. Mayo, “Impact of temperature and rainfall on rice production in Punjab, Pakistan,” Environ. Dev. Sustain., vol. 23, no. 2, pp. 1706–1728, 2021, doi: 10.1007/s10668-020-00647-8.

[46] M. A. ur R. Naseer, M. Ashfaq, A. Razzaq, and Q. Ali, “Comparison of water use efficiency, profitability and consumer preferences of different rice varieties in Punjab, Pakistan,” Paddy Water Environ., vol. 18, no. 1, pp. 273–282, 2020, doi: 10.1007/s10333-019-00780-9.

[47] K. Rashid and G. Rasul, “Rainfall Variability and Maize Production over the Potohar Plateau of,” Pakistan J. Meteorol., vol. 8, no. 15, pp. 63–74, 2009.
[48] Finance Division of the Government of Pakistan, “Pakistan Economic Survey 2020-21,” Islamabad, Pakistan, 2021.
[49] Pakistan Meteorological Department, “State of Pakistan’s Climate in 2020,” Islamabad, Pakistan, 2020.
[50] WFP, “WFP Pakistan: Sindh Flood Response (Situation Report #1),” Rome, Italy, 2020.
[51] WAPDA, “Highest-ever hydel contribution by WAPDA in 1st quarter of 2019-20,” 2019. https://wapda.gov.pk/index.php/newsmedia/news-views/458-highest-ever-hydel-contribution-by-wapda-in-1st-quarter-of-2019-20 (accessed Oct. 03, 2021).
[52] WAPDA, “Hydel share in total electricity generation increased to 32% in FY 20 compared to 26% in FY 19; reducing reliance on costlier production.” http://www.wapda.gov.pk/index.php/newsmedia/news-views/519-hydel-share-in-total-electricity-generation-increased-to-32-in-fy-20-compared-to-26-in-fy-19-reducing-reliance-on-costlier-production (accessed Oct. 03, 2021).
[53] M. Dabaieh, O. Wanas, M. A. Hegazy, and E. Johansson, “Reducing Cooling Demands in a Hot Dry Climate: A Simulation Study for Non-Insulated Passive Cool Roof Thermal Performance in Residential Buildings,” Energy Build., vol. 89, pp. 142–152, 2015, doi: 10.1016/j.enbuild.2014.12.034.
[54] T. M. Shanahan et al., “CO_2 and Fire Influence Tropical Ecosystem Stability in Response to Climate Change,” Nat. Publ. Gr., no. July, pp. 1–8, 2016, doi: 10.1038/srep29587.
[55] M. U. Rehman, Y. Zhang, X. Meng, X. Su, and F. Catani, “Analysis of Landslide Movements Using Interferometric Synthetic Aperture Radar: A Case Study in Hunza-Nagar Valley, Pakistan,” Remote Sens., vol. 12, no. 2054, pp. 1–19, 2020.
[56] H. Gilani, A. Ahmad, I. Younes, S. Abbas, and H. Gilani, “Estimation of annual soil erosion dynamics (2005 - 2015) in Pakistan using Revised Universal Soil Loss Equation (RUSLE),” Authorea, vol. January, pp. 1–21, 2021.
[57] IPBES, “Report of the Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on the Work of Its Seventh Session,” n.p., 2019.
[58] World Bank, “World Bank Open Data,” 2020. https://data.worldbank.org/ (accessed Oct. 03, 2021).
[59] S. Ullah, T. Gang, T. Rauf, F. Sikandar, and J. Qi, “Identifying the socio-economic factors of deforestation and degradation: a case study in Gilgit Baltistan, Pakistan,” GeoJournal, vol. 11 Novembe, 2020, doi: 10.1007/s10708-020-10332-y.
[60] Ministry of National Health Services Regulations and Coordination, “National Health Vision: 2016-2025,” Islamabad, Pakistan.
[61] WHO, “Pakistan country cooperation strategy at a glance,” Rome, Italy, 2018.
[62] M. Junaid Tahir, A. Rizwan Siddiqi, I. Ullah, A. Ahmed, J. Dujaili, and M. Saqlain, “Devastating urban flooding and dengue outbreak during the COVID-19 pandemic in Pakistan,” Med. J. Islam. Repub. Iran, vol. 2020, no. 7, pp. 14–15, 2020, doi: 10.47176/mjiri.34.169.
[63] J. Khan, “Outbreak Investigation of Dengue Fever in District Malir, Karachi, Sindh, Pakistan, 2015,” EMPHNET Sixth Reg. Conf., vol. 4, no. 1, 2018.
[64] UN News, “UN responds to malaria outbreak in flood-affected Pakistani provinces,” 2010. https://news.un.org/en/story/2010/10/355562-un-responds-malaria-outbreak-flood-affected-pakistani-provinces (accessed Oct. 02, 2021).
[65] E. A. Mordecai et al., “Optimal temperature for malaria transmission is dramatically lower than previously predicted,” Ecol. Lett., vol. 16, no. 1, pp. 22–30, 2013, doi: 10.1111/ele.12015.
[66] A. S. Siraj, M. Santos-Vega, M. J. Bouma, D. Yadeta, D. Ruiz-Carrascal, and M. Pascual, “Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia,” Sciences (New. York)., vol. 343, no. 1154, 2014, doi: 10.1126/science.1244325.
[67] M. P. Iqbal, “Effect of Climate Change on Health in Pakistan,” Life Environ. Sci., vol. 57, no. 3, pp. 1–12, 2020.
[68] G. N. Khan et al., “Prevalence and associated factors of malnutrition among children under-five years in Sindh, Pakistan: a cross-sectional study,” BMC Nutr., vol. 2, no. 69, pp. 1–7, 2016, doi: 10.1186/s40795-016-0112-4.
[69] I. Idris, “Areas and population groups in Pakistan most exposed to combined effects of climate change, food insecurity and COVID-19,” K4D Knowledge, Evid. Learn. Dev., vol. 8 March, 2021.
[70] P. Shahbaz, S. ul Haq, U. Bin Khalid, and I. Boz, “Gender-based implications of the COVID-19 pandemic on household diet diversity and nutritional security in Pakistan,” Br. Food J., 2021, doi: 10.1108/BFJ-05–2021-0464.
[71] Alliance for Health Policy and Systems Research, “Primary Care Systems Profiles & Performance (PRIMASYS): Pakistan Case Study,” Geneva, Switzerland, 2017.
[72] S. S. Habib, W. Z. Jamal, S. Mohammad, A. Zaidi, and J. Siddiqui, “Barriers to Access of Healthcare Services for Rural Women — Applying Gender Lens on TB in a Rural District of Sindh, Pakistan,” Int. J. Environ. Res. Public Health, vol. 18, no. 10102, 2021.

List of abbreviations

GDP Gross Domestic Product
GHG Greenhouse Gas
HDI Human Development Index
HIV Human Immunodeficiency Virus
IBIS Indus Basin Irrigation System
ILO International Labor Organization
INDC Intended Nationally Determined Contributions
ISIMIP Inter-Sectoral Impact Model Intercomparison Project
LMIC Lower Middle-Income Country
PPP Purchasing Power Parity
RCP Representative Concentration Pathway
SPEI Standardized Precipitation Evapotranspiration Index

This climate risk profile was commissioned and is conducted on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) in close cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) as the implementing partner.

The climate risk profile is based on data and analysis generated as part of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), which is gratefully acknowledged. Background information about the figures and analysis presented in this profile is available in the Climate Risk Profile – Supplemental Information.

On behalf of:
Federal Ministry for Economic Cooperation and Development (BMZ)
BMZ Bonn
Dahlmannstraße 4
53113 Bonn, Germany
www.bmz.de

Scientific content developed by:
Potsdam Institute for Climate Impact Research (PIK)
Telegraphenberg A 31
14473 Potsdam, Germany
www.pik-potsdam.de

Scientific coordination:
Christoph Gornott (PIK)

Main authors:
Julia Tomalka (PIK),
Stefan Lange (PIK),
Stephanie Gleixner (PIK),
Sebastian Ostberg (PIK),
Christoph Gornott (PIK)

Contributors:
Ylva Hauf (PIK),
Baptiste Chatré (GIZ),
Muhammad Abid (GIZ),
Godefroy Grosjean (CIAT),
James Giles (CIAT),
Sher Shah Hassan (Consultant)

Published and implemented by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH