Climate Risk Profile Iraq*

Summary

In Iraq, concerns are rising about the effects of climate change. In the last decades, the country has recurrently experienced heavy drought and flooding. Extreme heat-waves and air temperatures are already a major challenge, especially in the south of the country. Declines in water quantity and quality contribute to growing food and water insecurity, increase the risks associated with displacement, and undermine local and regional stability in Iraq.

This profile provides an **overview of projected climate parameters and related impacts** on different sectors in Iraq until 2080 **under different climate change scenarios provided by the IPCC**[1] (called Representative Concentration Pathways, RCPs). RCP2.6 represents a low emissions scenario that aims to keep global warming below 2 °C above pre-industrial temperatures; RCP6.0 represents a medium to high emissions scenario. **Model projections do not account for effects of future socioeconomic impacts.**

Air temperature: Depending on the climate change scenario, temperature in Iraq is projected to very likely **rise by between 1.6 and 2.4 °C by 2030, 1.9 and 3.2 °C by 2050, and 1.8 and 4.8 °C by 2080**, compared to pre-industrial levels. Rising air temperatures will affect the whole country, with the strongest increase in the northeast. Furthermore, the annual number of days with a maximum temperature above 35 °C is projected to rise with high certainty all over Iraq. **The rise will be highest in the northeast and the west**, with an increase of more than 20 very hot days by 2030, in comparison to the year 2000. In the rest of Iraq, the increase will be lower, amounting to between 8 and 12 additional very hot days by 2030 under both emissions scenarios.

Health: Rising temperatures and the increasing number of very hot days will very likely result **in higher rates of heat-related mortality.** According to the best estimates, heat-related fatalities will increase from 1.6 deaths per 100 000 people and year in 2000 to 3.0 and 3.2 deaths per 100 000 people and year until 2030 under RCP6.0 and RCP2.6, respectively.[2] By **2080, heat-related deaths will rise to 3.8 (RCP2.6) and 7.4 (RCP6.0) deaths per 100 000 people annually.** Under a high emissions scenario, temperature extremes will exceed a **threshold for human habitability in many cities in the Middle East and North Africa (MENA) region towards the end of the century** [1].

Sea level rise[4]**:** The sea level is **projected to rise with high certainty under both emissions scenarios affecting the Southern Basra Governorate.** The median of all climate models projects a sea level rise of 9.6 cm by 2030, 17.9 cm by 2050 and 30.2 cm by 2080 under RCP2.6, compared to the year 2000. Under RCP6.0, the sea level will rise by 9.1 cm until 2030, 17.9 cm until 2050, and 36.1 cm until 2080, according to the multi-model median. **Under a high emissions scenario, Iraq's second-largest city Basra could be largely inundated by water by 2050** [2].

Infrastructure: Until 2030, the **exposure of urban land area to river floods is projected to hardly change** under either RCP. Depending on the scenario and time period, urban land exposure to riverine flooding will very likely fluctuate between 0.05 and 0.80 % between 2000 and 2050.

Precipitation: Precipitation projections are much **less certain than temperature projections.** While under RCP2.6, models agree on an **increase in inter-annual variabilities, no clear direction of change in average precipitation levels can be derived. Under RCP6.0, however, despite inter-annual variabilities, precipitation will decrease over time** with the west and south of the country being most strongly affected.

Future projections regarding heavy precipitation events are uncertain. No clear trend can be derived under RCP2.6; the projections under RCP6.0 assume a slight decrease with

Water availability: Projections of water availability in Iraq are **highly uncertain under both GHG emissions scenarios.** Without accounting for future population growth, water availability is projected to very likely range between 541 and 3 883 m³ per year by 2080 under RCP2.6, and between 384 and 3 475 m³ under RCP 6.0. **When accounting for population growth, per capita water availability for Iraq will very likely sharply decline under both scenarios.** Despite this clear decrease, however, **model agreement is extremely low.** Projections range between 307 and 1 850 m³ (multi-model median of 479 m³) under RCP2.6, and between 279 and 1 787 m³ (multi-model median of 426 m³) under RCP6.0 per person and year by 2030. This decrease will continue to decline throughout 2080. By 2080, per capita water availability is projected to very likely range between 161 and 1160 m³ (multi-model median of 317 m³) under RCP2.6, and between 116 and 1035 m³ (multi-model median of 261 m³) under RCP6.0. In light of the water stress threshold of 1700 m³ per person and year, these projections should be taken as a warning sign, even if they are highly uncertain.

* This Climate Risk Profile draws on the methodology developed within the AGRICA project which is hosted at PIK.

1 For a shorter summary of the information presented in this risk profile, please see Summary for Policymakers.

2 The differences between the RCPs by 2030 are often very small, and impacts by 2030 may even be slightly higher under RCP2.6 than under RCP6.0. The reason is that the climate system responds relatively slowly to changes in the concentration of greenhouse gases.

3 The symbol displayed here indicates the projections which are subject to high levels of uncertainty. These projections must be interpreted cautiously. For further explanations on uncertainties and how to deal with them, please see the text box "Uncertainties in climate change projections" on page 6.

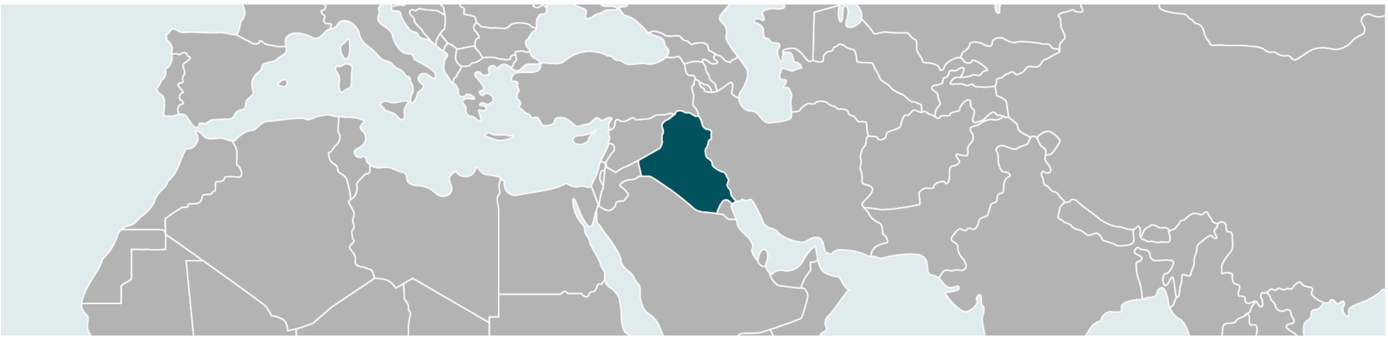
4 The sea level rise projection is based on two global climate models only, which limits the certainty of the projection.

Agricultural yields: Wheat yields are projected to increase across all models, despite inter-decadal variabilities. **Maize yields will decline**, particularly along Iraq's eastern border. For both crop types, however, uncertainties around the magnitude of the projected increase (wheat) and decrease (maize) rises with time. For future projections on **rice yields, no clear trend can be derived**. Furthermore, potential evapotranspiration, an important indicator for drought conditions and thus agricultural productivity [4], is projected to increase, though the magnitude of increase is highly uncertain.

Exposure to heatwaves: Rising temperatures and the **increasing number of very hot days will result in an increased exposure to heatwaves**. Depending on the scenario, by 2030, **between around 12 and 36 % of the total population will be exposed to heatwaves annually** (very likely range). Exposure to heatwaves will continue to increase sharply until 2080 under both scenarios. However, **modelling uncertainty about the magnitude of the increase are relatively large and become even more pronounced from 2050 onward.**

GDP exposure: The **exposure of the Iraqi GDP to heatwaves is very likely to strongly increase** under both GHG emissions scenarios, though the magnitude of increase is subject to high modelling uncertainty, and uncertainty grows the further one looks into the future. Depending on the GHG emissions scenario, by 2030, between approximately 13 and 35 % of the GDP of Iraq will very likely be exposed to heatwaves. Under RCP6.0, GDP exposure is projected to rise to around 28 to 57 % by 2080 (very likely range).

Ecosystems: The uncertainty of projections of species richness is very high under both emissions scenarios. Sparse data coverage in central and southern Iraq does not allow for projections in these parts of the country. Model agreement on the direction of change in tree cover is equally low and, consequently, no reliable conclusions can me made under either RCP.



General context

The Republic of Iraq is located in the Middle East, bordering Turkey, Syria, Jordan, Saudi Arabia and Kuwait, and has a 58 km coastline on the Persian Gulf. The estimated **total population is 39.3 million** [5]. With an **annual demographic growth rate of 2.3 %**, its population is expected to increase to nearly 80 million by 2050 [5]. **Over 70 % of the population lives in urbanized areas**. The current urbanization rate is 2.6 % [5]. With over 7.3 million inhabitants, the **capital Baghdad** is by far the most populous city in the country [6]. The country's population is largely concentrated in northern, central, and eastern Iraq, with many of the larger cities located along the two major rivers Euphrates and Tigris [7].

Iraq is an **upper middle-income country** [5]. Its **economy heavily relies on its oil exports**, which provide for approximately 85 % of national government revenues [7] [8]. Crude petroleum, refined petroleum and gold are Iraq's major export commodities [9]. In 2020, making up 54 % of the national GDP, the service sector accounted for the largest share of GDP, followed by the industrial sector (41 %) and the agricultural sector (6 %) [5].

Over the last decades, Iraq has transitioned from a smallholder-based food-producing country to a food-importing nation [10]. **Agricultural productivity declined from around 26 % of the country's GDP in 1995 to only 6 % in 2020**, mainly as a consequence of market disruptions and widespread displacement of rural communities during the so-called ISIS (Islamic State of Iraq and Syria) crises [10]. Nevertheless, the agricultural sector still **employs around one fifth of the population** [5]. The majority of agricultural production occurs on smallholder farms with an average farm size of less than 25 hectares [10]. **Crop production makes up around 75 % of agricultural activities**, while the rest is related to livestock or mixed crop and livestock production systems [10] [11]. **Important staple crops include wheat, barley, rice and maize. Dates** are a **major cash crop** [12] [13]. While agriculture in the northern parts of the country is generally rainfed, in the south it depends on irrigation from the Euphrates and Tigris rivers [13]. In 2018, 55 % of the estimated irrigation potential of 5 554 000 ha was equipped for irrigation [14].

Concerns are rising about the **effects of climate change**. In the last decades, the country has recurrently experienced **heavy droughts and floodings.** Specifically, rising temperatures and reduced precipitation have contributed to increasing water shortages and severe droughts between 1998-2000 and 2007-2009 [15]. **Extremely low precipitation levels** during the winter of 2017/2018 made 2018 the driest year that has been recorded so far [16].

The **increased water scarcity contributes to growing food and water insecurity and related displacement.** For example, in July 2019, over 21 000 Iraqis from southern and central Iraq left their homes due to water shortages [17]. Heavy drought in 2021 resulted in one out of every two families in drought-affected areas needing food assistance, leading to significant displacements [18]. Further, declines in water quantity and quality increase the **risks associated with displacement as well as tensions over access regulation.** They also **pose a risk to regional stability** [15].

Climate change impacts are expected to affect Iraq's economic sectors in different ways: On the one hand, Iraqi agricultural productivity will be increasingly undermined by climate impacts, including decreasing water availability and rising temperatures [19]. On the other hand, **the transition towards a green economy** will reduce the global demand for crude oil, with a high risk of turning oil reserves and related investments **into stranded assets.**[5] In light of the economy's enormous dependence on fossil fuels, diversification of the economic sector is essential to prevent major economic losses, increasing poverty and instability [20].

According to the Fragile State Index[6], Iraq ranked as the **19th most fragile state in the world** in 2021 [21]. **Successive crises** triggered by decades of ethno-religious tensions, authoritarian rule, armed conflict and the **occupation by the ISIS from 2014 to 2017 have severely destabilized the country** and **negatively impacted its political and socio-economic development. More than 3 million Iraqis were internally displaced** after ISIS took control over large parts of the country in 2014. An additional 260 000 people have sought refuge in neighbouring countries [22]. As conflict receded in 2017, international organizations and the government supported Internally Displaced Persons (IDPs) and refugees in their return, and the number of IDPs decreased from 3.28 million in 2014 to 1.22 million by the end of 2020 [23]. Despite regained control over the contested territories by the Iraqi government in 2017, **socio-economic difficulties, insecurity and political instability persist,** as armed group attacks and small military operations continue throughout the country. Due to this **insecurity and political instability**, **combined with the effects of climate change**, an estimated **18 % of Iraq's population remains in need of humanitarian assistance** [22].

Quality of life indicators

Human Development Index (HDI) 2019	ND-GAIN Vulnerability Index 2019	GINI Coefficient 2012	GDP per capita 2020	Poverty headcount ratio 2012	Prevalence of undernourishment 2018
0.674 **123 out of 189** (0 = low, 1 = high)	**43.6** **(115 out of 182)**	**29.5** (0–100; 100 = perfect inequality)	**4.927** (constant 2010 USD)	**1.7%** (at 1.90 USD per day, 2022, PPP)	**23.7 %**

[5] [24] [25] [26]

Topography and environment

Iraq's topography is characterised by **mountainous terrain in the northeast along the borders with Iran and Turkey**, with altitudes ranging between around 1 000 and 3 000 m above sea level, reaching a maximum elevation of 3 611 m at Cheekha Dar (Kurdish for "Black Tent") in the northeast of the country (Figure 1). Southwards, the mountains **descend to mostly broad plains** at a height of between 200 and 1 000 m above sea level. Large **desert plateaus** dominate the west of the country. **The south of Iraq is characterized by the Mesopotamian alluvial floodplain** through which the **Euphrates and Tigris rivers**, both originating from Turkey, flow into the Persian Gulf [27].

The climate in Iraq is **mainly subtropical and semi-arid**, with exception of the sub-humid mountainous regions in the northeast, and a desert climate in the southwest. Precipitation is of great spatial and temporal variability. Iraq can be divided into five major agro-ecological zones (AEZ): Desert/Arid, Subtropics-Warm/Semi-Arid, Sub-Arid, Subtropics Moderately Cool/Sub-Humid and Land with Severe Soil/Terrain Limitations (Figure 1).[7] Each of these zones is characterised by specific temperatures and moisture regimes and, consequently, specific patterns of crop production and pastoral activities.

5 This term is frequently used to refer to fossil fuels that have not yet been mined as well as the extraction and production infrastructure that have lost their investment value, especially due to the energy transition. In more general terms, stranded assets are infrastructures or resources that were once valuable but have now reached the end of their economic life cycle due to external factors such as technological change or social acceptance. They are no longer valuable enough to cover the owner's return on investment [20].

6 The Fragile State Index, which is annually published by the Fund for Peace, comprises twelve conflict risk indicators that are used to measure the condition of each state [21].

Groundwater use in Iraq is low [28]. The **Euphrates and the Tigris rivers provide nearly all of the country's water supply** and are thus a crucial source of drinking water, as well as for agriculture and hydropower generation. However, **water flows of these two major rivers have shrunk** by 30 % since 1980 and are expected to further decrease by up to 50 % until 2030, placing Iraq increasingly under water stress. At the same time, as a result of **rapid population growth and economic development, the need for freshwater resources is increasing** [29] [30].

The Euphrates and the Tigris rivers originate in Turkey and flow through Syria, making Iraq a **downstream recipient of water.** Starting in the 1970s, **major water infrastructure projects, including dam building and power plant constructions** on the Euphrates and the Tigris rivers by Turkey[8] and Syria have contributed to a **sharp decline in the supply of water** to Iraq. In addition, the inflow of diverse important tributaries of the Tigris river, which originate in Iran, has dramatically decreased due to a series of dams built by Iran, mainly affecting central and southern Iraq [29]. The diversion of water further upstream, in combination with climate impacts and poor water management contribute to **alarming water shortages in Iraq**. In the face of this sharp decline, significant **geopolitical tensions are rising with other riparian states** over the management, of transboundary water resources. To date, there is no agreement between the riparian states that ensures equitable sharing of transboundary water resources [29].

Declining surface water streams, recurrent drought and increasing water salinity are contributing to **large-scale desertification**, which affects an estimated 40 % of Iraq's total land area [31]. Furthermore, decades of unsustainable cultivation practices have contributed to diminished vegetation covers which create enabling conditions for **heavy dust and sand storms** [32].

7 It should be noted that there are different classifications of AEZs in Iraq. We focused on a commonly used classification of five AEZs.
8 In 1977, Turkey initiated the Southeastern Anatolia Project (GAP), an integrated regional development project in southeastern Turkey. GAP comprises one of the largest water infrastructure projects worldwide, aiming at the construction of 22 dams, 19 hydropower plants, as well as extensive drainage and irrigation networks, of which many have been completed. The total water storage capacity amounts to around three times the total river flow to Iraq and Syria, and is therefore of major concern for both downstream recipients [65] [30] [29].

These storms are driven by northwestern winds[9] called *Shamal*, which travel across the valleys of the Euphrates and Tigris rivers in central and southern Iraq. Dust storms remove topsoil and destroy crops and grassland, thereby further driving desertification. At the same time, the expansion of desert areas increases the development of sand storms [11]. In consequence, the **frequency of their occurrence increased drastically** and will continue to do so in the future[10], causing not only environmental but also economic damage as well as negative health outcomes, such as for respiratory health [33].

Decades of **conflict have caused massive environmental pollution and ecosystem degradation in Iraq**. Repeated military attacks on and the destruction of nuclear research reactors in 1980-1991 resulted in hazardous waste and soil contamination. Environmental pollution was later exacerbated by attacks by Islamist groups on oil and gas stations, resulting in oil spills, oil fires and oil clouds [34] [35]. Furthermore, large-scale wetland drainage for military purposes caused a major **degradation of the Mesopotamian Marshlands** [33].

Present climate [36]

Iraq has two main seasons: A hot and dry summer that lasts from April to October and a cool and wet winter that extends from November to March [37]. The average annual air temperature lies at 22.6 °C [38]. Temperatures greatly vary throughout the country and between seasons. Southern Iraq has a desert climate, with the hottest temperatures between June and August. During these months, average temperatures surpass 40 °C during the day and drop to around 30 °C at night. Temperatures are significantly lower in northern Iraq. During the summer months, temperatures rise to around 25 °C (July and August), while falling to below 0 °C in the mountainous regions during the months of December and January [13] [37].
Annual precipitation sums amount to an average of 179 mm [38] [19]. The amount of precipitation varies greatly throughout the country. Precipitation sums in the northern mountains range from around 350 mm to over 900 mm, depending on the location, with most precipitation occurring between November and March. Annual precipitation decreases as one moves south and west, where it can drop to under 100 mm. Most of the rain here falls between December and March [39] [40].

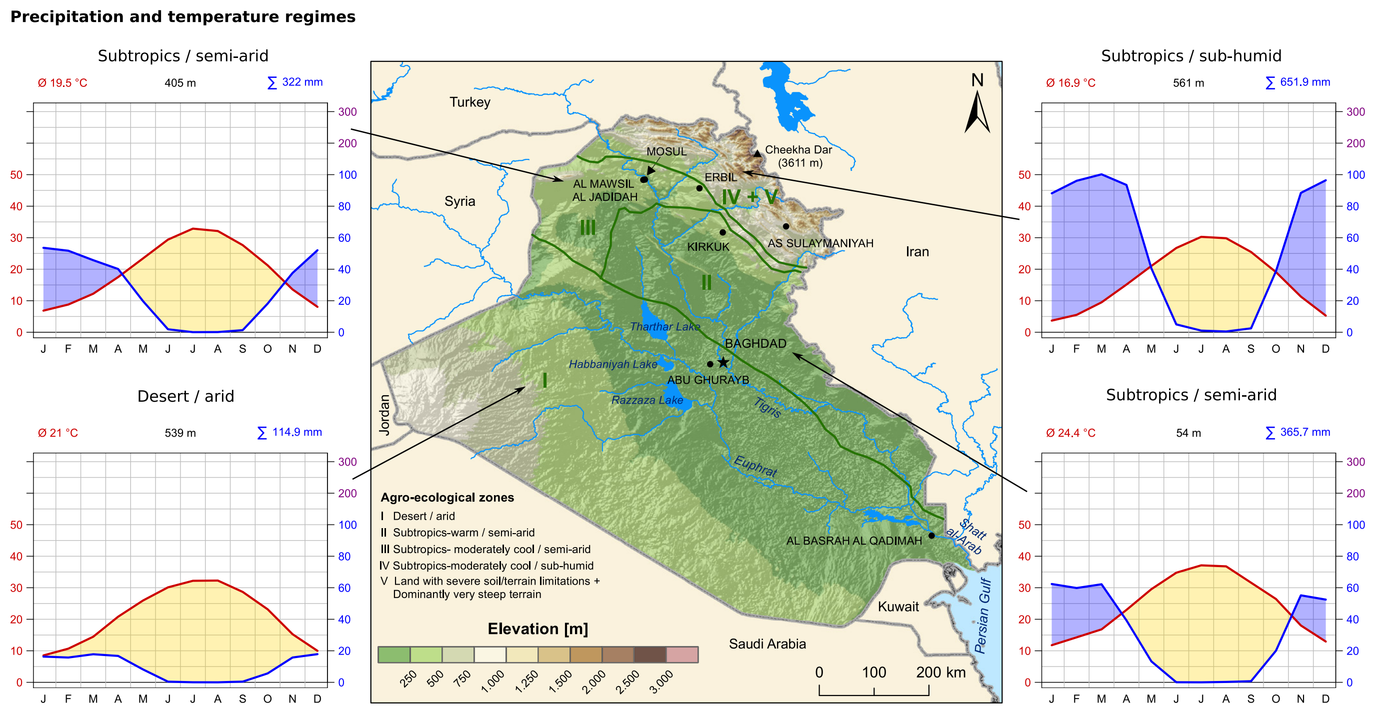


Figure 1: Topographical map of Iraq with existing temperature and precipitation regimes.[11]

9 They are strongest between June and September [32].
10 The Iraqi Ministry of Environment recorded 122 dust storms and 283 dusty days in 2014 and suggested that within the next ten years, Iraq could witness 300 dust storms per year [67].
11 The climate graphs display temperature and precipitation values which are averaged over an area of approximately 50x50 km. Especially in areas with larger differences in elevation, the climate within this grid size may vary.

How to read the plots

The maps and plots included in this section provide an overview of projected climate change parameters and related sector-specific impacts in Iraq until 2080 under two different climate change scenarios (RCPs): RCP2.6 represents a low emissions scenario that aims to keep global warming below 2 °C above pre-industrial temperatures, and RCP6.0 represents a medium to high emissions scenario. Projections are provided until the year 2080, with each year showing the mean value of a 31-year period.[12]

The **line plots** show climate impact projections averaged over the whole country, with the blue colour representing the RCP2.6 scenario, and the red colour representing the RCP6.0 scenario. While the lines depict the best estimate (representing the multi-model median of 10 climate models), the shaded areas represent the likely range (strongly shaded area) and the very likely range (lightly shaded area), indicating the range of model agreement of at least 66 and 90 % of all model projections, respectively.

How to read the line plots

historical RCP2.6 RCP6.0

best estimate likely range (central 66 %) very likely range (central 90 %)

The **map plots** display regionally explicit climate information under RCP2.6 and RCP6.0, in a spatial resolution of approximately 50 x 50 km. While the leftmost column represents the baseline period as found in the model data, the other three columns represent future projections in comparison to that baseline period. The colour values depict the multi-model median of the underlying models at each grid cell. The presence of a dot means that at least 75 % of the models agree on the sign of change depicted for the specific grid cell and scenario (i.e. whether an increase or a decrease can be expected). Conversely, the absence of a dot represents the lack of model agreement on the predicted change.

Uncertainties in climate change projections

It is important to acknowledge that uncertainties are always part of climate change projections. Uncertainties arise from a variety of factors, including natural variabilities, uncertainties in GHG emissions scenarios and differences in the models used [41]. Consequently, no future (climate change) projection comes without some level of uncertainty. The levels of (un)certainties, however, differ. We present the results of ten different global models. To indicate the (un)certainty of the projections we consider model agreement. The more these models agree the higher the certainty, the more they disagree the lower the certainty. For example, if different models project a similar result under the same scenario, the projected changes demonstrate low levels of uncertainty, however, if they project very different changes (in terms of range and even direction) under the same scenario, then the projections are uncertain.

Line plots and map plots depict uncertainty differently and cannot be compared: The line plots indicate the level of certainty through the shaded areas, depicting the likely (central 66 %) and very likely (central 90 %) range of all model projections (see section “How to read the plots”). Generally, the smaller the shaded areas, the more certain the projections (for an example of a relatively certain projection, see Figure 2, while for an example of a highly uncertain projection, see Figure 13). The map plots depict the level of certainty through the presence or absence of dots (see section “How to read the plots”). If dots are present, at least 75 % of all models agree on the direction of change or in other words an increasing or a decreasing trend (for an example, see Figure 3). If the dots are absent in a specific region or scenario, then model agreement within this specific region and scenario is below 75 % (for an example, see Figure 21).

To simplify the interpretation of the projections, all line plots and map plots that are subject to high levels of uncertainty are marked with a symbol ( ). This does not imply that these plots have no informational value, but rather draws attention to the limitations of such projections for future planning. **Consequently, they should be very carefully interpreted when they are used for planning measures.** In the case of high uncertainty, additional information will be provided on how to interpret the data.

12 To generate clear and consistent long-term projections which balance interannual variabilities and extremes, we use a period of 31 years.

Part A: Projected climatic changes

Temperature

As a result of increasing greenhouse gas (GHG) concentrations, the **air temperature over Iraq is very likely to rise by between 1.8 and 4.8 °C by 2080, relative to the year 1876** and depending on the future GHG emissions scenario (Figure 2). Compared to pre-industrial levels, the projected air temperature increase will very likely range between 1.6 and 2.5 °C by 2030, 1.9 and 2.8 °C by 2050, and 1.8 and 3 °C by 2080 under RCP2.6. The median climate model temperature projects an increase of approximately 2 °C by 2030, 2.4 °C by 2050 and 2.5 °C by 2060 for the same scenario. Between 2060 and 2080, the median air temperature change slightly drops to 2.4 °C in 2080.

Under the medium to high emissions scenario RCP6.0, air temperature will increase by between 1.6 and 2.4 °C by 2030, 2.2 and 3.2 °C by 2050, and 3.2 to 4.8 °C by 2080 (very likely range). The median climate model temperature projects an increase of 2 °C by 2030, 2.6 °C by 2050 and 3.8 °C by 2080.

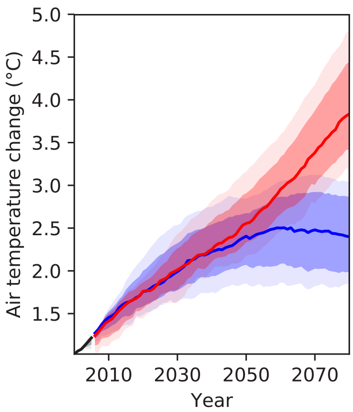


Figure 2: Air temperature projections for Iraq for different GHG emissions scenarios.[13]

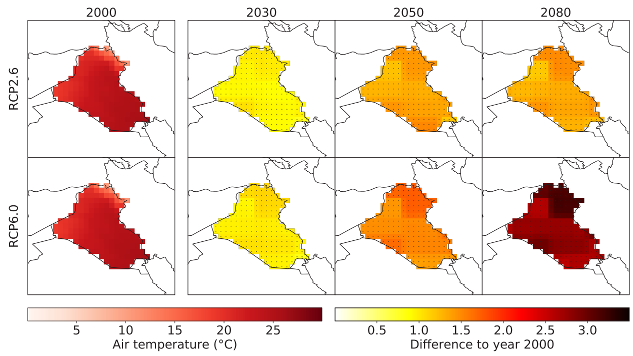


Figure 3: Air temperature projections for Iraq for different GHG emissions scenarios (regional variations).[14]

The increase in air temperature will affect the entire country with high certainty (Figure 3). **Under the low emissions scenario RCP2.6, the northeast of Iraq will be most affected.** By 2030, temperatures will rise by between 0.8 °C in the very southeast and over 1.0 °C in the northeast, compared to the year 2000.[14] By 2080, models project a rise by up to 1.5 °C in the north, and by between 1.2 and 1.4 °C across the rest of the country. **Under the medium to high emissions scenario** RCP6.0, temperature changes by 2030 will develop relatively similar to those under RCP2.6, with increases of between 0.8 °C and 1.1 °C in the southeast and the northeast of Iraq, respectively. In the long term, however, the **RCP6.0 scenario predicts a temperature rise of up to 3.2 °C by 2080**, compared to 2000, which is **more than twice as high as under RCP2.6.**

13 Changes are expressed relative to year 1876 temperature levels using the multi-model median temperature change from 1876 to 2000 as a proxy for the observed historical warming over that time period.
14 While the line plot on air temperature change (Figure 2) compares future projections with temperature changes between 1876 to 2000, this map plot (Figure 3) provides projected air temperature changes relative to the year 2000. Hence, projections of those plots are not comparable.

Very hot days

Extreme heatwaves and air temperatures are particularly prevalent close to the Persian Gulf. Onshore winds from the Gulf carry high levels of humidity to southern Iraq, causing some of the highest wet-bulb temperatures[15] in the world during the Iraqi summer. Temperature extremes and heatwaves have occurred more frequently in Iraq in recent years [42]. Figure 4 shows that the average number of very hot days (i.e. days with temperatures above 35 °C) in 2000 was around 150 days (multi-model median), with the highest recorded numbers in southern Iraq. In line with rising annual mean temperatures (Figures 2 and 3), **the annual number of very hot days is projected to rise with high certainty all over Iraq** (Figure 4). **The increase will be highest in the northeast and the west,** while it will be less in the rest of the country under both scenarios.

Under RCP2.6, the number of very hot days will rise by around 8 to 12 days in most parts of Iraq, with a maximum of over 20 days per year until 2030 in the northeast and west, compared to 2000. With the exception of the northeast and west, where very hot days will increase by up to 29 and 30 days annually until 2050 and 2080, respectively, projections for 2050 and 2080 differ only slightly from the year 2030 in most of the country.

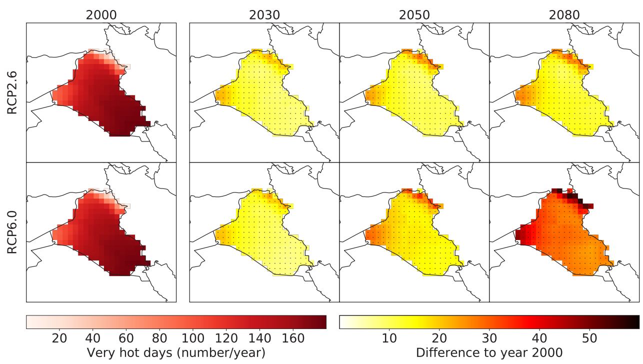


Figure 4: Projections of the annual number of very hot days (daily maximum temperature above 35 °C) for Iraq for different GHG emissions scenarios (regional variations).

Under RCP6.0, very hot days will increase similarly as under RCP2.6 by 2030. Until 2080, however, this rise will be much stronger than under RCP2.6: The smallest increase is projected to amount to 24 additional very hot days per year in the southeast. The very west will experience an increase by up to 47 days, while **in the most strongly affected northeast, the number of very hot days will rise by up to 57 annually until 2080.**

Higher heat stress poses a risk to the population's ability to work and live [43]. As research has found, under a business-as-usual scenario, wet-bulb temperature extremes will exceed a threshold for human habitability in many cities in the MENA region towards the end of the century [1]. The projections on the population's exposure to heatwaves and heat-related mortality (Figures 26 and 27) illustrate the consequences of the projected temperature changes in Iraq.

Sea level rise

Iraq borders the Persian Gulf to the south with a coastline of only 58 km [7]. Despite this relatively small shoreline length, future sea level rise will have serious impacts on the low-lying floodplains and deltas of Iraq's southern Basra Governorate. Sea level rise may cause serious inundation and increase salinity levels in the Delta region, reducing agricultural productivity. Furthermore, rising sea levels pose a threat to critical infrastructures along the Iraqi coast, including major ports, roads and coastal buildings [2]. **Under a high emissions scenario, Iraq's second-largest city Basra could be largely inundated by water by 2050** [44] [45].

Due to the increase in global average temperatures, the **sea level along the Iraqi coasts is projected to rise** (Figure 5). Until 2050, projections under both scenarios suggest similar changes: The median climate model projects a sea level rise of 9.6 cm by 2030 and 17.9 cm by 2050 under RCP2.6, and of 9.1 cm until 2030, and 17.9 cm until 2050 under RCP6.0. Until 2080, the sea level will rise more under RCP6.0 than under RCP2.6, amounting to an increase of 36.1 and 30.2 cm, respectively, in comparison to levels of the year 2000.

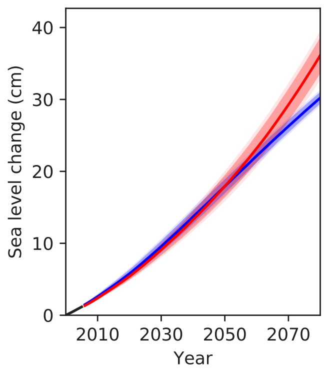


Figure 5: Sea level change projections for Iraq for different GHG emissions scenarios.[16]

15 Wet-bulb temperatures are air temperatures at 100 % humidity. Physical labour becomes difficult to impossible when wet-bulb temperatures exceed 31 °C, and heat stress can be fatal to humans when wet-bulb temperatures exceed 35 °C for six hours or more [42].
16 This sea level rise plot is based on two global climate models only, which limits the certainty of this projection.

Precipitation

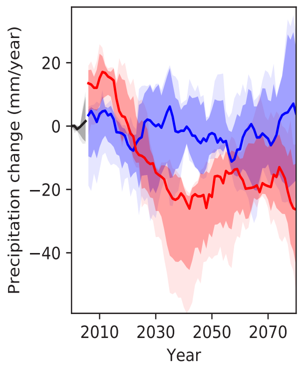


Figure 6: Annual mean precipitation projections for Iraq for different GHG emissions scenarios, relative to the year 2000.

Precipitation projections are much less certain than projections of temperature change (Figures 6 and 7). They are subject to **high inter-annual variability** and differ significantly in both the direction of change and the level of certainty around those changes, depending on the underlying scenario and the different time frames. **In addition to high variations, no clear future trend can be derived under RCP2.6. Under RCP6.0, precipitation will decrease.**

The RCP2.6 projections show strong variations with alternating median increases and decreases in precipitation relative to the year 2000. The underlying reason is that when considered independently, each model projects high inter-annual variations, resulting in differences in the direction of change between the models. Consequently, RCP2.6 projections suggest that future changes from 2000 levels will range from -29 to +13 mm/year by 2030 and from -10 to +8 mm/year by 2050. By 2080, precipitation changes will lie between -22 and +29 mm/year (very likely range).

While all models agree that **precipitation will decrease under RCP6.0,** one model predicts a much larger decline than the remaining models, as reflected in a wide range of projected changes. This range is particularly wide between 2030 and 2060 and between 2070 and 2080. Annual precipitation will very likely decrease by between 13 and 35 mm until 2030, and by between 8 and 42 mm by 2050. **By 2080, precipitation is expected to decline by 6 to 53 mm annually,** compared to the year 2000 (very likely range).

The certainty of geographically explicit projections of mean annual precipitation over Iraq varies greatly depending on the underlying emissions scenario, with much higher certainty regarding the direction of change under RCP6.0 than under RCP2.6.

There is very high uncertainty in geographically explicit mean annual precipitation projections under RCP2.6. The absence of dots in the plots across most regions of Iraq shows that there is little agreement among the models about whether precipitation will increase or decrease. Models, however, agree that rainfall will slightly decline in the northwest by 2030 and 2050, and that precipitation will slightly increase in the west by 2030 and in the southeast by 2050. **Under RCP6.0**, model agreement around annual precipitation changes is significantly higher, with models projecting decreases for the entire country and all time periods. **Compared to 2000, precipitation will decline by between 4 and 18 % by 2030, with relatively high variations across the country.** By 2050, this decrease will reach a maximum of 27 % in western Iraq. **Precipitation will decline by between 3 to 29 % by 2080, with relatively small decreases in northern and central, and strongest decreases in the very south and west of Iraq.**

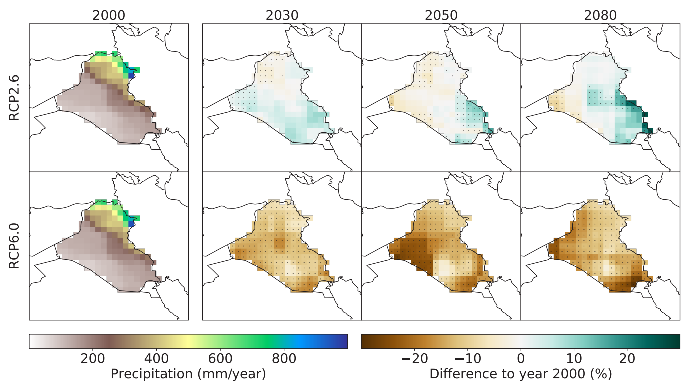


Figure 7: Annual mean precipitation projections for Iraq for different GHG emissions scenarios, relative to the year 2000 (regional variations).[17]

17 Please note that the line plots and the map plots represent uncertainty differently and cannot be compared (see section "uncertainties in climate change projections" on page 6).

Heavy precipitation events

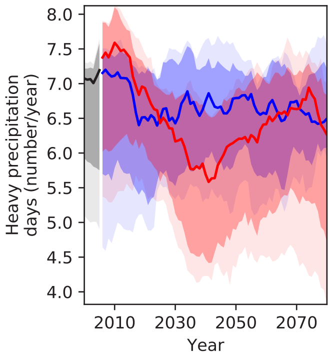


Figure 8: Projections of the number of days with heavy precipitation over Iraq for different GHG emissions scenarios, relative to the year 2000.

Under RCP6.0, heavy precipitation events will decrease. While projections until 2030 and 2050 are uncertain for some regions in southeastern Iraq, overall, heavy precipitation will slightly decrease across the rest of the country, with strongest declines in the very west. The certainty of long-term projections under RCP6.0 is higher, with heavy precipitation events projected to decrease across the country. **The reduction will be most pronounced in the southeast and west, but will be limited to below 2 days.** Long-term planning must consider the high uncertainty around future precipitation amounts and intensities.

In response to global warming, **heavy precipitation events are expected to become more intense and frequent** in many parts of the world due to the increased water vapour holding capacity of a warmer atmosphere [46].

For Iraq, the trend towards more frequent extreme precipitation events cannot be confirmed. Under both scenarios, the multi-model median suggests a decreasing trend by 2080, in comparison to the year 2000. However, one underlying model projects a strong decrease in the annual number of heavy precipitation days, while the remaining models project either no significant changes or a small increase. This translates into a high range of projected outcomes. **Under RCP2.6, heavy precipitation days per year will fluctuate between 5.4 and 7.5 by 2050, and between 5.9 and 7.6 by 2080** (very likely range). Under RCP6.0, according to the multi-model median, the number of heavy precipitation days per year will be less than 6 between 2035 and 2046, and then increase to nearly 7 by 2070. However, the very likely range is large, **from 4.8 to 6.8 days per year by 2030 and from 3.9 to 6.7 by 2080.**

Geographically explicit projections of heavy precipitation events are uncertain for many regions, particularly under RCP2.6. **While the southeast of Iraq might experience a slight increase in heavy precipitation events under the low-emissions scenario, heavy precipitation events in western Iraq are projected to decrease slightly by up to 1 day by 2080.**

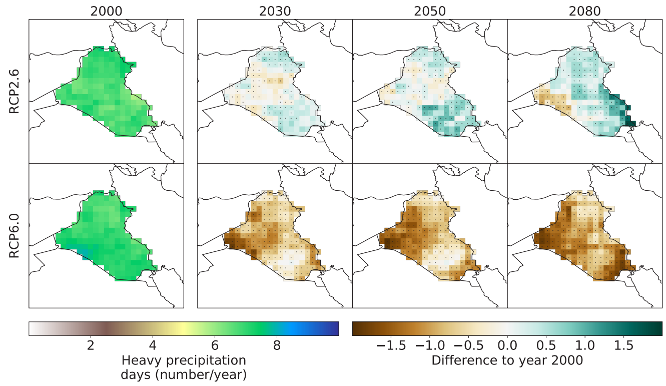


Figure 9: Projections of the number of days with heavy precipitation over Iraq for different GHG emissions, (regional variations).

Soil moisture

Soil moisture is an important indicator for drought conditions. In addition to soil parameters, soil moisture depends on both precipitation and evapotranspiration and, therefore, also on temperature, as higher temperatures translate to higher potential evapotranspiration.

Considerable modelling uncertainty makes it **difficult to identify a clear trend for future soil moisture changes in Iraq**. Median annual mean top 1-m soil moisture projections indicate almost no change under RCP2.6, and a decrease under RCP6.0, compared to the year 2000 (Figure 10). However, different models project different directions of change under both scenarios. **These deviations translate into a high range of projected changes,** which amount to between -5.9 and +7.3 mm under RCP2.6 and to between -8.8 and -1.4 mm under RCP6.0 by 2080 (very likely range). Long-term planning must consider the high uncertainty regarding the direction and magnitude of change.

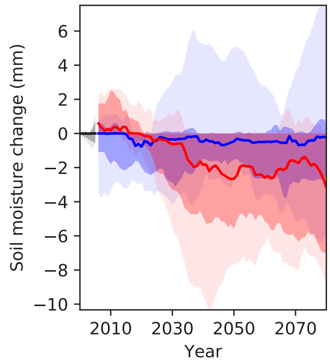


Figure 10: Soil moisture projections for Iraq for different GHG emissions scenarios, relative to the year 2000.

Potential evapotranspiration

Evapotranspiration contributes to the reduction of crop and soil moisture and thus has important implications for agricultural production and the availability of fodder vegetation. It is therefore an important drought indicator [4].[18] Mainly as a result of rising temperatures[19], evapotranspiration rates have increased in Iraq [47]. Furthermore, all models indicate a **future rise in potential evapotranspiration**[20] (Figure 11), but with a **wide range of projected increases due to significant uncertainties in the models.**

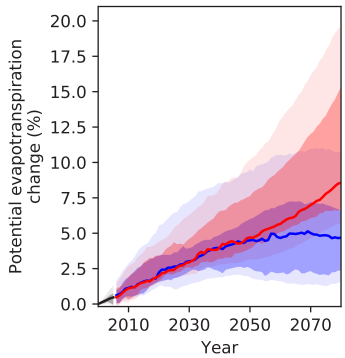


Figure 11: Potential evapotranspiration projections for Iraq for different GHG emissions scenarios, relative to the year 2000.

Projections under RCP2.6 show an increase in evapotranspiration until 2070. Until 2080, median projections will slightly decrease, compared to the level of 2070. However, the variation across the underlying models is high. This translates into an **increase of evapotranspiration between 1.4 and 7.3 % by 2030,** and between 1.5 and 10.7 % by 2080, compared to the year 2000 (very likely range). The rise in potential evapotranspiration under RCP6.0 will be relatively similar to the RCP2.6 scenario until 2050, but is expected to continue to increase between 2050 and 2080. However, modelling uncertainties under RCP6.0 are even higher than under RCP2.6, with **predicted changes ranging between 5.7 and 19.7 % until 2080** in the very likely range.

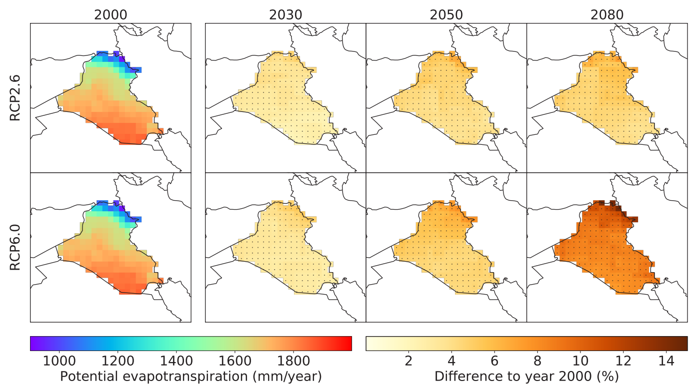


Figure 12: Potential evapotranspiration projections for Iraq for different GHG emissions scenarios, relative to the year 2000 (regional variations).

The geographically explicit projections show an **increase in potential evapotranspiration throughout Iraq.** Model agreement around this increase is high under both scenarios. **Under RCP2.6**, relative to the year 2000 levels, potential evapotranspiration is projected to increase by between 1.9 to 4.6 % by 2030 and by 3.7 to 7.3 % by 2080, with **stronger increases in the very north and more moderate increases across the rest of the country in all time periods.**

Under RCP6.0, potential evapotranspiration increases until 2030 will be similar to the projections under the RCP2.6 scenario, with a minimum rise of 2.7 % in the very south and a maximum increase of 5.2 % in the very north of Iraq. Potential evapotranspiration will be rising most strongly between 2050 and 2080. The increase until 2080 will affect the whole country with a **minimum of 7.4 % in the south and an increase of about 8 to 9.5% in most of the country. The highest difference, in comparison to 2000, will amount to up to 14.3 % in the very north of Iraq.** Long-term planning must consider the great uncertainty relating to future rises in potential evapotranspiration.

18 For example, the widely used Standardized Precipitation Evapotranspiration Index (SPEI) is a drought index that is based on the water balance. The water balance is defined as the difference between precipitation and potential evapotranspiration [68].
19 Evapotranspiration rates are affected by air temperature, humidity, radiation and wind speed.
20 Potential evapotranspiration is the amount of water that would be evaporated and transpired if sufficient water was available at and below the 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.

Part B: Sector-specific climate change risk assessment

Water resources

Iraq was once considered a country rich in water resources. However, today, the country **faces severe water shortages, mainly due to reduced water inflows, rapid population growth and high withdrawal rates for agricultural use** [29] [30] [48]. The **effects of climate change**, including rising temperatures, erratic rainfall and increasing intensity and frequency of droughts, high evaporation rates as well as rising saltwater intrusion from the Persian Gulf further exacerbate existing water scarcities.

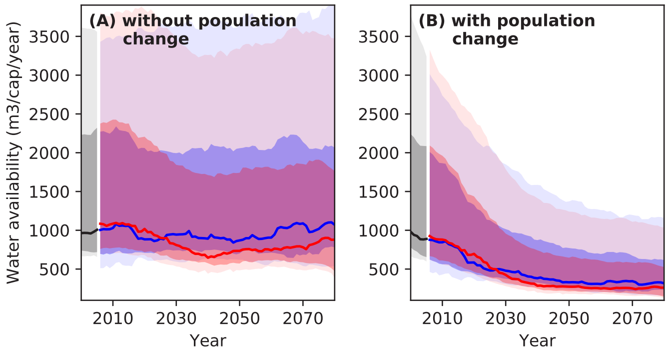


Figure 13: Projections of water availability from precipitation per capita and year in Iraq with (A) national population held constant at year 2000 level and (B) changing population in line with SSP2 projections for different GHG emissions scenarios.

Per capita water availability in Iraq ranged between 666 and 3 612 m³ per year (multi-model median of approximately 960 m³) around the year 2000 (Figure 13). Future projections **are highly uncertain under both GHG emissions scenarios.**

Assuming a constant population level (Figure 13A), the **range of projected water availability is extremely high.** Under RCP2.6, it amounts to between 541 and 3 883 m³ per year (multi-model median of 1 071 m³) by 2080. **Under RCP6.0, annual per capita water availability will range** between 384 and 3 475 m³ (multi-model median of 880 m³) by 2080 (Figure 13A). These projections are consistent with the uncertain projections of future precipitation changes (Figures 6 and 7).

When **accounting for population growth according to SSP2 projections (B),**[21] **per capita water availability for Iraq will sharply decline under both scenarios.** Despite this clear decrease, however, **model disagreement is extremely high,** causing projected water availability to very likely range between 161 and 1 160 m³ (multi-model median of 317 m³) under RCP2.6, and between 116 and 1 035 m³ (multi-model median of 261 m³) under RCP6.0 per person and year by 2080 (Figure 13B). **The multi model median decrease corresponds to a reduction of around two thirds under RCP2.6, and an even stronger decrease under RCP6.0.** In light of the water stress threshold of 1 700 m³ per person and year (water scarcity at levels below 1000 m3/cap/year)[22], this decrease is a clear warning sign.

Even **though declining water availability is primarily driven by the expected population growth instead of climate change,** projections highlight the need for strengthening water governance and the sustainable management of water resources.

21 Shared Socio-economic Pathways (SSPs) outline a narrative of potential global futures, including estimates of broad characteristics such as country-level population, GDP growth or rates of urbanization. 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.
22 See the Falkenmark Index [3].

Water availability from precipitation

Consistent with the precipitation change projections (Figures 6 and 7), projections on water availability from precipitation differ substantially in both the projected changes and the level of certainty around those changes, depending on the underlying scenario and the different time frames. **While no clear trend of increase or decrease can be derived under RCP2.6, water availability from precipitation will decline under the RCP6.0 projection, although not continuously.**

Under RCP2.6, projected changes vary widely: Relative to the year 2000, they will range between -27 and +13 % by 2030. By 2080, runoff changes will amount to between -21 and +30 % (very likely range). Under RCP6.0, water availability from precipitation will very likely decrease. The magnitude of reduction will greatly vary over time, with periods of intermittent increases, which are particularly pronounced between 2040 and 2070. In spite of this uncertainty, it is most prudent to plan for increasing variability and uncertainty for future water availability across the country.

Geographically explicit projections of future water availability from precipitation vary depending on the region and scenario (Figure 15)**.** While projections under RCP2.6 are highly uncertain and do not allow for any conclusions, the certainty is much higher

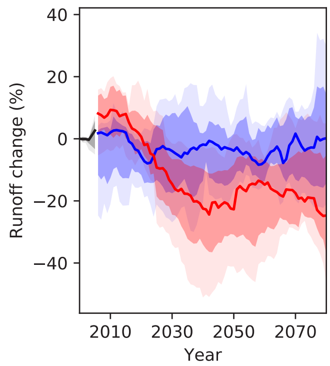


Figure 14: Water availability from precipitation (runoff) projections for Iraq for different GHG emissions scenarios.

under RCP6.0: Consistent with decreasing annual precipitation projections (Figures 6 and 7), **precipitation runoff will decline by up to 53 % in southern Iraq and by up to 49 % in the already arid western part of the country by 2050.** Variations within the rest of the country are large, with relatively smaller declines in much of Iraq's southeastern region and its very north. **By 2080, a decrease of over 60 % is expected in the far southwest of Iraq, and of up to 47 % in the northwest, while the multi-model median projects a decline of 26 % for the country as a whole**, in comparison to the year 2000.

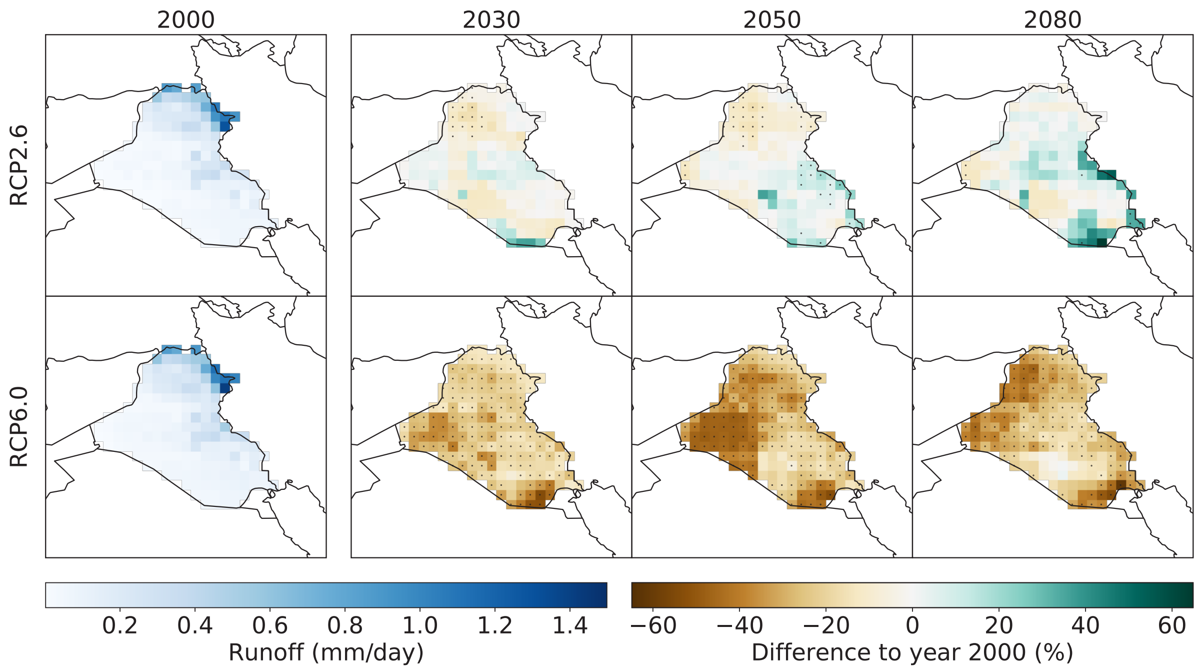


Figure 15: Water availability from precipitation (runoff) projections for Iraq for different GHG emissions scenarios (regional variations).

16 Shared Socio-economic Pathways (SSPs) outline a narrative of potential global futures, including estimates of broad characteristics such as country-level population, GDP growth, or rates of urbanization. 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

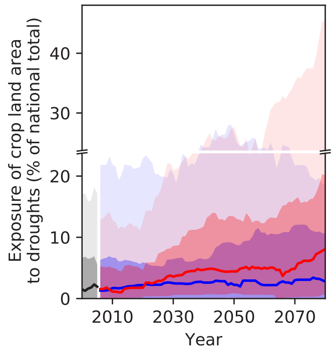
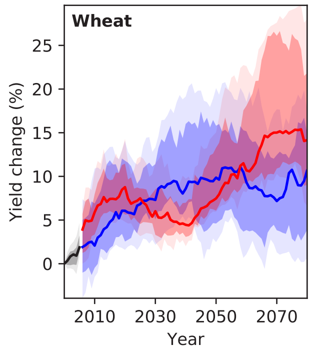
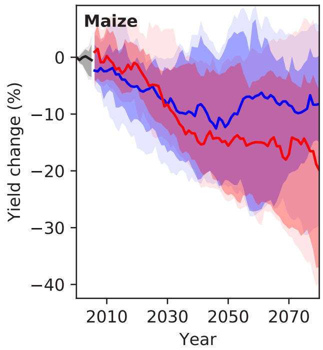
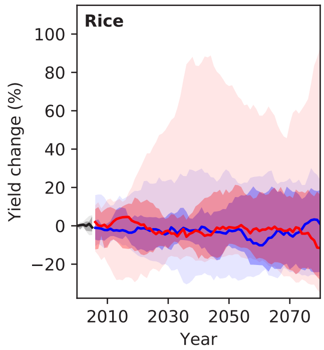


Figure 16: Projections of crop land area exposed to drought at least once a year for Iraq for different GHG emissions scenarios.







Figures 17-19: projections of crop yield changes for wheat yields (Figure 17), maize yields (Figure 18), and rice yields (Figure 19) for different GHG emissions scenarios assuming constant land use and agricultural management.

Currently, around **one fifth of Iraq's total population is engaged in agriculture.** However, a combination of historical, institutional, as well as climatic and environmental factors has led to a **strong decline in agricultural productivity** [10].

Water withdrawals for agriculture account for around 85 % of the total water consumption in Iraq and are thus far above the global average [48]. The large uncertainties regarding future water availability translate into **highly uncertain drought projections** (Figure 16). 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 in response to global warming. However, while most models project no or only slight changes in drought exposure, one model projects a strong increase under both scenarios. Consequently, under RCP6.0, the projected exposure of crop land area to drought ranges from 0 to 45.6 % in 2080 (very likely range). This means that **one model predicts nearly a threefold increase in drought exposure over this period, while others predict no change.** Hence, the informative value of the projections is limited.

Climate change will impact agricultural yields to different extends, depending on the crops grown.[23] Median model results indicate **a positive trend for wheat yields, a negative trend for maize yields, and no clear trend for rice yields.**

All models underlying the **wheat yield projections suggest an increase** in comparison to the year 2000 (Figure 17). However, the models display **considerable inter-decadal variability.** Until 2030, wheat yields are very likely to rise by 2.2 to 13.3 % (multi-model median increase of 7.3 %) under RCP2.6, and by 2.5 to 11.5 % (multi-model median increase of 6 %) under RCP6.0. Towards the end of the century, wheat yields will very likely increase by 0.7 to 17.5 % under RCP2.6 (multi-model median of 10.7 %) and by 6.6 to 28 % (multi-model median of 14.6 %) under RCP6.0.

Maize yields are expected to decline though the magnitude of decline is highly uncertain (Figure 18)**.** Compared to the year 2000, yields are very likely to decrease by 10.6 to 19 % (multi-model median decrease of 8.4 %) by 2030 under RCP2.6. Maize yields will decline until about 2050 and afterwards slightly recover. Under RCP6.0, maize yields show a large variance with projections ranging from -14.8 to +5 % by 2030 (multi-model median decrease of 8.5 %). Uncertainty increases the further one looks into the future: By 2080, yield changes will very likely range between -40 and +4.6 %.

The different models underlying the projections **for rice yields show different directions of change which might result either in an increase or a decrease of future rice yields** (Figure 19). Furthermore, variations exist between models that project an increase in yields. One model projects a significantly higher increase than the other models that also project an increase. These diverging trends result in large ranges in projected changes: Until 2080, yield changes will range from -24.6 to +23.9 % and -37 to +93 % under RCP2.6 and RCP6.0, respectively, compared to the year 2000 (very likely range).

23 Modelling data is available for a selected number of crops only. Hence, the crops listed on page 14 may differ.
24 Due to a lack of data, some grid cells on the geographically explicit yield projections for wheat (Figure 20), maize (Figure 21) and rice (Figure 22), particularly in southern Iraq, show no values and are therefore left uncoloured.

Geographically explicit information on future **wheat yields show varying degrees of certainty** (Figure 20).[24] Under RCP2.6, model agreement on increases in future yields is high. **However, there are geographical differences. The increase in northern Iraq will be moderate under all time frames. By contrast, in parts of southeastern Iraq, wheat yields are expected to rise significantly by up to 44 % and 36.5 % until 2050 and 2080,** respectively. However, modelling uncertainty increases with time and is significantly higher for southeastern Iraq. Under RCP6.0, the disagreement about the direction of change and therefore modelling uncertainty is much higher than under RCP2.6. While some increases can be expected in parts of the southeast by 2030 and the northeast by 2050, no conclusions can be drawn for the rest of the country in the short to medium term. **Long-term projections under RCP6.0 overall suggest a continuous increase in yields, which will be highest in parts of central and eastern Iraq.** However, as these results are uncertain, they should be treated with great caution.

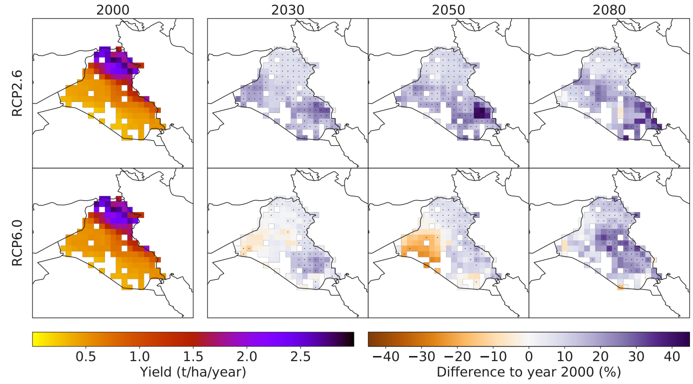


Figure 20: Projections of wheat yield changes for Iraq for different GHG emissions scenarios assuming constant land use and agricultural management (regional variations).

Regionally explicit projections of changes in maize yields (Figure 21) are more certain than those of wheat. Overall, consistent with Figure 18, **maize yields will decrease under all scenarios and time frames**, with a **significantly stronger decrease along the eastern border of Iraq** than in the rest of the country. Until 2030, yields will decrease to similar degrees under either projection. While maize yields under RCP2.6 will change only slightly between 2030 and 2080, under RCP6, they will decline by up to 76.4% in the northeast of Iraq (relative to 2000) by 2080.

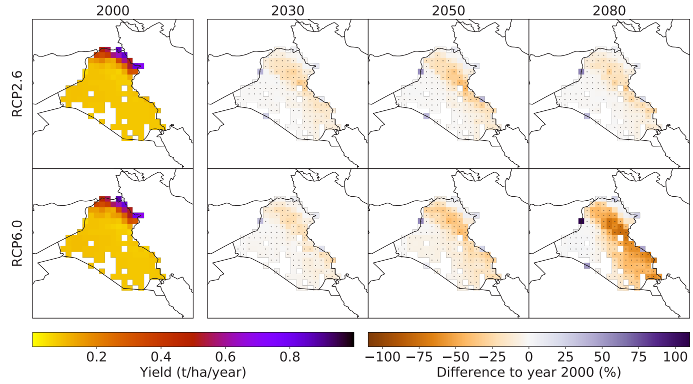


Figure 21: Projections of maize yield changes for Iraq for different GHG emissions scenarios assuming constant land use and agricultural management (regional variations).

The different models underlying the regionally explicit projections for **rice yields** show different directions of change that might result either in an increase or a decrease in future rice crops. **Consequently, the uncertainty is extremely high** across the time frames and scenarios presented. Decision makers should account for this uncertainty in their future planning.

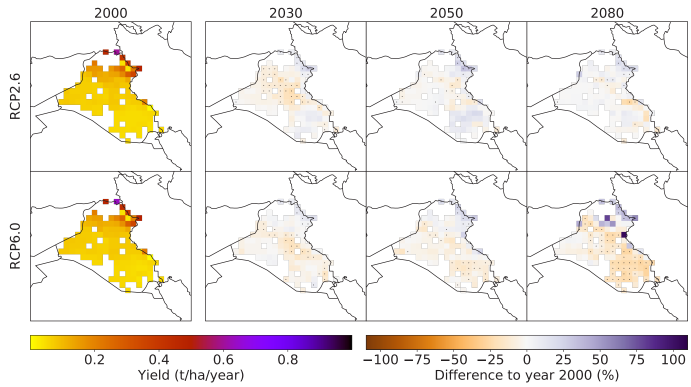


Figure 22: Projections of rice yield changes for Iraq for different GHG emissions scenarios assuming constant land use and agricultural management (regional variations).

Infrastructure

As a result of decades of conflict, Iraq's infrastructure has seen not only a lack of maintenance, but also heavy destruction. A damage-and-needs assessment compared the condition of Iraq's infrastructure in December 2017 with the period before the ISIS attacks in 2014 and estimated the costs of damage to transport infrastructure[25] at nearly US$ 2.8 billion. Around 2 300 km of roads, amounting to 18 % of the total road network, had been destroyed. Governorates in central and western Iraq[26] have been particularly affected [49].

Climate change is expected to affect Iraq's infrastructure, especially through extreme weather events such as floods and heatwaves. Extreme precipitation events can lead to flooding of transport infrastructure including roads and airports, while high temperatures can cause roads, bridges and protective structures to develop cracks and degrade more quickly. This results in substantial maintenance and replacement costs. Transport infrastructure is vulnerable to extreme weather events, yet essential for people's livelihoods. Roads serve communities to trade goods and to access healthcare, education, credit and other services. At the same time, extreme weather events can have devastating effects on human settlements and economic production sites, especially in urban areas with high population densities.

Informal settlements and IDP camps, both formal and informal, are particularly vulnerable to extreme weather events: For example, flooding in February 2018 heavily damaged shelters and communal infrastructures in at least 24 IDP camps in southern Kurdistan and central Iraq, affecting around 201 660 people [50].

Existing power grids are sensitive to heatwaves and cannot keep pace with temperature increases in Iraq's urban settlements. For instance, in the summers of 2019, 2020 and 2021, widespread power cuts left the people without electricity and air conditioning during the extreme heat, **stirring protests against the government in the cities of Bagdad and Basra** [51] [52].

Despite the risk of infrastructure damage being likely to increase as climate change progresses, predictions on the specific 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 uncertainty of future precipitation amounts and their spatial distribution, affecting flood occurrence (Figures 6 and 7). The uncertainties around future river flood events translate into high uncertainties of future exposure of infrastructure to floods in Iraq (Figure 23).

© UN Photo/Bikem Ekberzade

25 Including roads, bridges, airways and railway systems.
26 Anbar, Babel, Baghdad, Diyala, Kirkuk, Ninawa and Sala Al-Deen.

Exposure of urban land area to floods

The exposure of **urban land area to river floods is projected to hardly change under either emissions scenario or time frame.** In 2000, 0.1 % of the total urban land area was exposed to river floods at least once a year, while by 2080, this value is projected to increase to 0.2 % under RCP2.6, and to drop to 0.05 % under RCP6.0, according to the multi-model median. Hence, the **exposure of urban land area to flooding will be very small.**

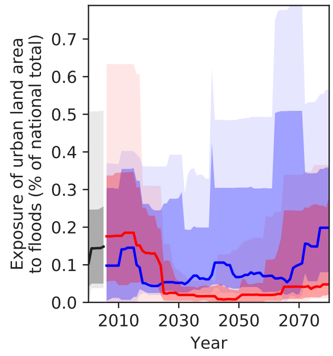


Figure 23: Projections of urban land area exposed to river floods at least once a year for Iraq for different GHG emissions scenarios.

Exposure of GDP to heatwaves

The exposure of GDP to heatwaves will substantially rise. All models project an increase in GDP exposure to heatwaves, **though the magnitude of increase is subject to high modelling uncertainty** and rises the further one looks into the future. By 2030, models project between 15.4 and 35.1 % of the national GDP to be exposed to heatwaves under RCP2.6, and between 12.5 and 27.4 % under RCP6.0. By 2050, exposure of GDP to heat waves is very likely to increase to between 20.1 and 45.2% under RCP2.6 and between 21.7 and 43.3% under RCP6.0 (very likely range). Under the low-emissions scenario, the multi-model-median stabilises after 2050 but with a wide very likely range from 20.1 to 49.8 % between 2050 and 2080. In contrast, **under RCP6.0, GDP exposure to heatwaves will drastically increase to between 28 and 54.1 % by 2080.**

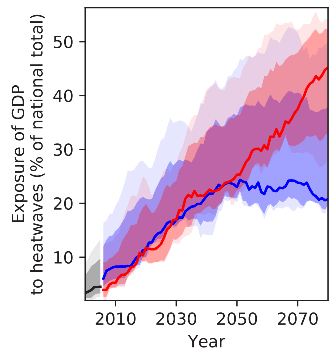


Figure 24: Projections of GDP exposure to heatwaves at least once a year for Iraq for different GHG emissions scenarios.

Ecosystems

Climate change is expected to have a significant impact on the ecology and distribution of tropical ecosystems, even though the magnitude and direction of these changes are uncertain [53]. Due to rising temperatures, increased frequency and intensity of droughts and shorter growing periods, **wetlands and riverine systems are increasingly at risk of being converted to other ecosystems,** with plant populations being succeeded and animals losing their habitats. Rising temperatures and droughts can also influence succession in forest systems, while simultaneously increasing the risk of invasive species, all of which affect ecosystems. In addition to these climate-related impacts, population growth and a reduced agricultural productivity might motivate further agricultural expansion, resulting in increased deforestation, land degradation and forest fires, all of which will impact animal and plant biodiversity [53].

Model projections of species richness (including amphibians, birds and mammals) and tree cover for Iraq are shown in Figures 25 and 26, respectively. Species richness is relatively high in northern and northeastern Iraq, while being lower in the central plains due to different climatic conditions and human influences, including extensive agricultural activities and high population density further south. However, resulting from decades of conflict, **Iraq lacks reliable and comprehensive data on the country's biodiversity** [54]. Projections of species richness are only available for northern, eastern and southeastern Iraq. **The uncertainty of those projections is high under both emissions scenarios,** as some models suggest an increase in species richness, while others project a decrease. In the long run, under RCP6.0, species richness is projected to decrease by up to 19 % in parts of northern Iraq, and to increase by up to 17 % in the very southeast, compared to the year 2010 (Figure 25).

In terms of tree cover change, model agreement is very low. Therefore, **no reliable estimates can be made about the direction of climate change impacts on tree cover** (Figure 26).

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 which are expected to remain its main driver in the future [55].

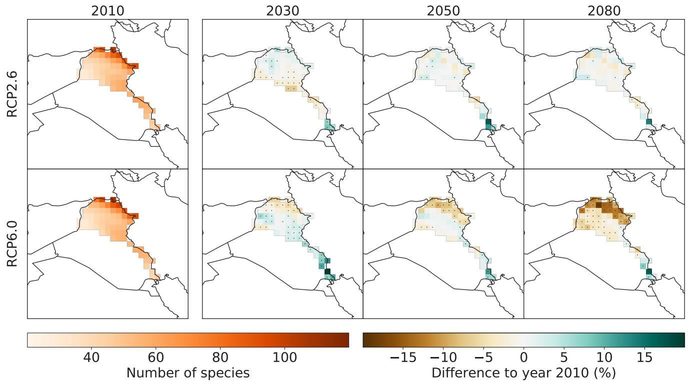


Figure 25: Projections of the aggregate number of amphibian, bird and mammal species for Iraq for different GHG emissions scenarios, compared to the year 2010 (regional variations).

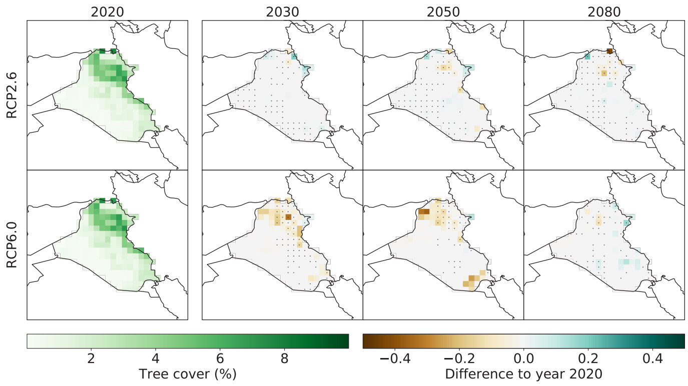


Figure 26: Tree cover projections for Iraq for different GHG emissions scenarios (regional variations).

Human health

During the 1970s and 1980s, Iraq had one of the best health care systems in the Middle East. However, **ensuing decades of conflict and successive wars have severely deteriorated the country's health infrastructure** through the destruction of health facilities[27] and massive outmigration of health professionals [56]. **Rapid population growth** is placing an additional strain on Iraq's healthcare system, which was also severely affected by the **COVID-19 pandemic** [57].

Climate change puts further stress on the health and sanitation sector, particularly in relation to food and water security as well as heat stress, flooding and other extreme events. **Malnutrition and food insecurity are widespread,** particularly in conflict-affected areas of the country: In 2020, out of 6 million conflict-affected people, around 731 000 people were food insecure [58]. **Water shortages** during periods of drought and the associated decreases in crop yields further malnutrition rates, especially among women and children [18]. **Sand and dust storms,** which are expected to increase in frequency and intensity, **cause severe respiratory illness** [33]. **Recurrent flooding** contaminates already polluted drinking water and thereby the spread of **waterborne diseases**, including gastrointestinal infections such as bacterial diarrhoea, hepatitis A, typhoid fever and cholera [28] [7]. Repeated cholera outbreaks in 2007, 2008, 2012, 2013 and 2015 registered more than 2 800 confirmed cases across the country [56].

The projected rise in temperature (Figures 2 and 3) will very likely result **in more frequent and intensive heatwaves in Iraq.** However, **modelling uncertainty about the magnitude of the increase are relatively large and become even more pronounced from 2050 onward.**

Under RCP2.6, the population affected by at least one heatwave per year will rise to between 15.4 and 36 % until 2030, and to between 20.3 and 46.7 % until 2050 (Figure 27). After 2050, median projections more or less stabilise on the level of 2050. However, the variance between the models remains high, meaning that projected changes range from 20.1 to 51.3 % by 2080 (very likely range). Under RCP6.0, the number of people exposed to heatwaves will rise similarly to the RCP2.6 projections until 2050, with an expected increase to between 12.1 and 28.2 % until 2030, and to between 21.7 and 44.3 % until 2050. Unlike the RCP2.6 projections, however, heatwave exposure under this scenario will continue to increase sharply **until 2080, affecting between 28 and 56.7 % of the total population** (very likely range).
During the summer months of recent years, the temperature in the cities of Bagdad and Basra repeatedly exceeded 50 °C [51] [52] [59].

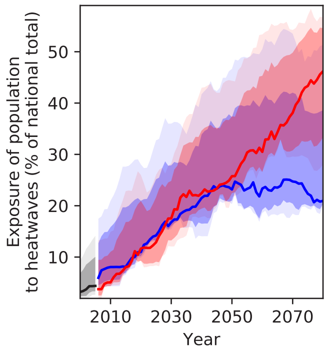


Figure 27: Projections of population exposure to heatwaves at least once a year for Iraq for different GHG emissions scenarios.

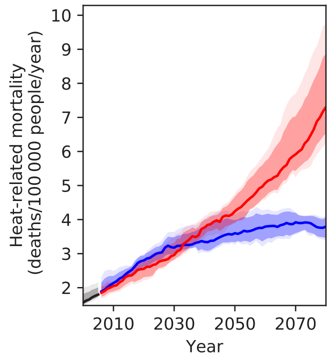


Figure 28: Projections of heat-related mortality for Iraq for different GHG emissions scenarios assuming no adaptation to increased heat.

When heatwaves coincide with power outages as has repeatedly been the case in Iraq, public exposure to extreme heat both outside and inside buildings can reach dangerous levels for people's health, as air conditioning systems stop working [60].

Heat-related mortality (Figure 28) **will very likely** rise following the projected increase in the number of very hot days (Figure 27). Under RCP2.6, heat-related mortality is projected to **increase from 1.6 deaths per 100 000 people annually in 2000 to 3.2 deaths per 100 000 people and year until 2030.** Between 2030 and 2080, the annual number of heat-related casualties stabilizes at approximately 3.8 deaths per 100 000 people until 2080 (multi-model median).

Under RCP6.0, heat-related mortality will similarly rise to the RCP2.6 projections until 2030, reaching 3 heat-related deaths per 100 000 persons a year. In the medium- to long-term, however, the multi-model median projects 4.2 and 7.3 deaths per 100 000 people annually until 2050 and 2080, respectively. This would translate to an increase by a factor of almost 5.6 towards the end of the century, provided that no adaptation to hotter conditions will take place. The projections **make it clear** that both rapid reductions in greenhouse gas emissions and climate change adaptation measures are urgently needed to reduce future exposure of people to climate risks in Iraq.

27 Between 2014 and 2017 alone, war-related damage and destruction in the health sector amounted to around US$ 2.3 billion [49].

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adelphi research gemeinnützige GmbH
Alt-Moabit 91, 10559 Berlin
+49 (030) 8900068-0
office@adelphi.de
https://www.adelphi.de/en

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Potsdam Institute for Climate
Impact Research (PIK) e.V.
Telegraphenberg A 31
14473 Potsdam, Germany
http://www.pik-potsdam.de

Scientific coordination:
Christoph Gornott (PIK), gornott@pik-potsdam.de
Barbora Šedová (PIK), sedova@pik-potsdam.de

Main authors:
Lisa Binder (PIK), binder@pik-potsdam.de
Barbora Šedová (PIK), sedova@pik-potsdam.de
Lukas Rüttinger (adelphi), ruettinger@adelphi.de
Julia Tomalka (PIK), tomalka@pik-potsdam.de
Stephanie Gleixner (PIK), gleixner@pik-potsdam.de

Contributors:
Ylva Hauf (PIK)
Stefan Lange (PIK)
Climate Policy Support Programme, SV Klima (GIZ)
Alina Viehoff (adelphi)
Michael Hornsby (adelphi)
Johanna Dieffenbacher (adelphi)
Laís Clemente Pereira (adelphi)

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