Global Water Security Center

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Environmental Insight Brief: Iran

Water and Environmental Security Challenges

While climate change exacerbates Iran's serious water problems, the primary cause is escalating water demand driven by a rapidly growing population and unsustainable agricultural practices. Unsustainable extraction of fossil groundwater currently offsets the most extreme impacts, but as climate changes:

01 Fossil Groundwater Offsets Looming **Water Shortage** — For Now

02 **Heat and Drought** Escalate Energy Challenges

03 Impacts of Water Scarcity Drive **Internal Displacement, Tension**

04 Water-Related **Transboundary Issues** Strain Regional Relations

Supplement

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Iran: Fossil Groundwater Offsets Looming Water Shortage — For Now

Water shortages caused by excessive consumption and declining precipitation will intensify as fossil groundwater supplies are diminished. Without water conservation efforts, more severe effects of water scarcity will impact the population, likely causing civil unrest.

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Since 1990, Iran's precipitation has declined by 8% to 27% depending on the region. Future projections vary widely, highlighting the need for effective water management to ensure water security in a highly variable environment by 2035. For more details, see page 10 of the supplemental materials.

Non-renewable groundwater is declining:

- **Tripled population since 1960** and growing urbanization help **drive excessive water consumption in Iran**. Non-renewable fossil groundwater provides 60% of Iran's water.
- **Inefficient agricultural practices** associated with the unsustainable goal of food self-sufficiency **use 90% of the groundwater**.

Along with the population surge, a significant increase in wells caused groundwater tables to decline an average of 49 cm/yr nationwide.

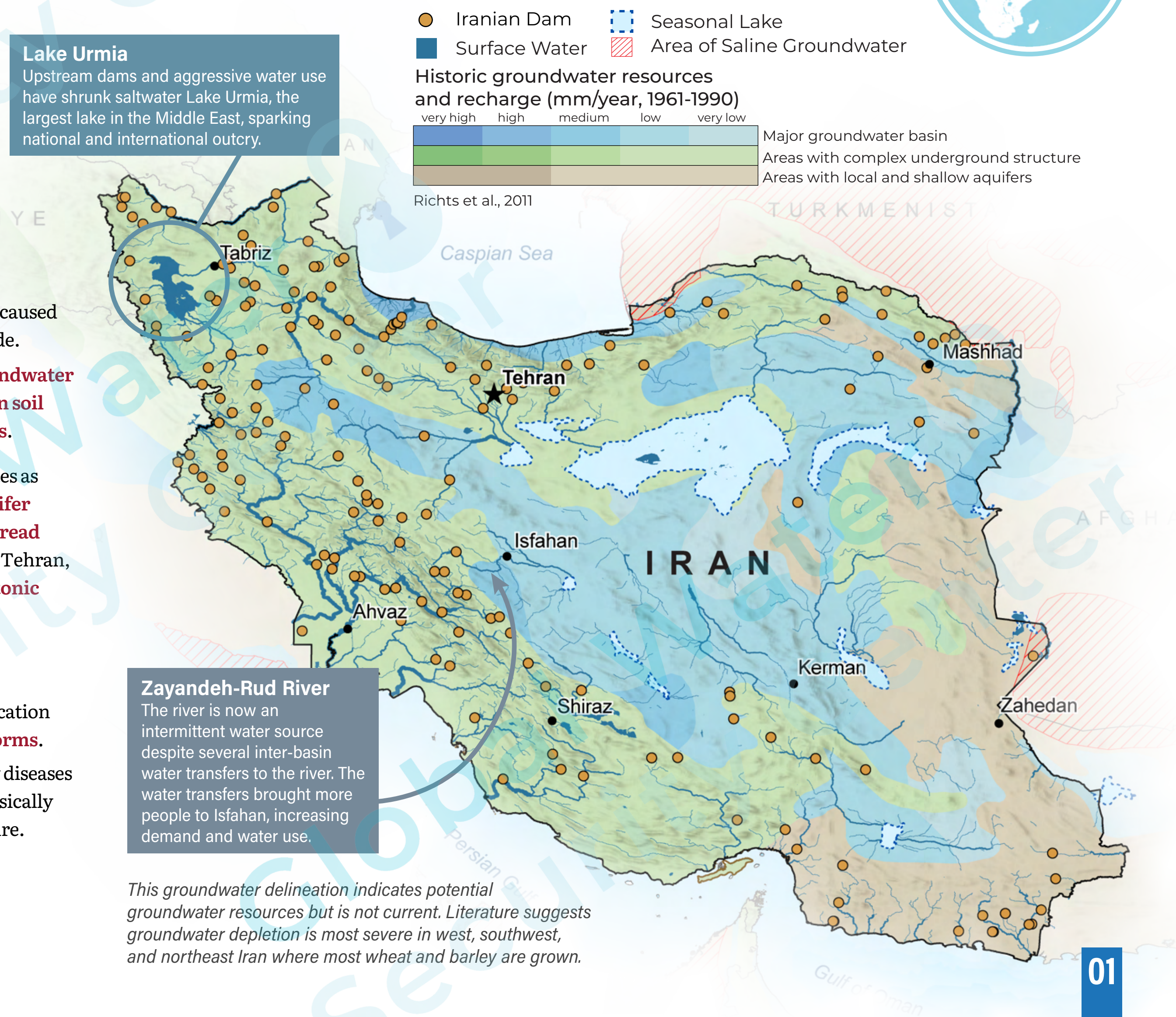
- Excessive groundwater withdrawals have **increased groundwater and soil salinity, with potentially devastating impacts on soil fertility, undermining agricultural goals and livelihoods**.
- Decreasing groundwater levels caused land subsidence rates as high as ~20 cm/yr in western Iran as of 2019, **reducing aquifer capacity, undermining soil stability and causing widespread sinkholes**. Groundwater-related soil instability in greater Tehran, home to 18% of Iran's population, could **interact with tectonic activity and cause earthquakes to be more catastrophic**.

Drying surface water, barren farmland, and increased desertification within Iran, Iraq, and Syria have caused an **increase in dust storms**.

- Dust storms can **increase human deaths** from respiratory diseases and spread fungal and viral infections. The storms are physically destructive to farming operations and critical infrastructure.
- Operationally, dust obscures visibility, hinders flights and vehicles, and can penetrate weapon system mechanics.

Map of Groundwater & Other Water Resources

Excessive dam-building has left Iran with water loss from evaporation, reduced groundwater recharge, and low downstream flows. Empty reservoirs remind citizens of the government's water-supply management failures.



This groundwater delineation indicates potential groundwater resources but is not current. Literature suggests groundwater depletion is most severe in west, southwest, and northeast Iran where most wheat and barley are grown.

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Iran: Heat & Drought Escalate Energy Challenges

Rising temperatures drive energy demands higher, while decreased and increasingly variable precipitation, along with outdated power technology, hinder electricity production.

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Water shortages lead to power blackouts, particularly in high-demand summer months. Hydropower generates only 4% of Iran's electricity, while over 90% relies on aging thermal power plants that require large amounts of water for cooling. Higher water temperatures reduce cooling efficiency and increase cooling-water demand.

Warming temperatures will likely worsen water and energy shortages in summer.

- **Days at or above 35˚C are projected to increase** across the country by 2035, with **as much as an additional month of days above 35˚C** in some areas. Extreme heat and temperature persistence can increase risk of death from hyperthermia, particularly in very young, elderly, or infirm people. The heat is already causing nationwide shutdowns to prevent risk of heat stroke.
- **Minimum summer temps are projected to get hotter, reducing evening reprieve from extreme heat.** Days with minimum temps above 25˚C will likely **increase by 30% in the hottest regions of the country**.

Warming temperatures in spring and winter affect precipitation and runoff pattern contributing to additional electricity losses.

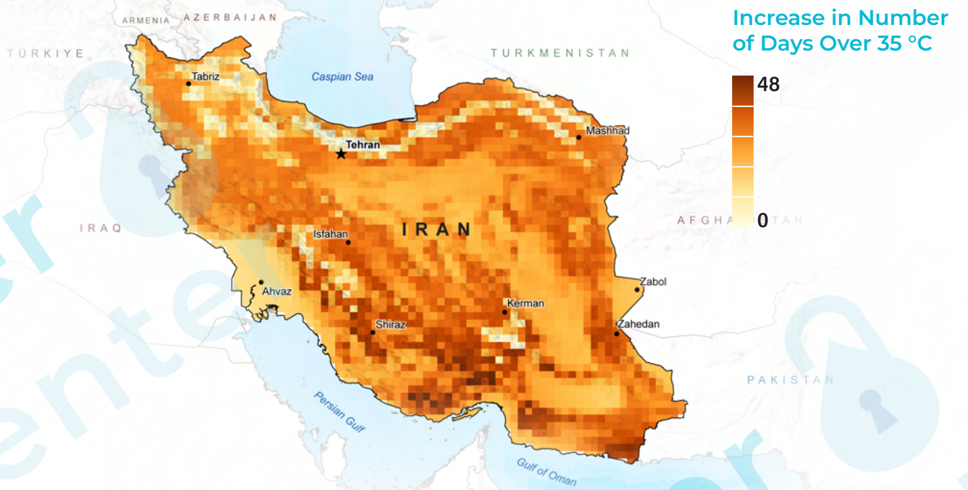
- Days below 0˚C in November and March are projected to be cut in half by 2035. **Rapid snowmelt in spring can overload reservoirs and cause floods, damaging riverside power plants resulting in spring electricity losses**.
- **Winter precipitation has declined** by 50% in arid regions and 25% in more temperate regions since 1990, decreasing snowpack in lower elevations. This combined with early and rapid spring melting will likely **lessen the amount of water in the snow-fed rivers throughout the year, exacerbating summer time water and energy shortages**.

While Iran possesses the second-largest natural gas reserve in the world, **high domestic energy demand and sanction-related lagging infrastructure have created daily natural gas deficits that contribute to blackouts**. The deficit is undermining **the nation's fossil fuel-reliant economy and diminishing its future capacity to export these fuels**.

- Low-quality Mazut fuel, sometimes used as a substitute, has contributed to severe air pollution linked to a substantial increase in hospitalizations and deaths attributed to pollutants.
- Sanctions hinder modernization and adoption of water-saving technologies for thermal energy production.
- A Russian-Iran gas pipeline development, announced July 2024, is slated to import 300 million cubic meters of Russian gas daily.

Maps of Extreme Heat & Drought

Iran is getting hotter and dryer with projected increases in number of days above 35°C by as much as a month in addition to increases in consecutive dry days by 2035, impacting the southeast acutely.



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Iran: Strained Resources, Extreme Events Drive Internal Displacement, Tension

A growing list of water-related grievances makes life difficult in Iran and undermines regime control.

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Iran has experienced a surge in urbanization since the 1960s. Today, 70% of Iran's 89 million people live in urban areas, with 18% in greater Tehran. One-third of the nation's urban population lives in informal fringe settlements with substandard housing.

As water scarcity has made agricultural livelihoods less viable, discontent has grown in rural populations while urban conditions have worsened with increasing population density.

Jobs

- **Loss of agricultural jobs, few other employment opportunities, and high inflation are degrading living standards, which can drive unrest**. Some efforts to create jobs in the petrochemical industry were halted for lack of water for cooling.

Power

- **Industrial sector power outages cost an estimated $6-8 billion/year**, affecting steel, cement, and automotive sectors most acutely. **Other businesses can operate just 3-4 days a week**, and A/C use has been prohibited in peak hours while temperatures in some cities exceed 50˚C as of June 2024.

Food Security

- U.S. sanctions have fueled inflation, significantly driving up food prices and causing **food insecurity in about 40% of Iran's population**.
- **Regular floods exacerbate already strained conditions.** In April 2019, devastating floods impacted around 10 million people. Drawn by increased humidity, a swarm of desert locusts ravaged remaining agricultural products. Extreme precipitation events are expected to increase by as much as 8% in otherwise dry Sistan and Baluchestan.

WASH (WAter, Sanitation, and Hygiene)

- As of summer 2024, **drinking water is cut off or unusable in 200 villages in Golestan Province, while the city of Tehran and Sistan and Baluchestan Province face outages**.
- **As of 2023, only 40% of Iran's wastewater is treated**. Disposal through injection wells, as well as open sewage canals and ditches, enable **ground and water pollution, seriously increasing risk of water-borne disease such as cholera, endemic in Iran, especially when combined with warm temperatures and low river flows.**

Map of Internal Migration

City populations in northern and central Iran are growing as people flee water scarcity, deprivation, and extreme events.

Migration
Province
Province with Water-Related Protests
Top Migration Destination Province
2019 Flood Heavily-Affected Province

Khuzestan, Sistan and Baluchestan, and **Isfahan** Provinces have become hot spots for water-related protests, which have spread to other cities, merged with anti-regime protests, and faced violent repression. Declining water availability will likely trigger protests to recur. In June 2024, small protests over water outages also began in Golestan Province.

Iran: Water-Related Transboundary Issues Strain Regional Relations

Climate change and drought are cited as primary drivers of water scarcity, but water extraction outweighs any changes in rainfall.

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The Caspian Sea, bordered by Iran, Russia, Kazakhstan, Turkmenistan, and Azerbaijan, **holds significant geopolitical importance due to its estimated reserves of 48 billion barrels of oil and 292 trillion cubic feet of natural gas**. A 2018 agreement delineated the waters but not the seabed. Currently, there is cooperation among Caspian countries, with Russia being the most powerful.

- Sea level has fallen 6-7 cm/yr due to increased evaporation from rising temperatures and from reduced input from Russia's Volga River. The decline affects northern countries more acutely. As coasts recede, new zones of jurisdiction may need to be established.
- The depth of the Caspian plunges to more than 1,000 meters in the southern end of the Sea, thus posing difficult technical conditions for drilling in Iran's waters. **Economic sanctions prevent Iran from developing this type of infrastructure.**

Disputes over the flow of the Helmand River date back to border drawing in 1872. **The 1973 water treaty has proven insufficient to resolve lingering modern water disputes and promote regional stability.**

- Tensions escalated in May 2023 when Iranian and Taliban border guards exchanged gunfire, killing three and injuring several others in Nimroz province.
- Iranian dams have dried downstream Afghan wetlands.
- Afghan's Kamal Khan Dam, opened in 2021, has shrunk Iran's artificial lakes, the only reliable source of water for people in Sistan and Baluchestan Province.
- Afghanistan requires water for irrigation in Helmand province.

90% of the Helmand Basin is in Afghanistan where flow originates, the river then flows in a circular pattern into Iran's Sistan Basin and back into Afghanistan, emptying into the Hamoun wetlands.

Iran-Turkey relations have flared over water resources. Iran holds sway over militant groups inside Iraq that could undermine the Iraq-Turkey Development Road project.

- **Iran has criticized Turkey's major dam projects on the Tigris and Euphrates Rivers**, calling them dangerous for the region, attributing dust storms in Iraq and Iran to Ankara. Relatedly, Iraq's water scarcity puts scrutiny on Iran's dams on tributaries to the Tigris River that have further reduced flows and threatened livelihoods in the Kurdistan Region of Iraq.
- Iran objected to Turkish dam construction on the Aras River, though Turkey says the dams will create no water limitations for Iran.

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United Nations office for the Coordination of Humanitarian Affairs (OCHA). (2019). Islamic Republic of Iran: Floods Response Plan (April 2019). https://www.unocha.org/publications/report/iran-islamic-republic/islamic-republic-iran-floods-response-plan-april-2019

Supplemental Materials

Lake Urmia Aerials

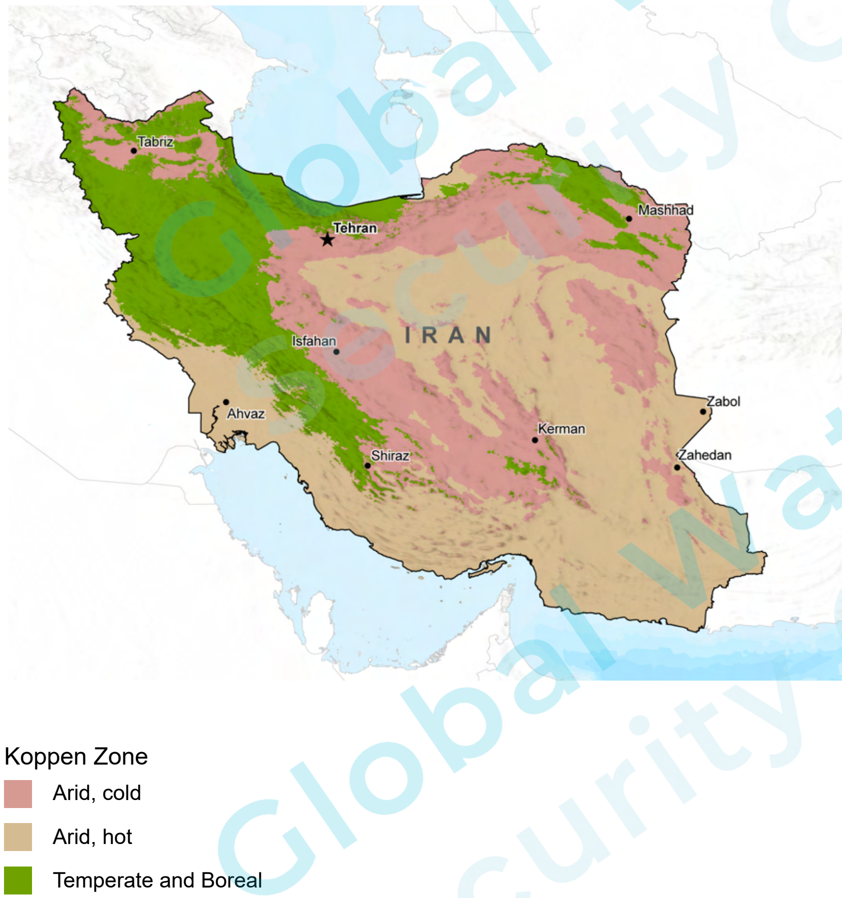
Lake Urmia lost 90% of its area (5000 km2) from 1995-2014. Government sponsored restoration efforts have been ongoing since 2013, however, due to the restricted river inflows, the lake remains largely reliant on precipitation. The September 2020 aerial image (left) shows the lake after a period of rain. In September 2023, the aerial (right) displays a desiccated lakebed. Images from NASA Earth Observatory. “Lake Urmia Shrivels Again.” NASA Earth Observatory, October 10, 2023. https://earthobservatory.nasa.gov/images/151913/lake-urmia-shrivels-again

Supplemental Materials

Climate Types

Generalized Koppen-Geiger Climate Zone Map

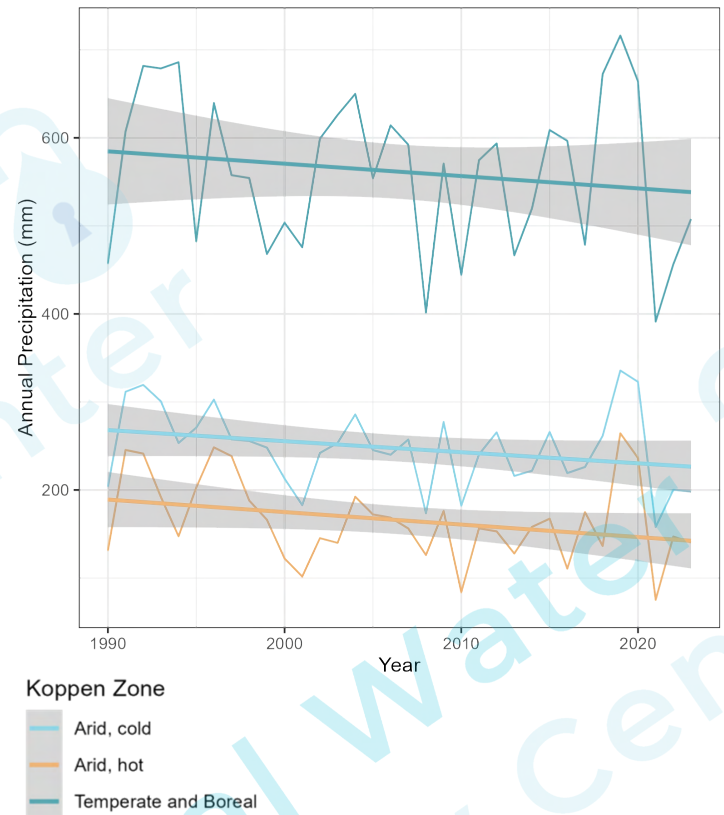
Generalized Koppen-Geiger climate zones were used to analyze climate data by type. Iran has three major climate zone types: arid hot, arid cold, and temperate and boreal. The temperate and boreal zone encompasses the country's mountainous areas. In the following analyses these Koppen zones were used.



Historic Precipitation 1990-2023

Total Annual Precipitation by Koppen Zone

Precipitation has been declining in Iran since 1990. This figure depicts total annual precipitation (mm) from 1990 to 2023 separated by Koppen Zones in Iran. The colored lines indicate a simple linear model applied to the depicted data. The decline in total seasonal precipitation is statistically significant and indicates a decline of about 1.3 mm per year, or approximately 44 mm since 1990. The mean annual precipitation across Iran is shown here for a clear summary. However, this average does not capture the full range of values across the country's diverse geography and extremes, such as those depicted in the consecutive dry day map on slide 2 or heavy rainfall events on the next page.

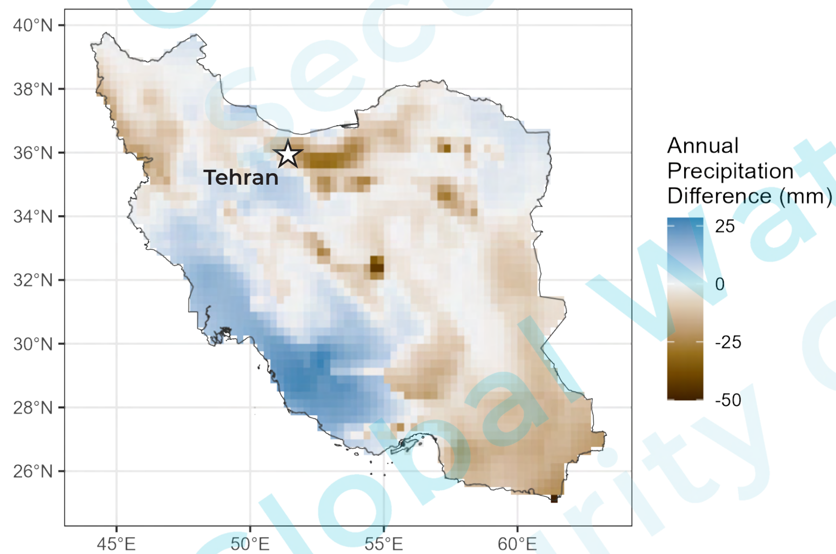


Supplemental Materials

Precipitation Projections for 2035

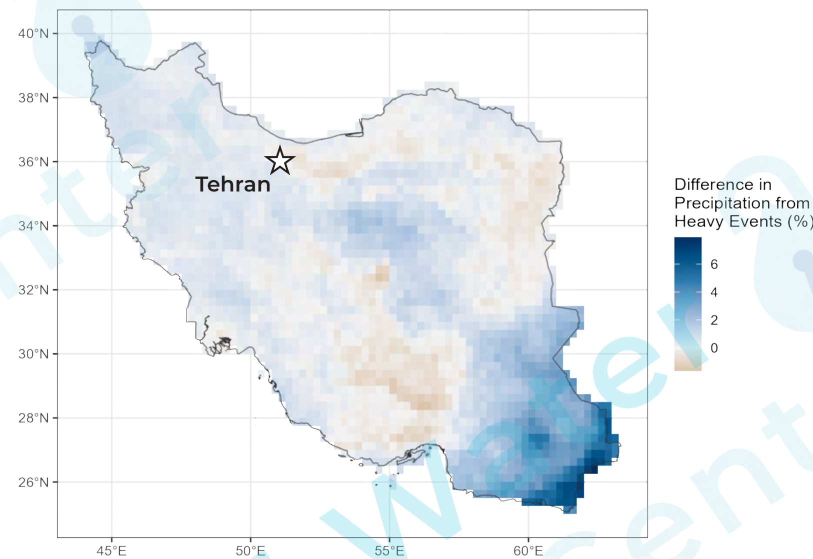
Change in Total Annual Precipitation from 2000 to 2035

This figure depicts the difference in total annual precipitation between 2000 and 2035. Blue indicates that 2035 will be wetter than 2000 while brown indicates that it will be drier. The greater Tehran area will see a decline, as well as southeastern Iran which includes the already strained Sistan and Baluchestan province—an area where water protests are common. Khuzestan province in the southwest, another hot spot for water protests is projected to see an increase.



Percent Change in Precipitation from Heavy Rainfall Events

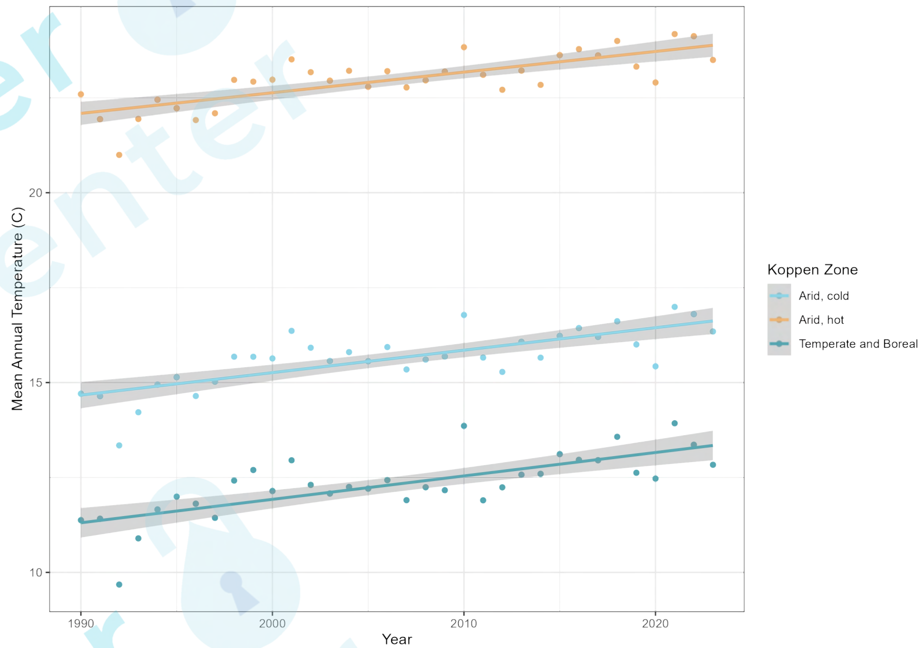
This figure depicts the change in the amount of rain that falls in heavy rain events over Iran between 2000 and 2035. This tells us how rain is distributed throughout the year and how that might change in the future. Dark blue locations are areas that are projected to get more of their rain in heavy events in 2035. The southeastern provinces are projected to receive 6-8% more of their rain from heavy events in 2035. If an area gets more of their rainfall in heavy rainfall days (rather than it being evenly distributed throughout the year) it has implications for flooding, water capture, and groundwater recharge. The southeastern region may have an elevated risk of flooding due to the arid, hot climate which can make sediment less permeable. When rain falls on impervious soils, the rain moves off faster, similar to a parking lot, so flood risk becomes high.



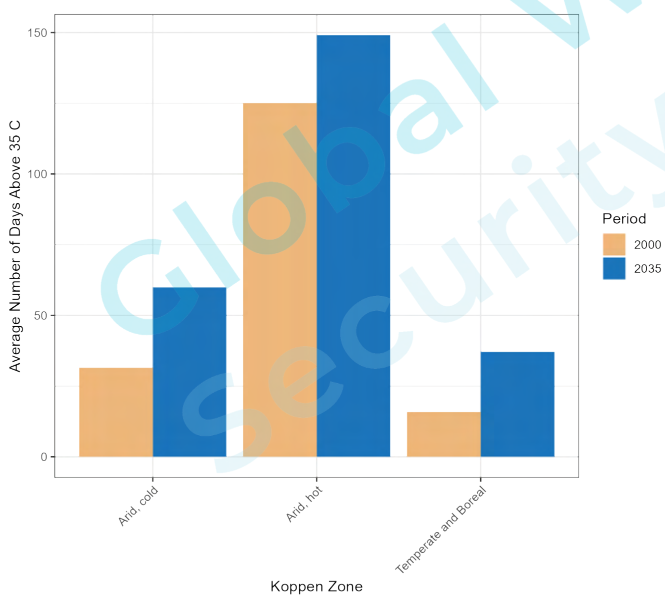
Supplemental Materials

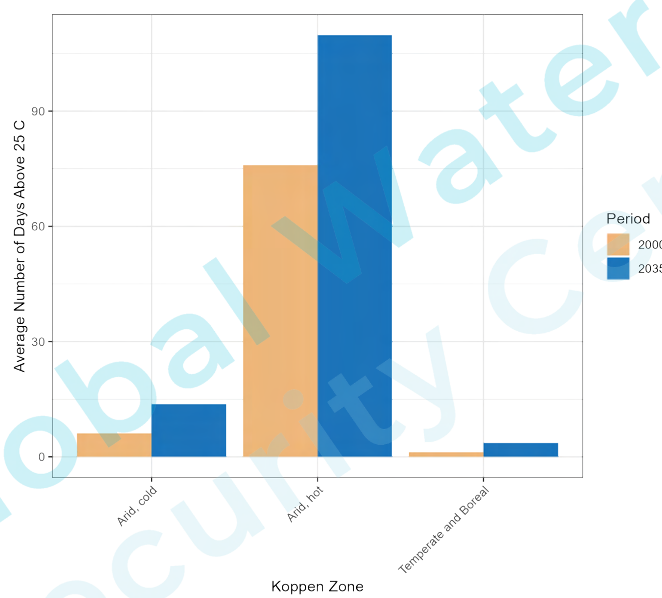
Temperature Projections for 2035

Increasing Temperatures
Temperatures are increasing across Iran. The line chart below depicts mean annual temperature from 1990 to 2023 separated by Koppen Zones in Iran. The colored lines indicate a simple linear model applied to the depicted data. The increase in temperature is statistically significant and indicates an increase of about 0.05 degrees Celsius per year, or approximately 1.9 degrees Celsius since 1990. The rising average temperature results in more extreme heat events. Slide two illustrates this in the map depicting the increase and distribution of extreme heat days. Extreme heat has already significantly impacted Iran, leading to nationwide shutdowns to avert the heat, power outages, economic losses, and increased health risks.



The Number of Very Hot Days and Nights That Don't Cool Down
These two bar charts illustrate the change in the number of very hot days between 2000 and 2035 separated by Koppen Zone. The first depicts the average number of days where the maximum daily temperature is at or above 35 degrees Celsius (very hot days) while the second depicts the average number of days where the minimum temperature is at or above 25 degrees Celsius (nights that don't cool down). All Koppen Zones are projected to see an increase in both of these metrics. The biggest changes in days above 35 degrees Celsius are likely to be felt in the Arid, cold and Temperate zones, while the increase in hot nights is likely to felt most acutely in the Arid, hot zone.





Supplemental Materials

Data and Methods

Scope:

This product was developed for the National Geospatial Agency to provide information on Iran related to water security and subsequent instabilities such as energy security, food security and transboundary conflicts. The product was developed to place the current hydrometeorological conditions into historical context and synthesize temperature and precipitation projections for 2035.

Data Sets:

- ERA5 Historical Weather Data [1990-2023] - daily values for precipitation, maximum temperature, minimum temperature, average temperature
- NASA Earth Exchange Global Daily Downscaled Projection CMIP6. SSP585 2025-2045. Historical 1985-2014. 17 models were used: ACCESS-ESM1-5, BCC-CSM2-MR, CanESM5, CMCC-ESM2, FGOALS-g3, GISS-E2-1-G, MIROC-ES2L, MPI-ESM1-2-HR, MRI-ESM2-0, NESM3, NorESM2-MM, CNRM-ESM2-1, EC-Earth3-Veg-LR, GFDL-ESM4, INM-CM5-0, IPSL-CM6A-LR, KIOST-ESM

Metric Calculation:

Each metric was calculated for the ERA5 historical range (1990-2010) to get an approximate '2000' value. They were also calculated for CMIP6 historical range ('2000') and the future time period ('2035'). The CMIP6 future time period was compared to the CIMP6 historical time period to calculate the projected difference. These differences were then added back to the ERA5 historical values to get future projections. We grouped results based on three Koppen Geiger Zones – 'Arid, hot', 'Arid, cold', and 'Temperate and Boreal'.

Precipitation

- Total Annual Precipitation: The summed total precipitation in mm within a given calendar year.
- Mean Annual Precipitation: The average of the yearly total precipitation over a specified time period.
- Total Winter Precipitation: Winter was defined as December, January. Total precipitation over these months were summed for each year with December being included in the next year's winter.
- Difference in precipitation in 2035: The difference in CMIP6 historical (1990 to 2010) precipitation values and the mean of CMIP6 precipitation projections from 2025 to 2045.
- Percent Change in Precipitation from Heavy Rainfall Events: Heavy rain quantity (exceeding the 95th percentile) within a year divided by total annual precipitation for that year over a defined region.
- Consecutive Dry Days: The summed total of days with less than 1 mm of rain within each year.

Temperature

- Mean Annual Temperature: The mean of the yearly average temperature over a specified time period.
- Difference in Temperature in 2035: The difference in CMIP6 historical (1990 to 2010) temperature values and the mean of CMIP6 temperature projections from 2025 to 2045.
- Extreme Heat Days: We looked at three categories for extreme heat days – days where the average daily temperature exceeded 25 C, days where the maximum daily temperature exceeded 35 C, and days where the minimum daily temperature exceeded 25 C. For each category, we calculated the number of days within a calendar year that met or exceeded the temperature threshold.

Statistical Analysis:

Historic trends (1990-2023) through time were examined for mean annual temperature, total annual precipitation, total winter precipitation. For each of these metrics, we used values averaged over the country by Koppen-Geiger Zones to not get an inflated sample size. Linear models were applied to these metrics over time with a significance threshold of $p<0.05$.

Supplemental Materials

Clarifying SSPs

Excerpt from "Explainer: How 'Shared Socioeconomic Pathways' explore future climate change":

> *Over the past few years, an international team of climate scientists, economists and energy systems modelers have built a range of new "pathways" that examine how global society, demographics and economics might change over the next century. They are collectively known as the "Shared Socioeconomic Pathways" (SSPs).*
>
> *The SSPs are based on five narratives describing broad socioeconomic trends that could shape future society. These are intended to span the range of plausible futures.*
>
> *They include: a world of sustainability-focused growth and equality (SSP1); a "middle of the road" world where trends broadly follow their historical patterns (SSP2); a fragmented world of "resurgent nationalism" (SSP3); a world of ever-increasing inequality (SSP4); and a world of rapid and unconstrained growth in economic output and energy use (SSP5).*

The Take Home:

The current state of the world is, by definition, best reflected in SSP2, the "middle of the road" scenario. There is no quantified likelihood of any of the SSPs. Meaning, we can't know which direction societal trends, like fossil fuel use, development, political leanings, or technology generation will go. Predictions for global mean temperatures from the different SSPs do not diverge appreciably until 2050 or later. Given the focus on 2035 for this product, the SSP chosen likely does not have an impact on the data presented.