

Climate Risk Analysis for Sustainable Water Resource Planning in Syria

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Abstract

Climate change threatens Water, Sanitation, and Hygiene (WASH) services globally, with post-conflict regions facing compounded legacies of infrastructure damage and institutional erosion. Syria exemplifies this challenge, combining extreme climate vulnerability with the enduring consequences of past conflict and economic collapse. This study assesses climate risks to Syria's WASH sector using the GWP–UNICEF Strategic Framework for Climate-Resilient WASH Development. We integrate climate hazard analysis, infrastructure exposure assessment, and multidimensional vulnerability evaluation using IPCC risk definitions ($\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$). Data are synthesised from international climate databases, UN reports, and peer-reviewed literature. Syria has experienced accelerated warming ($0.72^{\circ}\text{C}/\text{decade}$, 1991–2020), declining precipitation ($\sim 12\%$ per decade since 1990), and increasing hydroclimatic extremes. Under SSP5-8.5, temperatures could reach 24.7°C by 2100 ($+5.7^{\circ}\text{C}$ relative to baseline), while Euphrates River flow may decline by 73%. These hazards, combined with infrastructure damaged during the past conflict, 7.2 million internally displaced persons (IDPs), and the legacy of governance fragmentation, create extreme WASH risks culminating in the 2022 cholera outbreak. Climate-resilient WASH adaptation requires integrated strategies: infrastructure rehabilitation, climate-informed water management, early warning systems, institutional strengthening, and community-based adaptation. The framework is transferable to other post-conflict regions facing comparable hydroclimatic challenges.

1. Introduction

Climate change has emerged as one of the most significant threats to the sustainability of water resources and WASH services worldwide (IPCC, 2022). Rising temperatures, changing precipitation patterns, prolonged droughts, floods, storms, landslides, and wildfires are increasingly disrupting water availability, damaging critical infrastructure, and compromising public health (WMO, 2023; WHO, 2023). These impacts are particularly severe in regions recovering from conflict, where the legacies of infrastructure destruction, economic instability, and weakened institutions substantially constrain adaptive capacity (Selby et al., 2017; Gleick, 2014). Consequently, strengthening the climate resilience of WASH systems has become a global priority for achieving sustainable development and safeguarding vulnerable communities (GWP & UNICEF, 2017; UN-Habitat, 2022).

Syria is among the most climate-vulnerable countries in the Eastern Mediterranean, where the lingering effects of past climate trends and the aftermath of civil war interact to amplify water insecurity (Climate Centre, 2024; Naaouf & Torma, 2023). The country experienced persistent warming, declining and increasingly variable precipitation, prolonged droughts, and more frequent hydroclimatic extremes over recent decades (Climate Change Knowledge Portal, n.d.; Houmsi et al., 2019; Mathbout et al., 2023). These climatic changes have intensified water scarcity through increased evaporation, reduced groundwater recharge, and declining surface water availability (Ajjur & Al-Ghamdi, 2021; FAO, 202). Simultaneously, the past armed conflict severely damaged water supply systems, sanitation facilities, and supporting infrastructure, while eroding governance and reducing institutional capacity for maintenance and investment (UN OCHA, 2023; USAID, 2023; World Bank Group & EU, 2022). As a result, millions of Syrians continue to face limited access to safe drinking water and adequate sanitation, particularly internally displaced and vulnerable rural communities, owing to the cumulative legacy of these intertwined crises (WHO/UNICEF JMP, 2023; UNICEF, 2023; ICRC, 2021).

The interaction between climate hazards and the deteriorated WASH infrastructure inherited from the conflict has generated complex and interconnected risks (Abbas et al. 2026; Fanack Water, 2023; UN Water, 2022). Rising temperatures and prolonged droughts have reduced water availability, whereas floods and storms have further damaged treatment plants, pumping stations, distribution networks, and sanitation facilities (Abd-Elhamid et al., 2024). These impacts have increased dependence on unsafe water sources, reduced wastewater treatment capacity, and elevated the incidence of waterborne diseases (Tarnas et al., 2023; Rayan et al., 2021). The economic decline and institutional fragility that followed the conflict further constrain the capacity of communities and government agencies to respond effectively to climate-related hazards (Concern Worldwide, 2024; Bolton, 2020; UNDP, 2024).

Developing climate-resilient WASH systems in a post-conflict setting requires a comprehensive understanding of the interactions among climate hazards, infrastructure exposure, and multidimensional vulnerability (Dückers et al., 2015). Although

previous studies have investigated Syria's climate (Naaouf & Torma, 2023; Homsy et al., 2020), water resources (UN-Water, 2022; Drgham, 2020), and humanitarian conditions (UN OCHA, 2023; UNHCR, 2024), relatively few have integrated these components within a comprehensive climate risk assessment specifically focused on the WASH sector in a post-conflict context (World Bank, 2023; UN-Habitat, 2022). Accordingly, this study presents a comprehensive climate risk assessment of Syria's WASH sector using the GWP-UNICEF framework (GWP & UNICEF, 2017). The assessment integrates analyses of climate hazards, exposure, and vulnerability to evaluate the principal climate risks affecting water supply, sanitation, and hygiene services, and identifies priority adaptation measures to support evidence-based, climate-resilient WASH recovery and planning.

2. Methodology

2.1 Study Framework

This study adopts the Strategic Framework for Climate-Resilient WASH Development developed by the Global Water Partnership (GWP) and UNICEF (GWP & UNICEF, 2017). The framework provides a systematic approach for integrating climate resilience into WASH planning by linking climate hazards, exposure, vulnerability, and adaptation within a structured decision-making process. The framework follows four interconnected stages: (i) Understanding the Problem; (ii) Identifying and Appraising Adaptation Options; (iii) Delivering Climate-Resilient Solutions; and (iv) Monitoring and Continuous Improvement (Fig. 1) (GWP & UNICEF, 2017; UNICEF, 2022).

FIGURE 1: Strategic Framework for Climate-Resilient WASH Development (GWP & UNICEF, 2017)]

The assessment follows the IPCC conceptual definition of climate risk, whereby risk results from the interaction of climate hazards, exposure, and vulnerability (IPCC, 2022; Dückers et al., 2015). Accordingly, the overall climate risk to Syria's WASH sector was evaluated through a sequential assessment of these three components (IPCC, 2022; GWP & UNICEF, 2017) (Fig. 2).

FIGURE 2: Analytical Framework – Interaction between Hazards, Exposure, and Vulnerability

2.2 Data Collection

The assessment is based on an extensive review and synthesis of secondary information from peer-reviewed literature, international agency reports, national publications, and publicly available climate databases (Climate Change Knowledge Portal, n.d.; UNDP, 2023; World Bank, 2023). Historical climate records were compiled from the Climate Change Knowledge Portal (n.d.), IPCC Sixth Assessment Report (IPCC, 2022), UN-Water (2022), UN OCHA (2023), and USAID (2023). Additional information on Syria's hydrology, socio-economic conditions, demographics, and WASH infrastructure was collected from government reports (Syrian Arab Republic, 1996; Meslmani, 2010) and international organisations (UN-Water, 2022; WHO/UNICEF JMP, 2023; World Bank Group & EU, 2022). Information from multiple sources was cross-validated to improve consistency and reliability (FAO, 2021; UNESWC, 2023).

2.3 Climate Risk Assessment

2.3.1 Hazard Assessment

The hazard assessment identified principal climate hazards affecting Syria's WASH sector, including increasing temperatures, droughts, floods, storms, landslides, wildfires, and changes in precipitation patterns (IPCC, 2022; Climate Centre, 2024). Each hazard was characterised according to frequency, intensity, duration, geographical extent, and projected future trends (Naaouf & Torma, 2023; Mathbout et al., 2023; Homsy et al., 2020), with a focus on hazards directly affecting water availability, water quality, sanitation infrastructure, and public health (Abbas et al., 2026; WMO, 2023; WHO, 2023; Rayan et al., 2021).

2.3.2 Exposure Assessment

The exposure assessment evaluated the degree to which communities, water resources, and WASH infrastructure are subject to climate hazards (IPCC, 2022; GWP & UNICEF, 2017). The analysis considered drinking water supply systems, wastewater treatment facilities, pumping stations, water towers, groundwater resources, river basins, and vulnerable populations

particularly internally displaced communities (UN-Water, 2022; ICRC, 2021; UNICEF, 2023). Spatial relationships between climate hazards and critical infrastructure were examined to identify areas of elevated exposure (World Bank Group & EU, 2022; UN-Habitat, 2022; World Bank, 2023), with particular attention to infrastructure damaged during the past conflict (PAX, 2023; Doctors Without Borders, 2023).

2.3.3 Vulnerability Assessment

Vulnerability was assessed using six complementary dimensions: physical (condition and location of water infrastructure, including conflict-related damage) (World Bank Group & EU, 2022; ICRC, 2021); social (poverty, displacement, and access to services) (UNHCR, 2024; IDMC, n.d.; World Vision, n.d.); financial (economic limitations affecting operation and maintenance) (Bolton, 2020; UNDP, 2024; World Bank, 2022); environmental (ecosystem degradation and declining water resources) (Global Forest Watch, 2023; Atesoglu et al., 2020; Mohamed et al., 2020); human (institutional and technical capacity eroded during the conflict) (Brookings Institution, n.d.; The Day After, 2022; PeaceRep, 2022); and political (governance constraints associated with the legacy of instability) (Tarnas et al., 2023; PAX, 2023; Carnegie Endowment, 2024). Collectively, these dimensions determine the adaptive capacity of WASH systems under changing climatic conditions (Dückers et al., 2015; Calverley & Walther, 2022; UNESWCW, 2023).

2.4 Climate Risk Integration

The final climate risk assessment integrated the results of the hazard, exposure, and vulnerability analyses to identify priority climate risks affecting Syria's WASH sector (IPCC, 2022; GWP & UNICEF, 2017). The integrated assessment provides the basis for prioritising adaptation measures, including infrastructure rehabilitation, climate-informed water resources management, early warning systems, community-based adaptation, and strengthened institutional governance (UNDP, 2023; UNICEF, 2022; UN-Habitat, 2022).

3. Results

3.1 Study Area and Hydroclimatic Baseline

Syria occupies approximately 185,880 km² in Western Asia (Fig. 3) and exhibits considerable geographical diversity, ranging from Mediterranean coastal plains to mountainous terrain, steppe landscapes, and extensive desert regions (Geo Ref, 2021; Worldometer, 2024). More than half of the country's land area is classified as arid desert (FAO, 2008; Climate Change Knowledge Portal, n.d.). This physiographic diversity creates substantial spatial variability in climate, water availability, and ecosystem characteristics, directly influencing the distribution and performance of WASH services (Houmsi et al., 2019; Mathbout et al., 2023).

FIGURE 3: Geographical Map of Syria and Surrounding Regions (Open Street Map)

Population distribution is highly uneven (Fig. 4). Major urban centres Damascus, Aleppo, Homs, and Hama support the highest population densities, whereas eastern and desert regions remain sparsely populated (Worldometer, 2024; Geo Ref, 2021). The past conflict displaced more than half of Syria's pre-war population, resulting in approximately 6.8 million refugees and 7.2 million internally displaced persons (IDPs) (IDMC, n.d.; UNHCR, 2024; World Vision, n.d.). Rapid urban expansion has increased pressure on water supply, sanitation, and wastewater systems in host communities, while service accessibility has declined in regions most affected by the conflict (Wind & Ibrahim, 2020; Ibrahim & Novotny, 2018; UN-Habitat, 2022).

FIGURE 4: Population Density Distribution (2021) – Geo Ref, 2021

Economic indicators demonstrate severe deterioration (Fig. 5). Agriculture, historically one of the country's largest water-consuming sectors, experienced substantial decline owing to the combined effects of the past conflict, water scarcity, and environmental degradation (World Bank, 2022; WFP, 2023; Food Security Cluster, 2023). Similar contractions occurred in industrial and service sectors, constraining investment in water infrastructure, operation, and maintenance (Bolton, 2020; UNDP, 2024; The Day After, 2022).

FIGURE 5: Share of Economic Sectors in GDP (2004–2022) – World Bank, 2022

Between 2011 and 2022, drinking water supplies plummeted by 40%, with two-thirds of water treatment plants rendered inoperable due to damage incurred during the conflict (Fig. 6) (ICRC, 2021; PAX, 2023; Doctors Without Borders, 2023). Contaminated Euphrates water, frequently untreated, has left 40% of Syrians dependent on unsafe alternatives, including polluted wells and untreated surface water (UN-Water, 2022; Fanack Water, 2023; Tarnas et al., 2023). This culminated in a catastrophic cholera outbreak in 2022, with reported cases surging to 9,427 cases and 49 fatalities by late November (underreporting is a critical concern, with only 14% of cases laboratory-confirmed) (WHO, 2023; UNICEF, 2022; Tarnas et al., 2023). Gradual improvements in service coverage between 2015 and 2022 are largely attributable to humanitarian interventions and early infrastructure rehabilitation efforts (WHO/UNICEF JMP, 2023; UNICEF, 2023; Humanitarian Action, 2025).

FIGURE 6: Rural and Urban Service Levels (2015–2022) – JMP, 2022

International financial assistance has been vital in the post-conflict recovery phase, peaking at approximately \$72.5 million in 2022 (Fig. 7) (UN-Water, 2022; UNICEF Syria, 2022; KfW Entwicklungsbank, 2023).

Figure 7: Amount of water- and sanitation-related official development assistance received by Syrian Arab Republic in 2022, by sub-sector. *Source: UN Water, 2022*

Water Resources Baseline

Syria's renewable water resources are estimated at approximately 16.8 billion m³ yr⁻¹, derived from rainfall, surface water, and groundwater (UN-Water, 2022; Drgham, 2020). However, approximately 78% of annual precipitation is lost through evaporation (Jamal et al., 2007; FAO, 2008). Surface water contributes approximately 4.29 billion m³ yr⁻¹, while groundwater supplies approximately 5.64 billion m³ yr⁻¹, although many aquifers are increasingly vulnerable to overexploitation and contamination (Table 1)(UNESCW, 2023; UN-Water, 2022; FAO, 2021).

Table 1
Key Water-Related Features (UN-Water, 2022)

Feature	Value
Mean rainfall	252 mm/year
Renewable water resources	16.8 billion m³/year (2020)
Water withdrawals	16.75 billion m³/year (2020)
Environmental flow	4 billion m³/year (2020)
Water-use efficiency	2.8 USD / m³ in 2020 (decreasing trend since 2000)
Water stress	124% (includes environmental flow)

Table 1: Key Water-Related Features (UN-Water, 2022)

Marked variations in topography further influence climatic and hydrological processes (Fig. 8) (Mathbout et al., 2023; Houmsi et al., 2019). Mountainous regions in western and northern Syria receive relatively high precipitation and support greater vegetation cover, whereas central and eastern lowlands experience predominantly arid conditions with limited rainfall and high evaporation rates (Climate Change Knowledge Portal, n.d.; FAO, 2008). These elevation gradients strongly control runoff generation, groundwater recharge, and agricultural productivity (Naaouf & Torma, 2023; Houmsi et al., 2019).

Figure 8: Hypsometric map based on regionalized in-situ observations based on SRTM elevation data at spatial resolution of 30 s (~ 1 km²). *Source: Mathbout et al., 2023*

Syria encompasses three principal Köppen–Geiger climate zones: Mediterranean (Csa), semi-arid steppe (BSh), and hot desert (BWh) (Climate Change Knowledge Portal, n.d.; Houmsi et al., 2019). Consequently, annual precipitation ranges from less than

100 mm in the eastern desert to nearly 1,000 mm along the Mediterranean coast (FAO, 2021; Climate Centre, 2024). Approximately 60% of the country receives less than 250 mm of rainfall annually, contributing to widespread water scarcity and strong regional differences in water resource availability (Fig. 9) (UN-Water, 2022; Mathbout et al., 2023).

Figure 9: Köppen-Geiger Climate Classification Map (1991–2020) with Climate Zone Codes. *Source: Climate Change Knowledge Portal, n.d.*

Hydrometeorological conditions also exhibit considerable spatial variability (Houmsi et al., 2019; Climate Change Knowledge Portal, n.d.). Mean temperatures exceed 30°C during summer across much of the country, while potential evaporation ranges from approximately 1,300 mm yr⁻¹ in western Syria to nearly 3,000 mm yr⁻¹ in the eastern desert (Ajjur & Al-Ghamdi, 2021; Jamal et al., 2007). Relative humidity declines markedly from the Mediterranean coast toward inland regions, accompanied by decreasing wind speeds and frequent sandstorms that further increase atmospheric evaporative demand (Houmsi et al., 2019; Al Zubi et al., 2024; Kurdistan24, 2024). Together, these climatic characteristics contribute to high levels of aridity and place significant pressure on water resources and WASH infrastructure (Fig. 10 & 11) (Climate Centre, 2024; UNESCW, 2023).

Figure 10: (Left) Spatial variability in daily mean temperature over Syria; (Middle) Annual Temperature and Precipitation Variability: Monthly Averages and Extremes; (Right) Average total rainfall (1951–2010). *Source: Climate Change Knowledge Portal, n.d.*

Figure 11: Geographical distribution of annual (d) relative humidity (%); and (f) wind speed (km/h) from 1951 to 2010. *Source: Houmsi et al., 2019*

3.2 Observed Climate Trends (1951–2023)

Observed climate records demonstrate a pronounced warming trend. Mean annual air temperature increased by approximately 0.27°C decade⁻¹ between 1950 and 2020, accelerating to 0.51°C decade⁻¹ after 1971 and 0.72°C decade⁻¹ during 1991–2020 (Climate Change Knowledge Portal, n.d.; Naaouf & Torma, 2023; Houmsi et al., 2019). These warming rates exceed the global average, indicating that Syria has become a climate change hotspot in the Eastern Mediterranean (Fig. 12) (IPCC, 2022; Climate Centre, 2024; Selby et al., 2017).

Figure 12: Annual Trends in Average Mean Surface Air Temperature in the Syrian Arab Republic (1951–2023): Significance of Trend per Decade. *Source: Climate Change Knowledge Portal, n.d., 2026*

Rainfall records reveal an accelerating drying trend. Since 1990, annual precipitation has declined by approximately 12% per decade, accompanied by delayed rainfall onset, shortened wet seasons, and increasing rainfall intensity (Climate Change Knowledge Portal, n.d.; FAO, 2021; Mathbout et al., 2023). Approximately 30% of annual rainfall within the Euphrates Basin now occurs during only 5–10 high-intensity events, increasing flash flood risk while reducing groundwater recharge (Fig. 13) (Abd-Elhamid et al., 2024; Mueller et al., 2021; CSIS, 2023).

Figure 13: Annual Trends in Average Precipitation in the Syrian Arab Republic (1951–2023): Significance of Trend per Decade. *Source: Climate Change Knowledge Portal, n.d., 2026*

Rising seasonal temperatures and reduced rainfall have sharply increased potential evapotranspiration (PET), accelerating soil moisture depletion and intensifying hydrological drought (Fig. 14) (Ajjur & Al-Ghamdi, 2021; Houmsi et al., 2019; Naaouf & Torma, 2023).

Figure 14: Anomaly in aridity and different meteorological variables over the study period (1951–2010). *Source: Houmsi et al., 2019*

3.3 Future Climate Projections

3.3.1 Temperature Projections

During the reference period (1995–2014), the country's average annual temperature ranged between 18.07°C and 18.94°C (mean ~ 18.5°C) (Climate Change Knowledge Portal, n.d.; UNDP, 2023). Climate models project accelerating temperature rises across all SSP scenarios (Table 2 & Fig. 15).

Table 2
Projected Average Mean Surface Air Temperature under SSP Scenarios
(Reference: 1995–2014 = ~ 18.5°C) Source: Climate Change Knowledge
Portal, n.d., 2026; UNDP, 2023.

Scenario	2020 (°C)	2040 (°C)	2060 (°C)	2080 (°C)	2100 (°C)
Historical	19.5	—	—	—	—
SSP1 2.6	19.0	19.5	20.0	20.5	21.0
SSP2 4.5	19.0	19.5	20.0	20.5	21.8
SSP3 7.0	18.5	19.0	19.5	20.0	20.5
SSP5 8.5	19.5	20.0	21.0	21.5	24.7

Table 2: Projected Average Mean Surface Air Temperature under SSP Scenarios (Reference: 1995–2014 = ~ 18.5°C) Source: Climate Change Knowledge Portal, n.d., 2026; UNDP, 2023.

Figure 15: Projected Average Mean Surface Air Temperature in the Syrian Arab Republic: Multi-Model Ensemble Analysis (Reference Period: 1995–2014). Source: Climate Change Knowledge Portal, n.d.

3.3.2 Extreme Heat

The warming trend will dramatically increase the frequency and intensity of extreme heat (Climate Change Knowledge Portal, n.d.; UNDP, 2023) (Fig. 16). By mid-century, the annual number of days exceeding 35°C is projected to rise from 99.15 days (2014 baseline) to 122.13 days, surging to 156.87 days by 2100 under SSP5-8.5 (Fig. 17) (Climate Change Knowledge Portal, n.d.; UNDP, 2023). Such prolonged heatwaves will strain energy grids, disrupt agriculture, and render outdoor labour unsafe, disproportionately impacting rural and displaced populations (Climate Centre, 2024; WFP, 2023; UNHCR, 2024).

Figure 16: Annual Trends of number of days with heat index > 35°C in the Syrian Arab Republic (1951–2023): Significance of Trend per Decade. Source: Climate Change Knowledge Portal, n.d., 2026

Figure 17: Projected number of hot days by mid and end of the century (Tmax > 35°C). Source: UNDP, 2023

Spatially, eastern governorates Al-Hasakah, Deir ez-Zor, Ar-Raqqa, and Aleppo experience the highest extreme heat hazard levels, with projected rises of 3–4°C above pre-industrial levels by 2100 under high-emission scenarios (Figs. 18 & 19) (ThinkHazard, n.d.; UNDP, 2023; Naaouf & Torma, 2023).

Figure 18: Spatial Distribution of maximum extreme heat hazard level. Source: thinkhazard, n.d., 2026

Figure 19: Projected changes (relative to the 1989–2008 reference period) in mean temperature under RCP4.5 and RCP8.5 scenarios. Source: Naaouf and Torma, 2023

3.3.3 Precipitation Projections

Under all SSP scenarios, precipitation is projected to decrease throughout the 21st century (Climate Change Knowledge Portal, n.d.; Homsí et al., 2020; Mathbout et al., 2023). While average precipitation during the reference period (1995–2014) was 208.94 mm, it is projected to decline to 199.58 mm by mid-century and further to 182.94 mm by 2100 under SSP5-8.5 (Fig. 20) (Climate Change Knowledge Portal, n.d.; FAO, 2021; UNDP, 2023).

Figure 20: Projected Precipitation Trends in the Syrian Arab Republic: Multi-Model Ensemble Analysis (Reference Period: 1995–2014). Source: Climate Change Knowledge Portal, n.d.

Spatially, precipitation patterns will remain highly uneven across coastal, inland, and eastern regions (Fig. 21) (Naaouf & Torma, 2023; Homsy et al., 2020; Houmsi, 2020):

- **Coastal Areas:** Northwest and southwest zones are projected to experience severe declines in precipitation under higher-emission scenarios (RCPs 4.5, 6.0, 8.5), with reductions ranging from 30% to 85.2% (Naaouf & Torma, 2023; Houmsi, 2020). Low-emission scenarios (RCP 2.6) show milder declines (0.0% to – 30%) (Climate Change Knowledge Portal, n.d.; UNDP, 2023).
- **Inland Areas:** Regions immediately inland from the coast may see precipitation increases of 6% to 87.3%, potentially due to shifts in storm tracks, localized rainfall intensification, or topographic influences (Naaouf & Torma, 2023; Homsy et al., 2020; Houmsi, 2020).
- **Eastern Regions:** Widespread drying is expected, though isolated patches linked to microclimates or mountainous terrain could see increases of up to 18% (Climate Change Knowledge Portal, n.d.; FAO, 2021; Mathbout et al., 2023).

Figure 21: Projected changes (relative to the 1989–2008 reference period) in precipitation under RCP4.5 and RCP8.5 scenarios.
Source: Homsy, 2020

3.3.4 Evapotranspiration and River Flow Impacts

Regional PET projections under SSP2-4.5 show annual PET climbing from 340 mm (1981–2021 average) to 355 mm by mid-century and 386 mm by 2100 an acceleration from 0.375 mm/year to 0.51 mm/year after 2050 (Ajjur & Al-Ghamdi, 2021; Houmsi et al., 2019; Houmsi, 2020).

Critically (IPCC, 2022; CSIS, 2023; Mueller et al., 2021):

- The IPCC warns that Euphrates River flow could decrease by 73% due to regional climate changes.
- The Yarmouk River is projected to lose 37.7% to 58% of its annual flow by 2070–2099 (Abdulla & Al-Shurafat, 2020; Rajsekhar & Gorelick, 2017).

3.4 Climate Risk Assessment of the WASH Sector

The climate risk assessment demonstrates that Syria's WASH sector is exposed to multiple interacting climate hazards. Among these, prolonged drought and increasing temperatures represent the most significant threats owing to their widespread impacts on water availability, groundwater recharge, and drinking water supply (WMO, 2023; UN Water, n.d.; Climate Centre, 2024). Floods and storms pose localised but severe risks by damaging water treatment facilities, pumping stations, pipelines, and sanitation infrastructure risks that are amplified by the fragile condition of infrastructure inherited from the past conflict (Abd-Elhamid et al., 2024; Toprak et al., 2025). Exposure analysis indicates that critical WASH infrastructure treatment plants, pumping stations, water towers, river basins, and densely populated urban centres is highly vulnerable to climate hazards (World Bank Group & EU, 2022; ICRC, 2021; UN-Habitat, 2022). Exposure is particularly elevated in regions with high population density, extensive displacement, and dependence on climate-sensitive water resources (UNHCR, 2024; Wind & Ibrahim, 2020).

Vulnerability Assessment

Six interacting dimensions physical, social, financial, environmental, human, and political collectively reduce the adaptive capacity of Syria's WASH sector (Table 3) (Dückers et al., 2015; Calverley & Walther, 2022; UNESCW, 2023). The vulnerability profile is heavily influenced by the legacies of the past conflict (Selby et al., 2017; Gleick, 2014; PeaceRep, 2022).

Table 3
Key Vulnerability Dimensions and Underlying Drivers Affecting WASH Services in Syria

Dimension	Current Status	Key Driver
Physical	60–70% of infrastructure damaged or destroyed during the conflict	Legacy of conflict related destruction
Social	6.8M refugees, 7.2M IDPs; limited access to services	Displacement following the conflict
Financial	GDP collapsed; O&M funding severely constrained	Economic aftermath of the conflict
Environmental	Declining water resources; aquifer depletion; land degradation	Climate change + over extraction
Human	Brain drain; limited technical capacity and training	Erosion of human capital during the conflict
Political	Fragmented governance; weak institutional coordination	Legacy of institutional disruption

Table 3: Key Vulnerability Dimensions and Underlying Drivers Affecting WASH Services in Syria

The integrated assessment confirms that climate risk within Syria's WASH sector is driven not only by increasing hydroclimatic hazards but also by the interaction between infrastructure exposure (exacerbated by past damage) and multidimensional vulnerability (rooted in the conflict's aftermath) (IPCC, 2022; GWP & UNICEF, 2017; World Bank, 2023). These findings emphasise the need for integrated adaptation strategies that address both climate resilience and post-conflict recovery (UNICEF, 2022; UNDP, 2023; UN-Habitat, 2022).

4. Discussion

This study provides one of the first integrated climate risk assessments specifically focused on Syria's WASH sector in a post-conflict context using the GWP-UNICEF framework (GWP & UNICEF, 2017; World Bank, 2023; UN-Habitat, 2022). The findings demonstrate that climate change is not an isolated driver of water insecurity but acts as a risk multiplier, exacerbating the enduring impacts of infrastructure damage, economic decline, and institutional fragility inherited from the past conflict (Selby et al., 2017; Gleick, 2014; Tarnas et al., 2023; Abbas et al., 2016). The interaction of these stressors has significantly reduced the resilience of Syria's WASH sector and increased the vulnerability of communities to climate-related disruptions (Concern Worldwide, 2024; Fanack Water, 2023; UN OCHA, 2023).

The observed warming trend, accelerating from 0.27°C decade⁻¹ to 0.72°C decade⁻¹ during 1991–2020, is consistent with regional assessments for the Eastern Mediterranean, where warming rates exceed the global average (IPCC, 2022; Naaouf & Torma, 2023; Climate Centre, 2024). Rising temperatures have increased evaporative demand, reduced soil moisture, and intensified hydrological drought, thereby reducing both surface water availability and groundwater recharge (Ajjur & Al-Ghamdi, 2021; Houmsi et al., 2019; Mathbout et al., 2023). Given that approximately 78% of annual precipitation is lost through evaporation (Jamal et al., 2007; FAO, 2008), even relatively small reductions in precipitation produce disproportionately large declines in effective water availability (UN-Water, 2022; Drgham, 2020).

Changes in precipitation characteristics are equally important. The shift from prolonged, moderate rainfall to fewer high-intensity storm events reduces infiltration and groundwater recharge while increasing flash flood risk and soil erosion (Abd-Elhamid et al., 2024; Mueller et al., 2021). Such hydroclimatic shifts present a dual challenge for the WASH sector simultaneously reducing water availability during dry periods and increasing infrastructure damage during extreme rainfall events, with the latter posing particular risks to systems already weakened by past conflict damage (Toprak et al., 2025).

A comprehensive climate risk assessment underscores that the severity of impacts on water, sanitation, and hygiene (WASH) services is not solely a function of the physical intensity of climate hazards. Instead, it is critically mediated by how exposed the infrastructure is to these hazards and the inherent social vulnerability of the populations relying on these services (IPCC, 2022; GWP & UNICEF, 2017; Dückers et al., 2015). Notably, drought and extreme heat emerge as the foremost, extreme-priority concerns due to their pervasive and prolonged effects, whereas floods and storms, while posing substantial threats, are

characterized by high to moderate risks that are typically confined to specific localities (Climate Centre, 2024; ThinkHazard, n.d.; UNDP, 2023). However, these climatic threats are compounded by a significant underlying factor: the enduring repercussions of past conflicts. The conflict period has systematically degraded the resilience of WASH systems by interrupting regular maintenance schedules, stalling crucial rehabilitation efforts, and severely limiting operational redundancies that would normally provide a buffer during crises (World Bank Group & EU, 2022; ICRC, 2021; PAX, 2023). As a result, the current infrastructure possesses a diminished capacity to withstand climatic extremes, making these already-prioritized hazards even more dangerous for vulnerable communities.

A thorough assessment of vulnerabilities across physical, social, financial, and political dimensions reveals that all of these areas are critically elevated, representing the highest order of concern (UNHCR, 2024; IDMC, n.d.; Bolton, 2020). This finding carries a crucial implication: achieving climate-resilient WASH services requires more than just upgrading pipes, pumps, and treatment plants. Strengthening governance frameworks, enhancing institutional coordination across sectors, and building robust financial capacity are equally—if not more—essential to long-term resilience (PeaceRep, 2022; The Day After, 2022; UNDP, 2024). The legacy of past conflict has deeply entrenched these non-physical vulnerabilities, creating systemic weaknesses that cannot be resolved through engineering fixes alone. Consequently, any infrastructure investment that fails to simultaneously tackle these governance and financial deficits will ultimately fall short of delivering climate-resilient outcomes, as the underlying fragility will continue to undermine even the most technically sound interventions (UNICEF, 2022; UN-Habitat, 2022; GWP & UNICEF, 2017). On a more hopeful note, the ongoing rebuilding process presents a pivotal window of opportunity. Rather than hastily reconstructing the same vulnerable systems that existed before the conflict—which were already ill-equipped to handle climate extremes—decision-makers can deliberately embed climate adaptation principles into every stage of recovery. This strategic approach can break the cycle of reinstating fragility and instead forge a more durable, adaptive, and equitable WASH infrastructure for the future (World Bank, 2023; UNESCW, 2023; UNDP, 2023).

From a policy perspective, the results demonstrate that traditional engineering solutions alone will be insufficient (GWP & UNICEF, 2017; UN Water, n.d.; IPCC, 2022). Adaptation strategies should integrate climate-informed water resources planning, rehabilitation of damaged infrastructure, diversification of water supplies, demand management, groundwater protection, early warning systems, nature-based solutions, and institutional strengthening (UNDP, 2023; UNICEF, 2022; UN-Habitat, 2022). Prioritising investments in high-risk areas identified through integrated climate risk assessments can improve resource allocation and enhance long-term resilience under increasing climatic uncertainty (World Bank, 2023; Carnegie Endowment, 2024; INFORM, 2023).

Study Limitations

Several limitations should be acknowledged. The assessment primarily relies on secondary data from national and international sources, reflecting the limited availability of long-term field observations due to the disruption caused by the past conflict (UN OCHA, 2023; USAID, 2023; World Bank, 2023). In addition, the analysis focuses on current and historical climate risks and does not explicitly quantify future risks under probabilistic scenario ensembles (IPCC, 2022; Naaouf & Torma, 2023). Future research should incorporate regional climate model projections, hydrological modelling, geospatial risk mapping, and quantitative multi-criteria decision analysis to evaluate adaptation pathways and support long-term investment planning (Mathbout et al., 2023; Homsy et al., 2020; Abd-Elhamid et al., 2024). Despite these limitations, the study establishes a robust evidence base for climate-resilient WASH planning in post-conflict Syria and provides a transferable methodological framework for other fragile and conflict-affected countries undergoing recovery (GWP & UNICEF, 2017; UN-Habitat, 2022; World Bank, 2023).

5. Policy Implications

The findings have important implications for climate adaptation planning and sustainable WASH management in Syria's post-conflict recovery phase (Table 4) (UNDP, 2023; UNICEF, 2022; UN-Habitat, 2022). The integrated climate risk assessment demonstrates that future water security will depend not only on infrastructure rehabilitation but also on incorporating climate risk considerations into national planning, investment, and institutional decision-making transforming recovery into an opportunity for resilience-building (GWP & UNICEF, 2017; World Bank, 2023; Carnegie Endowment, 2024).

Table 4
Actionable Policy Recommendations for Climate-Resilient WASH in Post-Conflict Syria.

Recommendation	Specific Action	Implementing Actor(s)	Timeframe
Climate-resilient infrastructure	Install solar-powered water treatment and pumping systems in 5 high-priority governorates (Aleppo, Deir ez-Zor, Ar-Raqqa, Al-Hasakah, Homs) to replace systems damaged during the conflict.	MoWR + INGOs (UNICEF, UNDP)	2025–2027
Integrated Water Resources Management (IWRM)	Implement a national groundwater monitoring network in Damascus, Aleppo, and Homs basins; reduce distribution losses by 15% by 2030.	MoWR + FAO + UN-Water	2025–2028
Early warning and climate information	Deploy a drought/flood forecasting system for the Euphrates and Yarmouk basins; link to municipal emergency protocols.	MoWR + WMO + Syria Meteorological Department	2026–2027
Institutional strengthening & capacity building	Train 500 WASH engineers and technicians in climate-resilient design, O&M, and risk assessment to rebuild human capital eroded during the conflict.	UNICEF + MoWR + local universities	2025–2028
6. Climate risk screening integration	Mandate systematic climate risk screening for all new WASH projects and major rehabilitation works by 2026.	MoWR + MoPD + donors	2025–2026

Table 4: Actionable Policy Recommendations for Climate-Resilient WASH in Post-Conflict Syria.

Overall, enhancing climate resilience within Syria's WASH sector requires a transition from emergency response toward long-term, risk-informed water governance (GWP & UNICEF, 2017; UN Water, n.d.; UNDP, 2023). Integrating climate science into infrastructure planning, strengthening institutional capacity, and prioritising investments based on climate risk will improve the sustainability of WASH services under future climatic uncertainty (IPCC, 2022; World Bank, 2023; UNESCW, 2023). The post-conflict reconstruction phase offers a unique window to embed climate resilience rather than replicate previous vulnerabilities (UN-Habitat, 2022; PeaceRep, 2022; Carnegie Endowment, 2024). The framework applied in this study also provides a practical approach that can be adapted to other post-conflict and water-scarce countries seeking to mainstream climate resilience into national WASH strategies (GWP & UNICEF, 2017; UNICEF, 2022; Ali & Shahreen, 2024).

6. Conclusions

This study presents a comprehensive climate risk assessment of Syria's WASH sector using the GWP-UNICEF framework. The findings demonstrate that climate change acts as a risk multiplier, exacerbating infrastructure damage, economic decline, and institutional fragility inherited from the past conflict.

Syria has experienced accelerated warming (0.72°C/decade since 1991) and declining precipitation (~ 12% per decade since 1990). Under SSP5-8.5, temperatures could reach 24.7°C by 2100, with hot days surging from 99 to 157 annually. Euphrates River flow may decline by 73%, while water stress already exceeds 124% of renewable resources.

The integrated risk assessment identified drought and extreme heat as the dominant hazards. Vulnerability across physical, social, financial, and political dimensions remains critically elevated, driven by infrastructure destruction (60–70% damaged), mass displacement (7.2 million IDPs), economic collapse, and governance fragmentation.

Enhancing resilience requires coordinated investments in climate-resilient infrastructure, water resources management, early warning systems, institutional strengthening, and community-based adaptation. The post-conflict reconstruction phase offers a unique opportunity to embed climate resilience rather than replicate previous vulnerabilities.

The methodological framework is transferable to other post-conflict and water-scarce regions. Future research should incorporate climate projections, hydrological modeling, and spatial decision-support tools to evaluate adaptation pathways and strengthen long-term water security in fragile states.

Declarations

Conflict of Interest:

The authors declare that there are no conflicts of interest concerning the publication of this Data

Author Contribution

Conceptualization, all authors; methodology, NAA, NA; software, NAA, NA.; validation, all authors; investigation, NAA, and NA.; data curation, NAA, NA.; writing—original draft preparation, all authors; visualization, all authors; project administration, NAA and NA; All authors have read and agreed to the published version of the manuscript.

Data Availability

Data is available by contacting the corresponding author

References

1. Abbas N, Wasimi SA, Al-Ansari N (2016) Impacts of climate change on water resources in Diyala River Basin, Iraq. *J Civil Eng Archit* 10(9):1059–1074
2. Abbas RA, Najafi M, Zare S, Jannatdoust S (2026) Environmental Evaluation of VOC Emissions in CIPP Rehabilitation: Comparative Analysis of Resin Types and Curing Techniques. *Pollutants* 6(1):14
3. Abbas R, Najafi M, Zare S, Jannatdoust S, Abbas N Underground Innovation: Integrating Trenchless Technology into Smart City Framework. In *Pipelines 2026: Multidiscipline and Oil and Gas* (pp. 379–390)
4. Abd-Elhamid HF, Zelenáková M, Soláková T, Saleh OK, El-Dakak AM (2024) Monitoring flood and drought risks in arid and semi-arid regions using remote sensing data and standardized precipitation index: A case study of Syria. *J Flood Risk Manag*, 17(1), e12961
5. Abdulla F, Al-Shurafat AW (2020) Assessment of the impact of potential climate change on the surface water of a trans-boundary basin: Case study Yarmouk River. *Procedia Manuf* 44:172–179
6. Ajjur SB, Al-Ghamdi SG (2021) Evapotranspiration and water availability response to climate change in the Middle East and North Africa. *Clim Change* 166(3):28
7. Al Zubi R, Gill TE, Lee JA, Ardon-Dryer K, Kandakji T (2024) Spatiotemporal analysis of sand and dust emission point sources detected from satellite imagery in Syria, Jordan, and Iraq. *Sci Total Environ* 949:175157
8. Ali M, Shahreen T (2024) Climate-resilient water resource management for Rohingya refugee camps in Bangladesh
9. Atesoglu A, Akturk E, Rasouli A, Erpay S, Ozel HB (2020) Monitoring of land-cover/land-use changes in Syria by involving the Collect Earth methodology approach. *Environ Monit Assess* 192(12):1–15
10. Bolton L (2020) The economic situation for individuals and communities in Syria. K4D Helpdesk Report 728. Institute of Development Studies, Brighton, UK
11. Brookings Institution (n.d.). The war on Syria's health system. Retrieved from <https://www.brookings.edu/articles/the-war-on-syrias-health-system/>
12. Calverley CM, Walther SC (2022) Drought, water management, and social equity: Analyzing Cape Town, South Africa's water crisis. *Front Water* 4:910149
13. Carnegie Endowment for International Peace (2024), April Syria's water and food security crisis. Retrieved from <https://carnegieendowment.org/sada/2024/04/syrias-water-and-food-security-crisis?lang=en>
14. Center for Strategic and International Studies (CSIS) (2023) The future of the Euphrates River. Retrieved from <https://features.csis.org/the-future-of-the-Euphrates-River/>

15. Climate Centre (2024) Country profiles: Syria. Retrieved from https://www.climatecentre.org/wp-content/uploads/RCCC-Country-profiles-Syria_2024_final.pdf
16. Climate Change Knowledge Portal (n.d.). Syria climate data and projections. Retrieved from <https://climateknowledgeportal.worldbank.org>
17. Concern Worldwide (2024) The Syria crisis explained. Retrieved from <https://www.concern.net/news/syria-crisis-explained>
18. Doctors Without Borders (2023), March 21 War and earthquakes leave displaced people without water in Syria. Retrieved from <https://www.doctorswithoutborders.org/latest/war-and-earthquakes-leave-displaced-people-without-water-syria>
19. Drgham MM (2020) The Current Water Balance in Syria: Evaluating the potential contribution of Constructed Wetlands as a treatment plant of municipal wastewater in Al-Haffah
20. Dückers M, Frerks G, Birkmann J (2015) Exploring the plexus of context and consequences: An empirical test of a theory of disaster vulnerability. *Int J Disaster Risk Reduct* 13:85–95
21. Fanack Water (2023) Water challenges and management in Syria: 2023 report. Retrieved from <https://water.fanack.com>
22. Food and Agriculture Organization (FAO) (2008) Syria: Land use and water resources. Retrieved from <https://www.fao.org/4/y4357e/y4357e12.htm>
23. Food and Agriculture Organization (FAO) (2021) Syrian Arab Republic: Precipitation analysis, 1980–2021. Rome. <https://doi.org/10.4060/cb7151en>
24. Food Security Cluster (2023) July-August). Agriculture and Food Security Monthly Snapshot: July-August 2023. Retrieved from https://fscluster.org/sites/default/files/documents/aafsms_july-august_2023_f_0.pdf
25. Geo Ref (2021) Syria geographical reference. Retrieved from <https://www.geo-ref.net/ph/syr.htm>
26. Gleick PH (2014) Water, drought, climate change, and conflict in Syria. *Weather Clim Soc* 6(3):331–340
27. Global Forest Watch (2023) Syria country dashboard. World Resources Institute. Retrieved from <https://www.globalforestwatch.org/dashboards/country/SYR/>
28. Global Water Partnership (GWP) & UNICEF (2017) Climate-resilient water, sanitation, and hygiene (WASH) systems: A framework for action. Retrieved from https://www.gwp.org/globalassets/global/about-gwp/publications/unicef-gwp/gwp_unicef_monitoring-and-evaluation-brief.pdf
29. Homsy R, Shiru MS, Shahid S, Ismail T, Harun SB, Al-Ansari N, Yaseen ZM (2020) Precipitation projection using a CMIP5 GCM ensemble model: A regional investigation of Syria. *Eng Appl Comput Fluid Mech* 14(1):90–106
30. Houmsi MR (2020) Modeling impacts of climate change on aridity and crop water demand in Syria (doctoral dissertation). Universiti Teknologi Malaysia
31. Houmsi MR, Shiru MS, Nashwan MS, Ahmed K, Ziarh GF, Shahid S, Kim S (2019) Spatial shift of aridity and its impact on land use of Syria. *Sustainability* 11(24):7047
32. Humanitarian Action (2025) Syrian Arab Republic. Retrieved from <https://humanitarianaction.info/plan/1276/document/syrian-arab-republic-humanitarian-response-priorities-january-march-2025/article/39-water-sanitation-and-hygiene-0>
33. Ibrahim B, Novotny V (2018) Planning for sustainable development and environmental protection in post-conflict phase: Case study of Syria. In *Proceedings of the International Scientific Conference*
34. INFORM (2023) INFORM Risk Index 2023. Retrieved from <https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Risk-Profile>
35. Intergovernmental Panel on Climate Change (IPCC) (2022) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter10.pdf
36. Internal Displacement Monitoring Centre (IDMC) (n.d.). Syria. Retrieved from <https://www.internal-displacement.org/countries/syria/>
37. International Committee of the Red Cross (ICRC) (2021) Syria water crisis: Up to 40% less drinking water after 10 years of war. Retrieved from <https://www.icrc.org/en/document/syria-water-crisis-after-10-years-war>

38. Jamal M, Arslan A, Dayoub K (2007) Harnessing salty water to enhance sustainable livelihoods of the rural poor in four countries in West Asia and North Africa: Syria. GCSAR-MAAR, Syrian Arab Republic
39. KfW Entwicklungsbank (2023) KfW's commitment during the civil war in Syria. Retrieved from https://www.kfw-entwicklungsbank.de/About-us/News/News-Details_836480.html
40. Kurdistan24 (2024) Heavy dust storm kills 7 in eastern Syria: SOHR. Retrieved from <https://www.kurdistan24.net/en/story/388362/Heavy-dust-storm-kills-7-in-eastern-Syria-SOHR>
41. Mathbout S, Martin-Vide J, Bustins JAL (2023) Drought characteristics projections based on CMIP6 climate change scenarios in Syria. *J Hydrology: Reg Stud* 50:101581
42. Meslmani Y (2010, April) Initial national communication of the Syrian Arab Republic. Ministry of State for Environment Affairs (MSEA), UNDP, GEF, submitted to UNFCCC. Damascus, Syria
43. Mohamed MA, Anders J, Schneider C (2020) Monitoring of changes in land use/land cover in Syria from 2010 to 2018 using multitemporal Landsat imagery and GIS. *Land* 9(7):226
44. Mueller A, Detges A, Pohl B, Reuter MH, Rochowski L, Volkholz J, Woertz E (2021) Climate change, water and future cooperation and development in the Euphrates-Tigris basin. *ResearchGate/Geoscience/Report*, 38–53
45. Naaouf N, Torma CZ (2023) Climate of Syria based on CORDEX simulations: Present and future. *Earth Syst Environ* 7(3):679–697
46. PAX (2023) Protection of Civilians: Case Study 12, CASE 12, Weaponizing drinking water. Retrieved from https://protectionofcivilians.org/wp-content/uploads/reports/PAX_POC_BOOK_CASE12_SINGLE_PAGES_FINAL-1.pdf
47. PeaceRep (2022) Resilience Syria 2022. Retrieved from <https://peacerep.org/wp-content/uploads/2022/12/Resilience-Syria-2022.pdf>
48. Rajsekhar D, Gorelick SM (2017) Increasing drought in Jordan: Climate change and cascading Syrian land-use impacts on reducing transboundary flow. *Sci Adv*, 3(8), e1700581
49. Rayan RA, Choudhury M, Deb M, Chakravorty A, Devi RM, Mehta J (2021) Climate change: Impact on waterborne infectious diseases. *Water conservation in the era of global climate change*. Elsevier, pp 213–228
50. Selby J, Dahi OS, Fröhlich C, Hulme M (2017) Climate change and the Syrian civil war revisited. *Political Geogr* 60:232–244
51. Syrian Arab Republic (1996) Initial national communication to the United Nations Framework Convention on Climate Change (UNFCCC). Retrieved from <https://unfccc.int/resource/docs/natc/syrnc1.pdf>
52. Tarnas MC, Karah N, Almhawish N, Aladhan I, Alobaid R, Abbara A (2023) Politicization of water, humanitarian response, and health in Syria as a contributor to the ongoing cholera outbreak. *Int J Infect Dis* 131:115–118
53. The Day After (2022) Mechanisms of exploitation: Economic and social changes in Syria during the conflict. Friedrich-Ebert-Stiftung. Retrieved from <https://library.fes.de/pdf-files/bueros/beirut/19603-20221017.pdf>
54. ThinkHazard (n.d.). Syrian Arab Republic - Landslides. Global Facility for Disaster Reduction and Recovery (GFDRR). Retrieved from <https://thinkhazard.org/en/report/238-syrian-arab-republic/LS>
55. Toprak S, Wham BP, Nacaroglu E, Ceylan M, Dal O (2025) Performance of water systems during the February 6th Kahramanmaraş earthquakes. *Earthq Spectra* 41(1):322–353
56. UN Water (n.d.). Water and climate change. Retrieved from <https://www.unwater.org/water-facts/water-and-climate-change>
57. United Nations Children's Fund (UNICEF) (2022) Syria Crisis CER 2021. Retrieved from <https://open.unicef.org/sites/transparency/files/2022-04/Syria%20Crisis%20CER%202021.pdf>
58. United Nations Children's Fund (UNICEF) (2022) WASH climate annual results report 2022. UNICEF East Asia and Pacific. Retrieved from <https://www.unicef.org/eap/reports/WASH-climate-annual-results-report-2022>
59. United Nations Children's Fund (UNICEF) (2023) Syria humanitarian response snapshot: WASH - May 2023. Retrieved from <https://www.unicef.org/syria/media/13326/file/Syria-humanitarian-response-snapshot-wash-May-2023.pdf>
60. United Nations Children's Fund (UNICEF) (2023) Syrian Refugees. Retrieved from <https://open.unicef.org/sites/transparency/files/2024-05/Syrian%20Refugees%20CER%202023.pdf>

61. United Nations Children's Fund Syria (UNICEF Syria) (2022) Budget brief: WASH sector 2022. Retrieved from https://www.unicef.org/syria/media/10586/file/Budget%20brief_2022_F.pdf
62. United Nations Development Programme (UNDP) (2023) Syria Climate Fact Sheet. Retrieved from https://prddsgofilestorage.blob.core.windows.net/api/documents/Syria_-_Climate_Fact_Sheet/SYRIA_Climate_Fact_Sheet_EN.pdf
63. United Nations Development Programme (UNDP) (2024) Syria Socio-Economic Impact Assessment (SEIA) Final Report. Retrieved from <https://www.undp.org/sites/g/files/zskgke326/files/2025-02/undp-sy-seia-final-24022025.pdf>
64. United Nations Economic and Social Commission for Western Asia (UNESCWA) (2023) Water development in the Arab region: Challenges and opportunities (Water Development Report 9). Retrieved from <https://www.unescwa.org/sites/default/files/pubs/pdf/water-development-report-9-english.pdf>
65. United Nations High Commissioner for Refugees (UNHCR) (2024) The climate crisis fuels flooding and deepens displacement. Retrieved from <https://www.unhcr.org/news/stories/climate-crisis-fuels-flooding-and-deepens-displacement>
66. United Nations Human Settlements Programme (UN-Habitat) (2022a) Infrastructure for sustainable development. Retrieved from <https://unhabitat.org/sites/default/files/2022/09/infrastructure.pdf>
67. United Nations Human Settlements Programme (UN-Habitat) (2022b) Pursuit of environmental sustainability and climate resilience through urban recovery in Syria. Retrieved from https://unhabitat.org/sites/default/files/2022/09/environment_paper.pdf
68. United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) (2023) Syria facing dual challenge of climate change and conflict. Retrieved from <https://www.unocha.org/news/syria-facing-dual-challenge-climate-change-and-conflict>
69. UN-Water (2022) SDG 6 Country Data: Syrian Arab Republic. Retrieved from <https://www.sdg6data.org/en/country-or-area/Syrian%20Arab%20Republic>
70. USAID (2023) Syria - Environment and global climate change. Retrieved from <https://idea.usaid.gov/cd/syria/environment-and-global-climate-change>
71. WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation, and Hygiene. (2023). JMP Data. Retrieved from <https://washdata.org/data/household>
72. Wind B, Ibrahim B (2020) The war-time urban development of Damascus: How the geography and political economy of warfare affects housing patterns. *Habitat Int* 96:102109
73. World Bank Group & European Union (2022) Syria Joint Damage Assessment of Selected Cities. <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099125303072236903/P1782520d1177f03c0ab180057556615497>
74. World Bank (2022) Syria: Share of economic sectors in the GDP from 2012 to 2022. Statista. Retrieved from <https://www.statista.com/statistics/326616/share-of-economic-sectors-in-the-gdp-in-syria/>
75. World Bank (2023a) Project appraisal document for Syria earthquake 2023. Retrieved from <https://documents1.worldbank.org/curated/en/099093003162314369/pdf/P1721710e2b4a60b40a5940f0793f8a0d24.pdf>
76. World Bank (2023b) Syria: Climate Vulnerability and Environmental Degradation. World Bank Open Knowledge Repository. <https://openknowledge.worldbank.org/server/api/core/bitstreams/0a1b1684-8a14-5eb3-a785-6ad92294e05c/content>
77. World Food Programme (WFP) (2023) Half of Syria's population faces hunger as conflict passes 12-year milestone and earthquakes deepen economic woes. Retrieved from <https://www.wfp.org/news/half-syrias-population-faces-hunger-conflict-passes-12-year-milestone-and-earthquakes-deepen>
78. World Health Organization (WHO) (2023a) Cholera situation report 8 - April 2023. WHO Regional Office for the Eastern Mediterranean. https://www.emro.who.int/images/stories/syria/Cholera-Sitrep_8_april_2023.pdf
79. World Health Organization (WHO) (2023b) Landslides. Retrieved from <https://www.who.int/health-topics/landslides>
80. World Meteorological Organization (WMO) (2023) Drought. Retrieved from <https://wmo.int/topics/drought>

81. World Vision (n.d.). Syrian refugee crisis: Facts. Retrieved from <https://www.worldvision.org/refugees-news-stories/syrian-refugee-crisis-facts>
82. Worldometer (2024) Syria demographics. Retrieved from <https://www.worldometers.info/demographics/syria-demographics/>

Figures

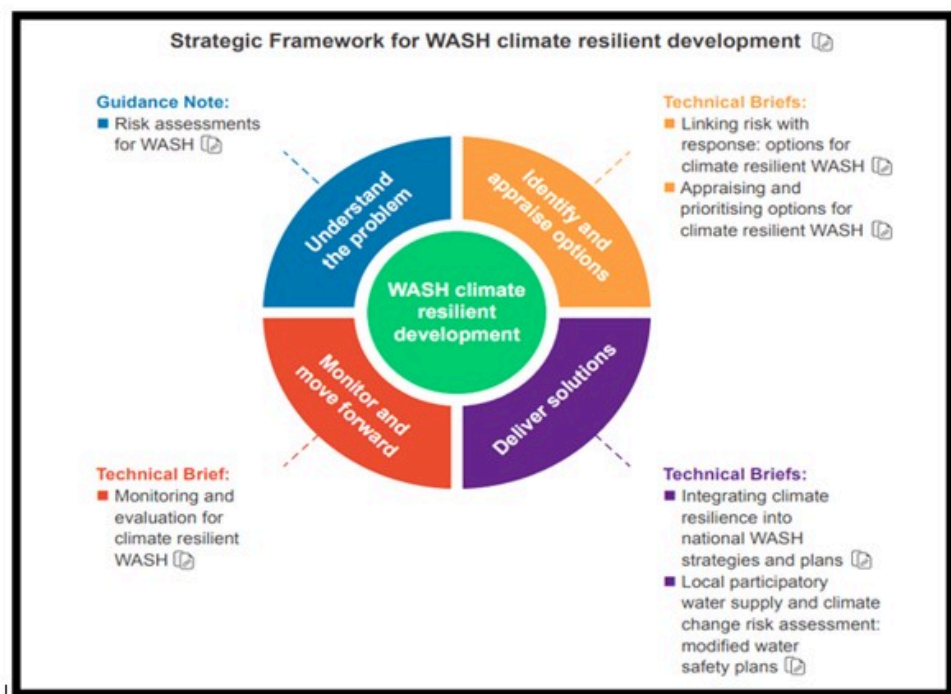


FIGURE 1: Strategic Framework for Climate-Resilient WASH Development (GWP & UNICEF, 2017)]

Figure 1

See image above for figure legend.

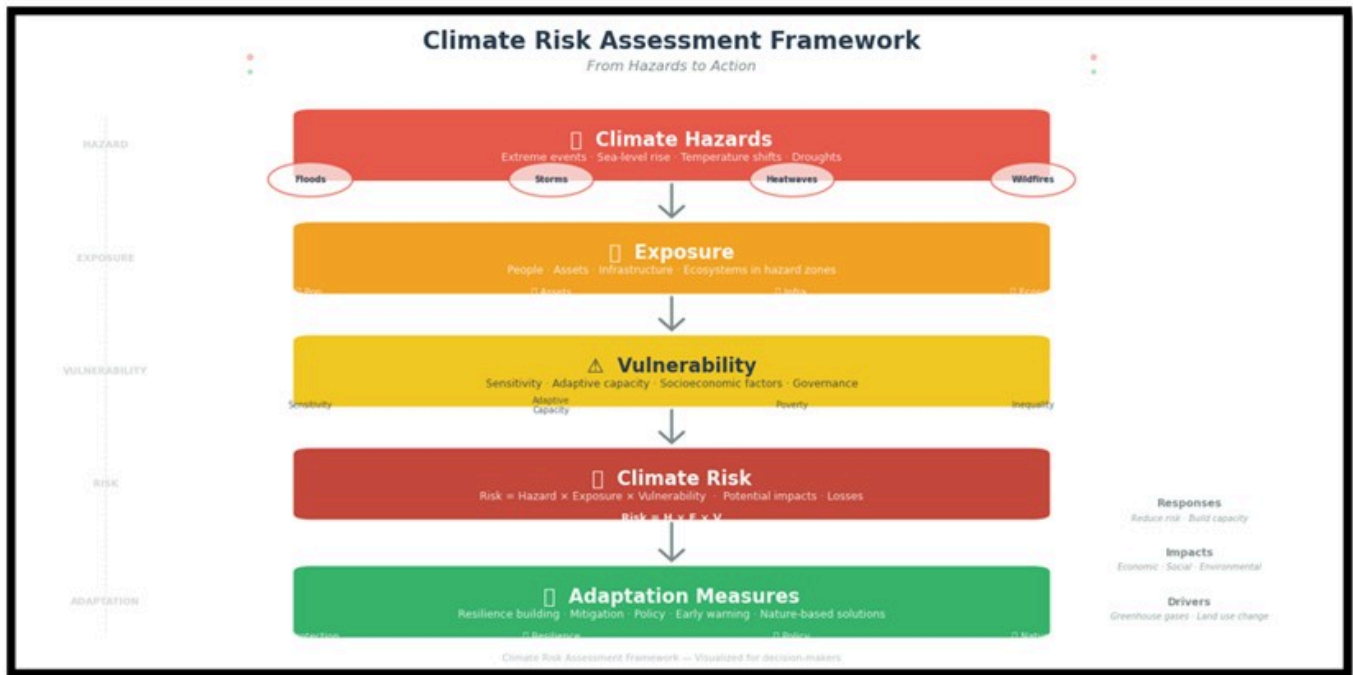


FIGURE 2: Analytical Framework – Interaction between Hazards, Exposure, and Vulnerability

Figure 2

See image above for figure legend.



FIGURE 3: Geographical Map of Syria and Surrounding Regions (Open Street Map)

Figure 3

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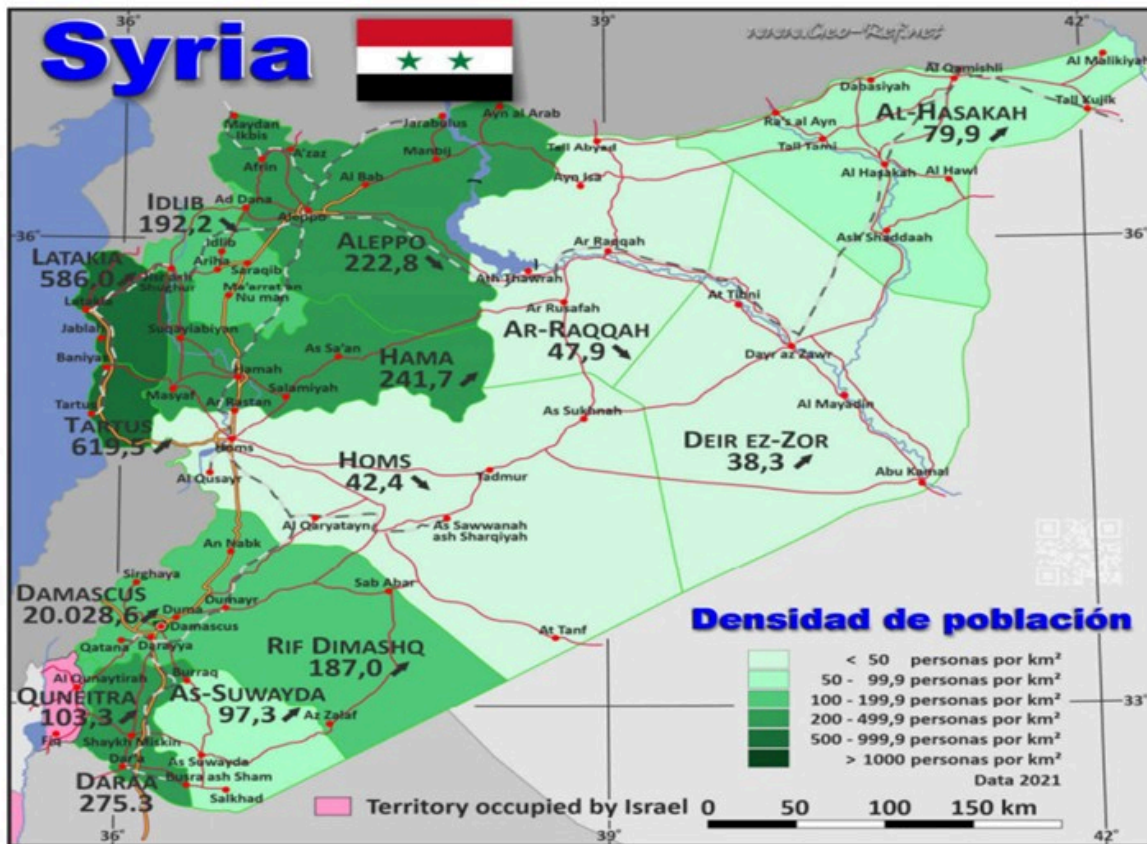


FIGURE 4: Population Density Distribution (2021) – Geo Ref, 2021

Figure 4

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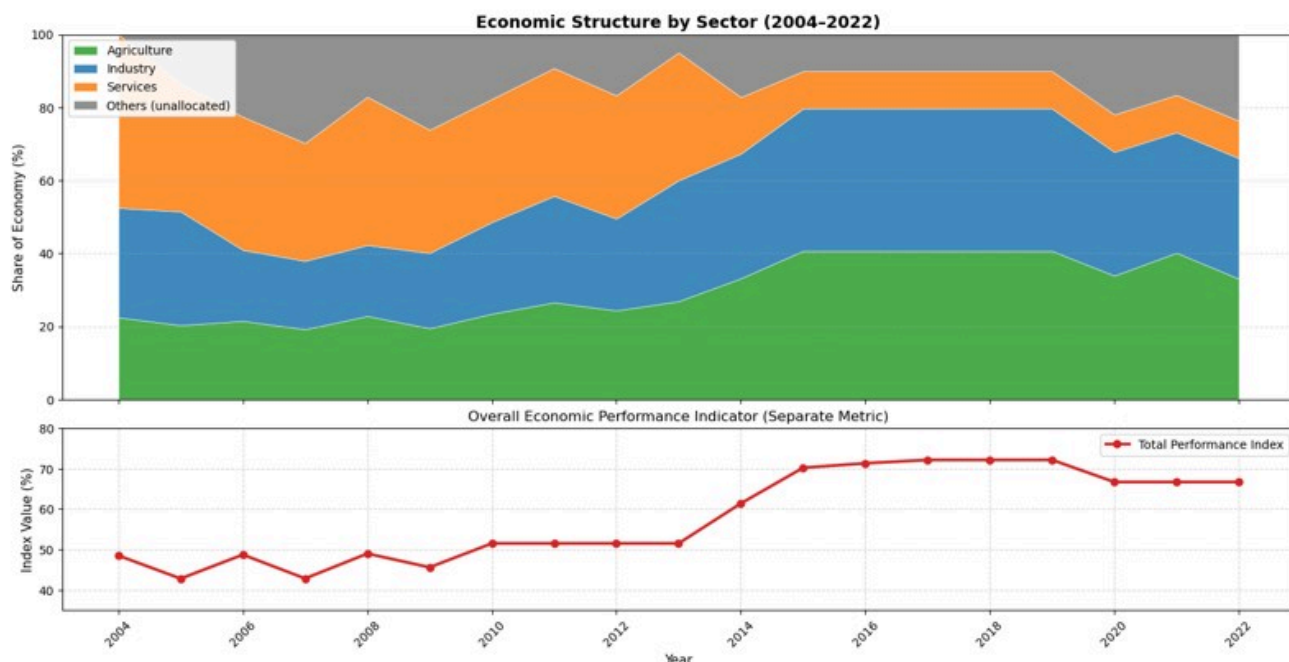


FIGURE 5: Share of Economic Sectors in GDP (2004–2022) – World Bank, 2022

Figure 5

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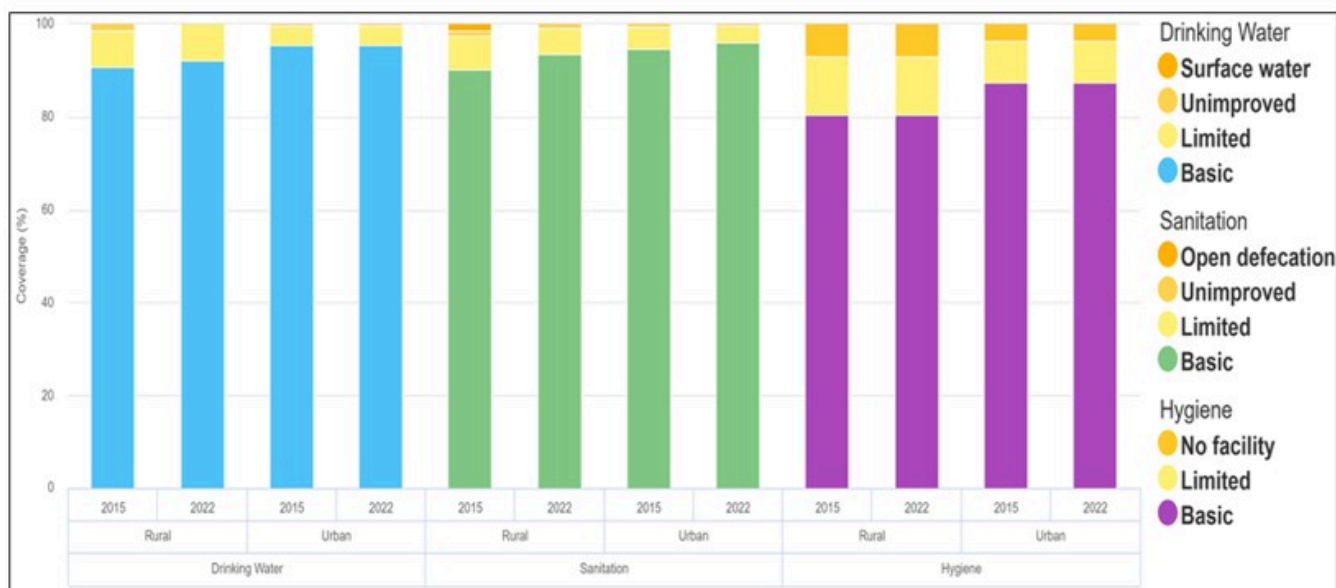


FIGURE 6: Rural and Urban Service Levels (2015–2022) – JMP, 2022

Figure 6

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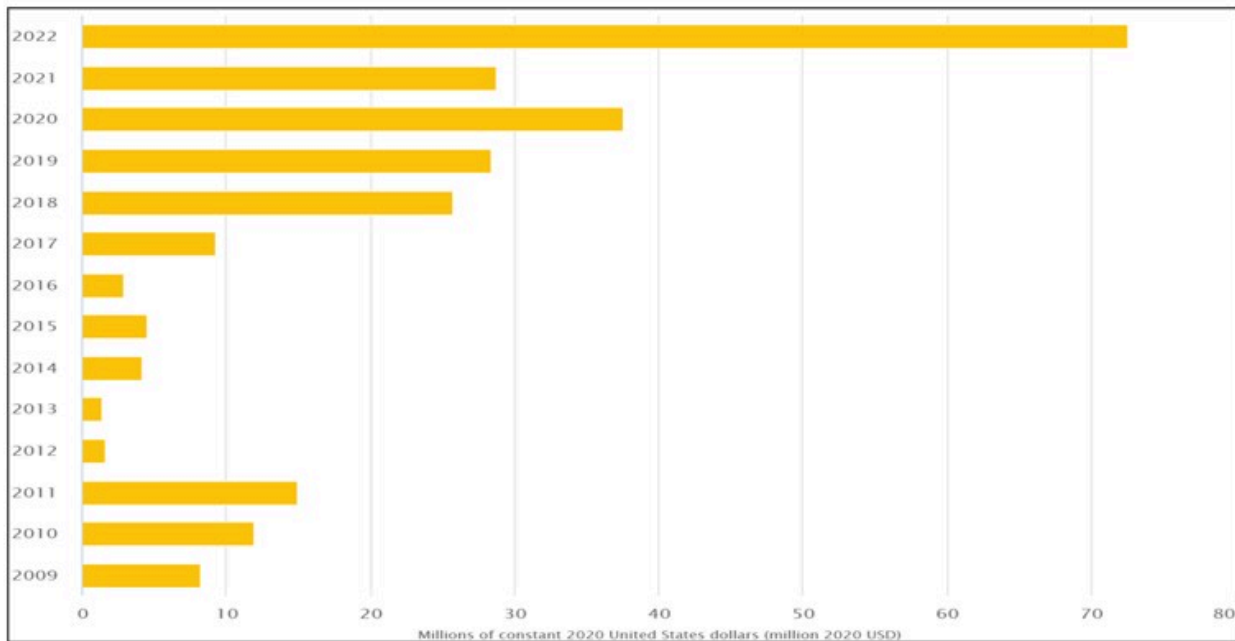


Figure 7: Amount of water- and sanitation-related official development assistance received by Syrian Arab Republic in 2022, by sub-sector. *Source: UN Water, 2022*

Figure 7

See image above for figure legend.

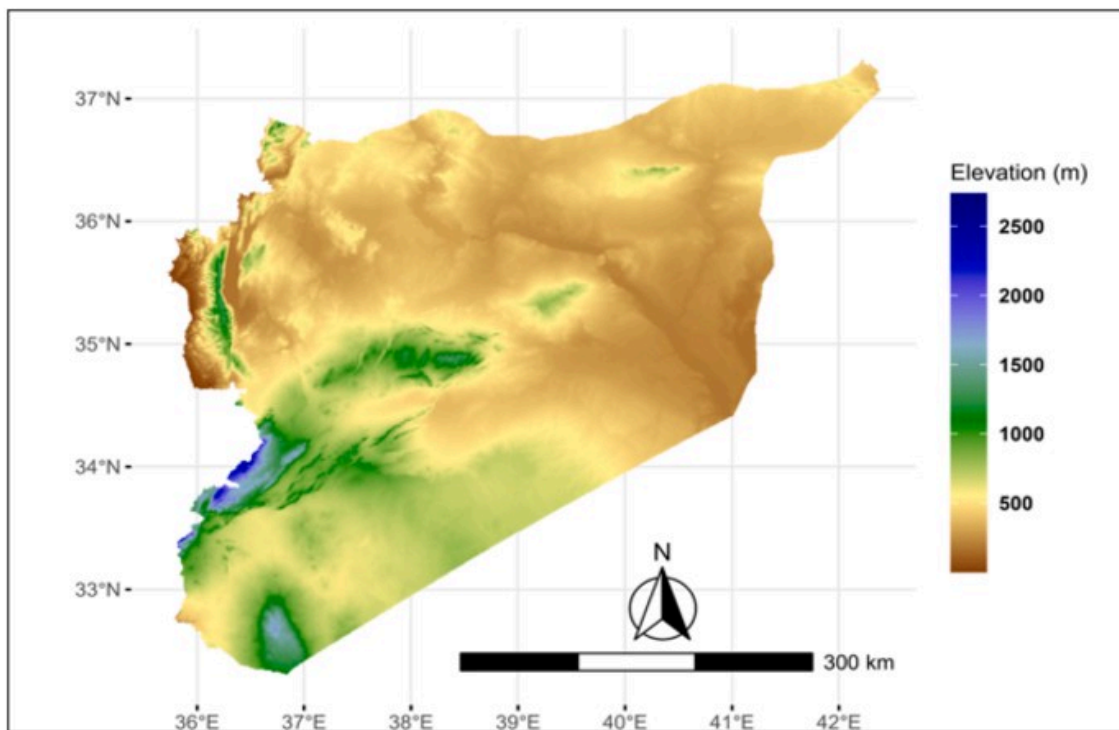


Figure 8: Hypsometric map based on regionalized in-situ observations based on SRTM elevation data at spatial resolution of 30 s (~1 km²). *Source: Mathbout et al., 2023*

Figure 8

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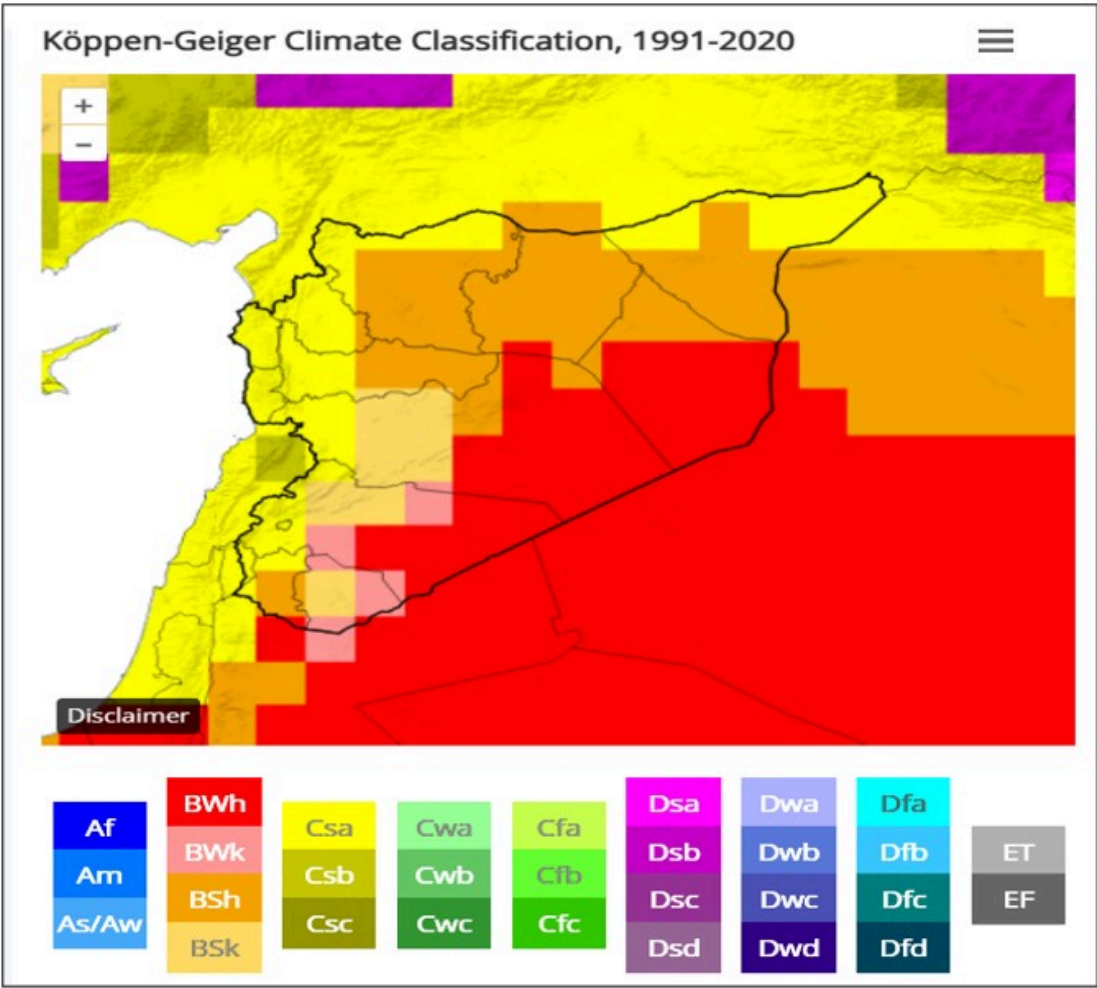


Figure 9: Köppen-Geiger Climate Classification Map (1991-2020) with Climate Zone Codes. *Source: Climate Change Knowledge Portal, n.d.*

Figure 9

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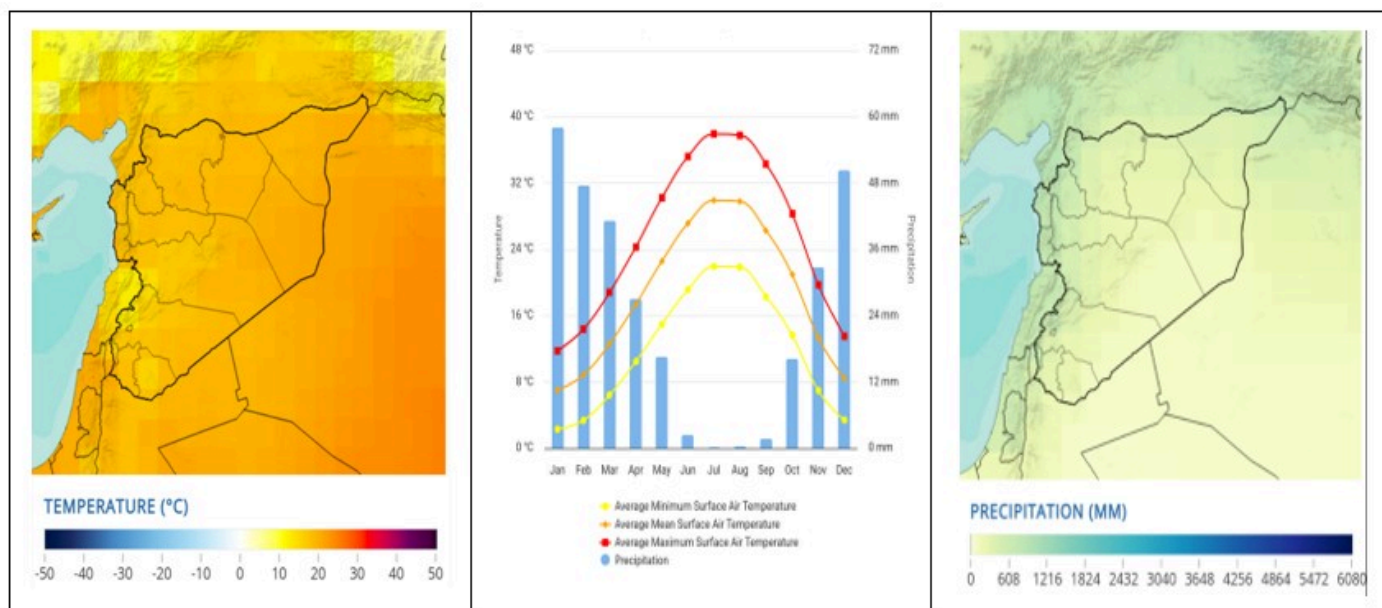


Figure 10: (Left) Spatial variability in daily mean temperature over Syria; (Middle) Annual Temperature and Precipitation Variability: Monthly Averages and Extremes; (Right) Average total rainfall (1951–2010). *Source: Climate Change Knowledge Portal, n.d.*

Figure 10

See image above for figure legend.

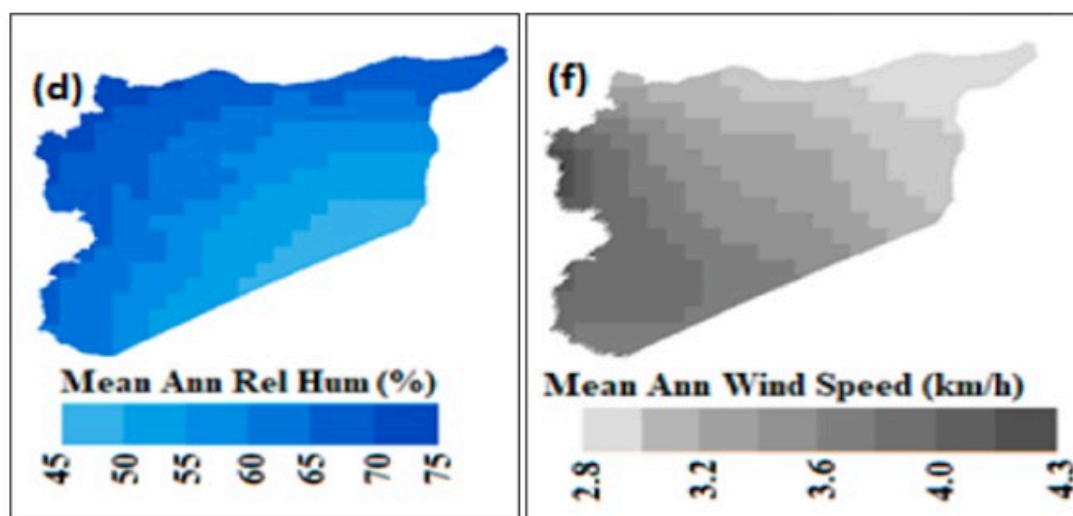


Figure 11: Geographical distribution of annual (d) relative humidity (%); and (f) wind speed (km/h) from 1951 to 2010. *Source: Houmsi et al., 2019*

Figure 11

See image above for figure legend.

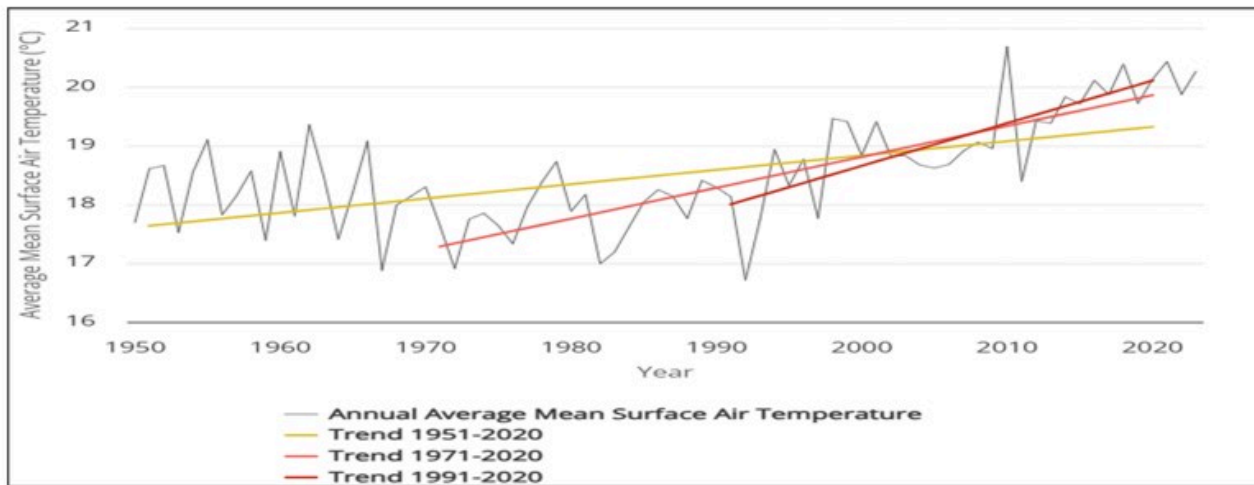


Figure 12: Annual Trends in Average Mean Surface Air Temperature in the Syrian Arab Republic (1951-2023): Significance of Trend per Decade. *Source: Climate Change Knowledge Portal, n.d., 2026*

Figure 12

See image above for figure legend.

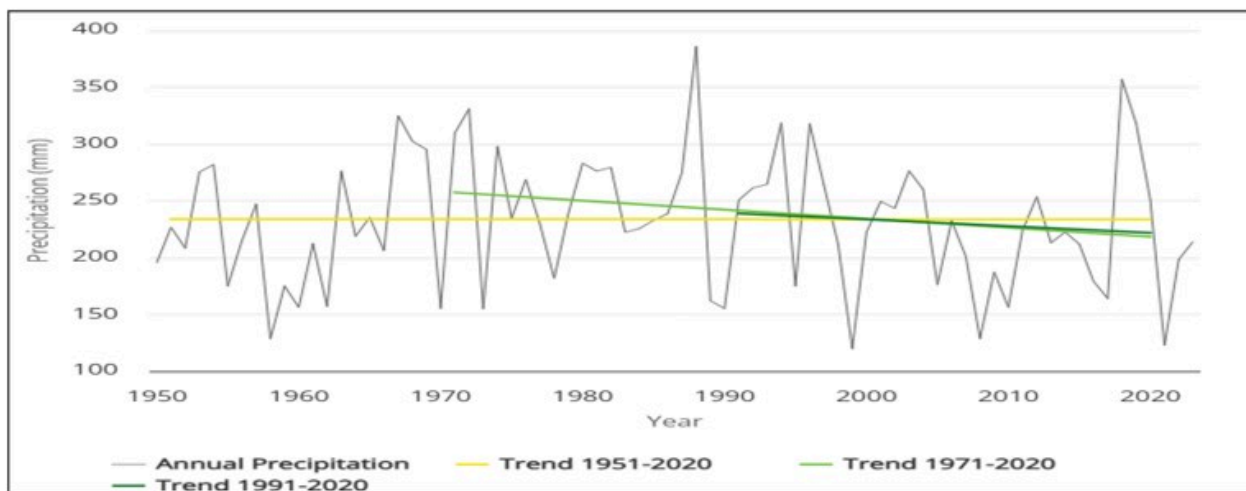


Figure 13: Annual Trends in Average Precipitation in the Syrian Arab Republic (1951-2023): Significance of Trend per Decade. *Source: Climate Change Knowledge Portal, n.d., 2026*

Figure 13

See image above for figure legend.

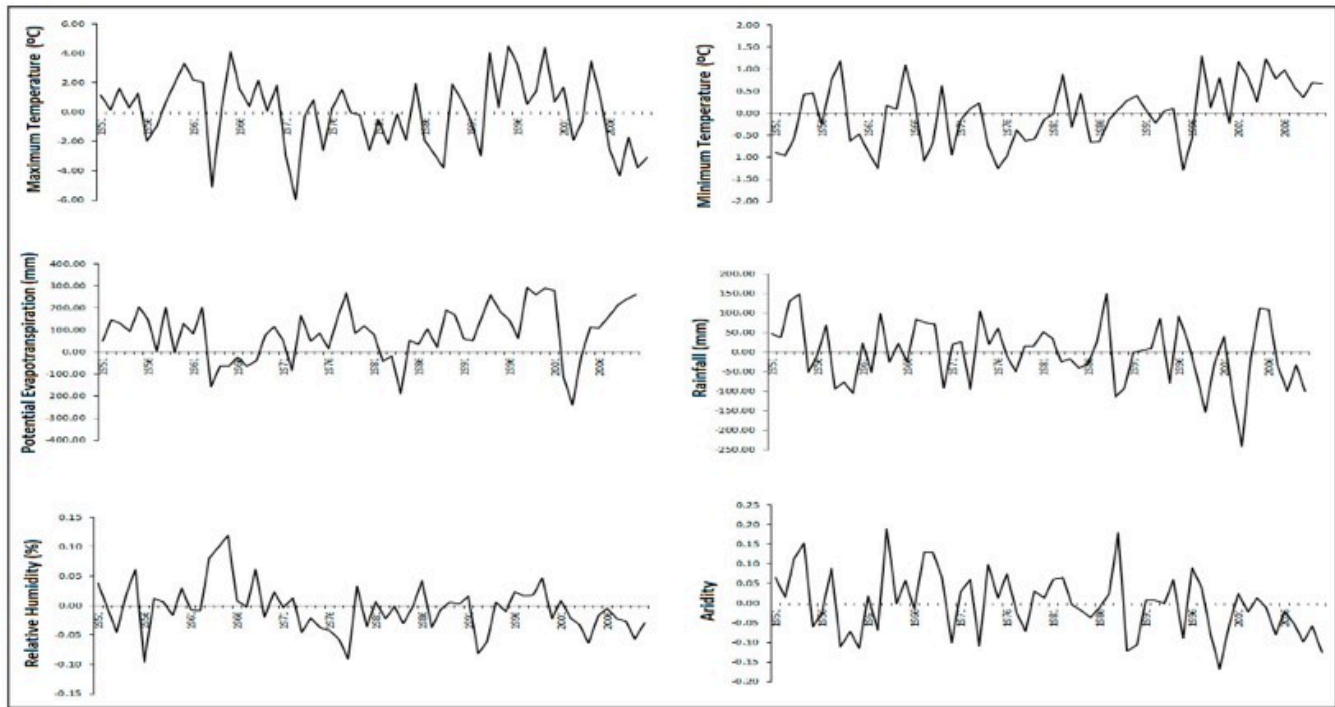


Figure 14: Anomaly in aridity and different meteorological variables over the study period (1951–2010). *Source: Houmsi et al., 2019*

Figure 14

See image above for figure legend.

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Figure 15

This image is not available with this version.

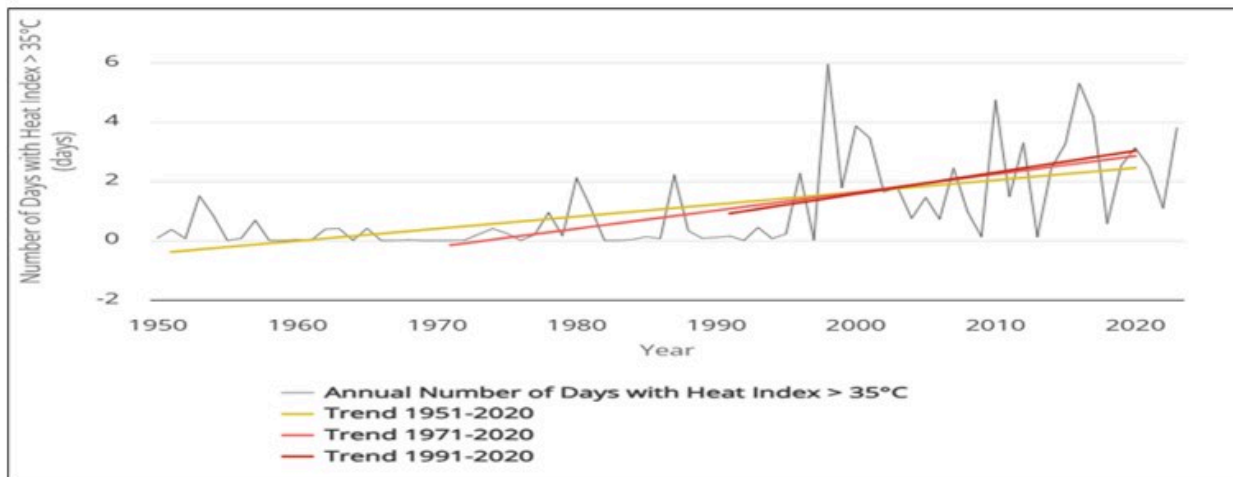


Figure 16: Annual Trends of number of days with heat index >35°C in the Syrian Arab Republic (1951-2023): Significance of Trend per Decade. *Source: Climate Change Knowledge Portal, n.d., 2026*

Figure 16

See image above for figure legend.

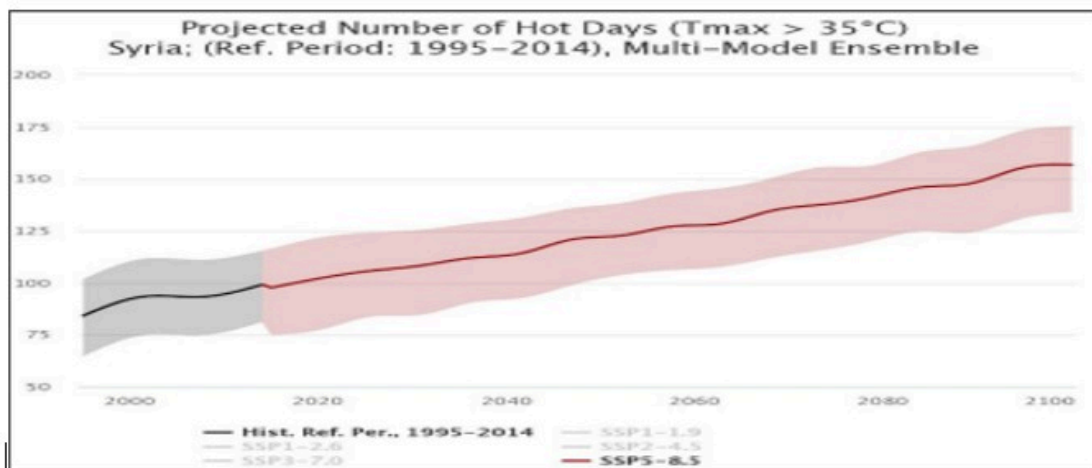


Figure 17: Projected number of hot days by mid and end of the century (Tmax >35°C). *Source: UNDP, 2023*

Figure 17

See image above for figure legend.

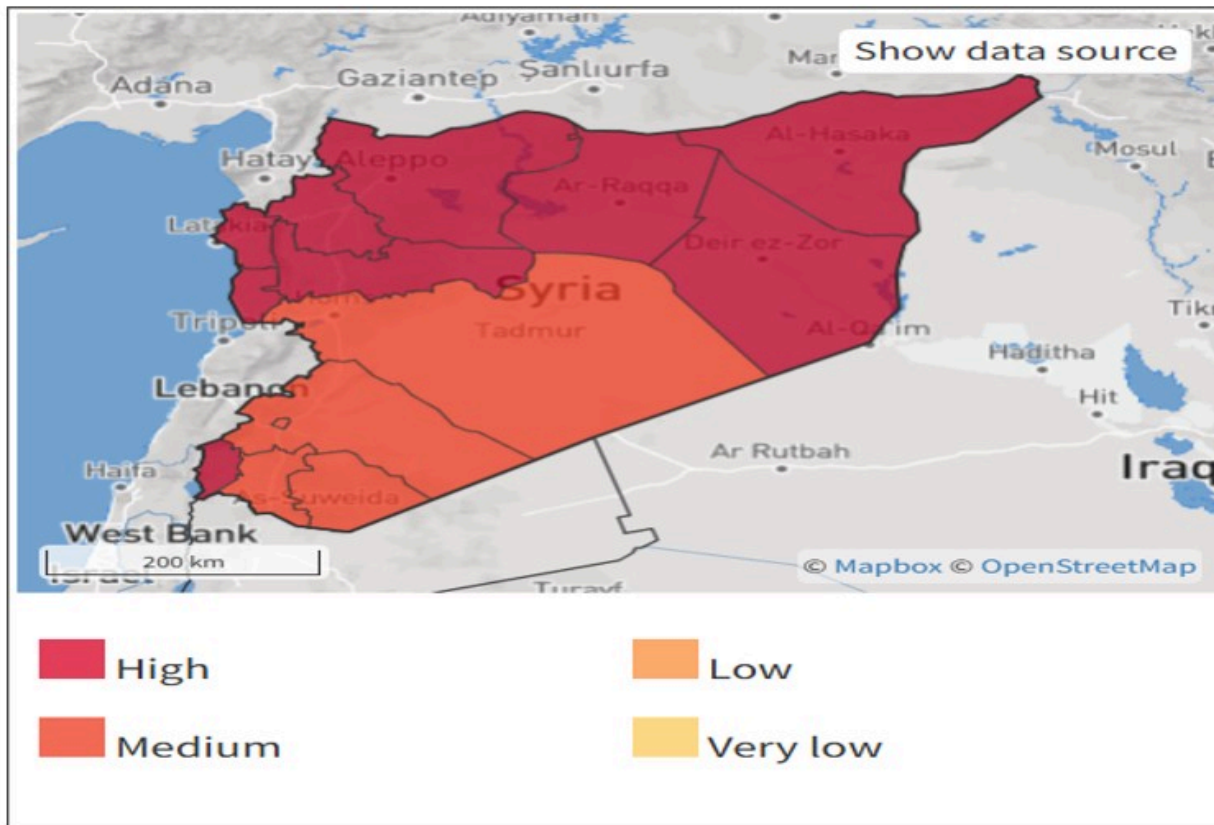


Figure 18: Spatial Distribution of maximum extreme heat hazard level. *Source: [thinkhazard](#), n.d., 2026*

Figure 18

See image above for figure legend.

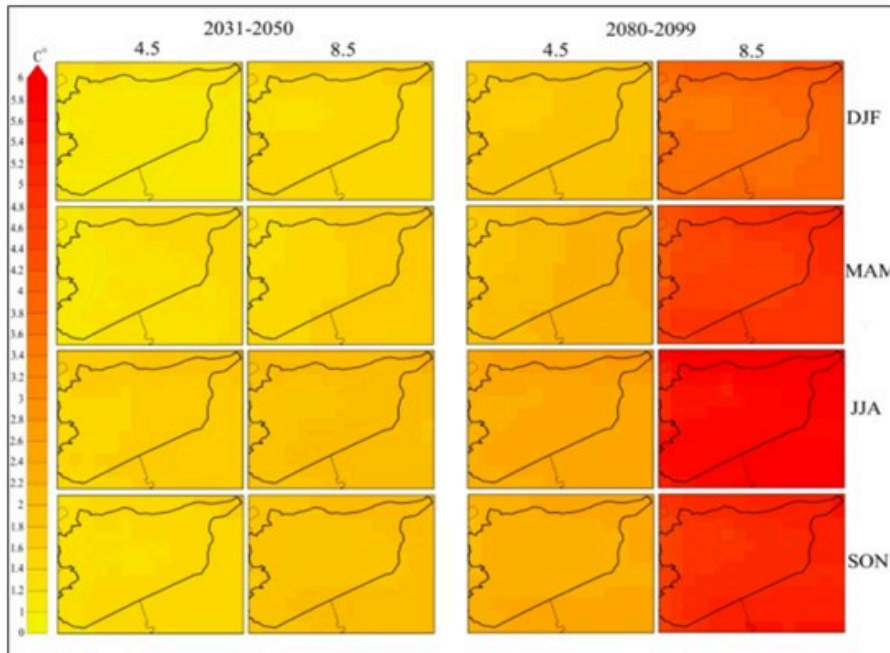


Figure 19: Projected changes (relative to the 1989–2008 reference period) in mean temperature under RCP4.5 and RCP8.5 scenarios. *Source: Naqouf and Torma, 2023*

Figure 19

See image above for figure legend.

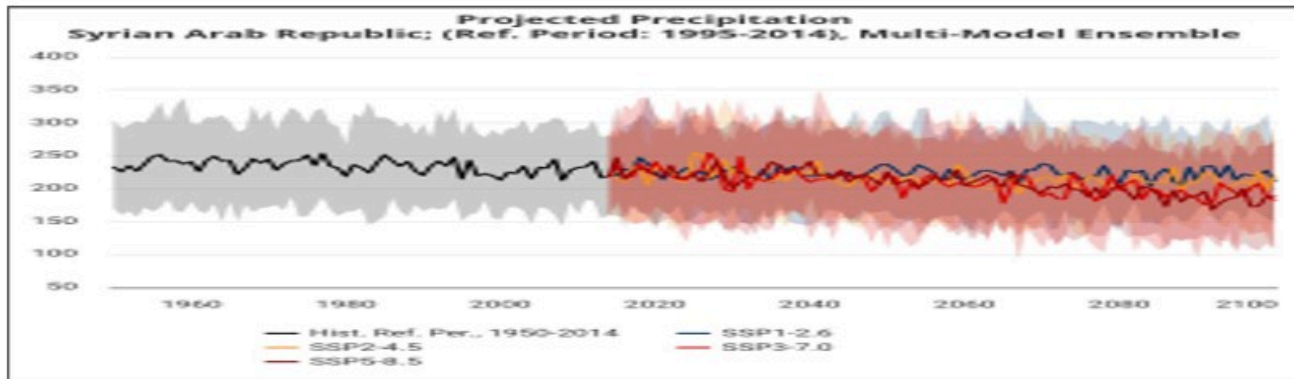


Figure 20: Projected Precipitation Trends in the Syrian Arab Republic: Multi-Model Ensemble Analysis (Reference Period: 1995–2014). *Source: Climate Change Knowledge Portal, n.d.*

Figure 20

See image above for figure legend.

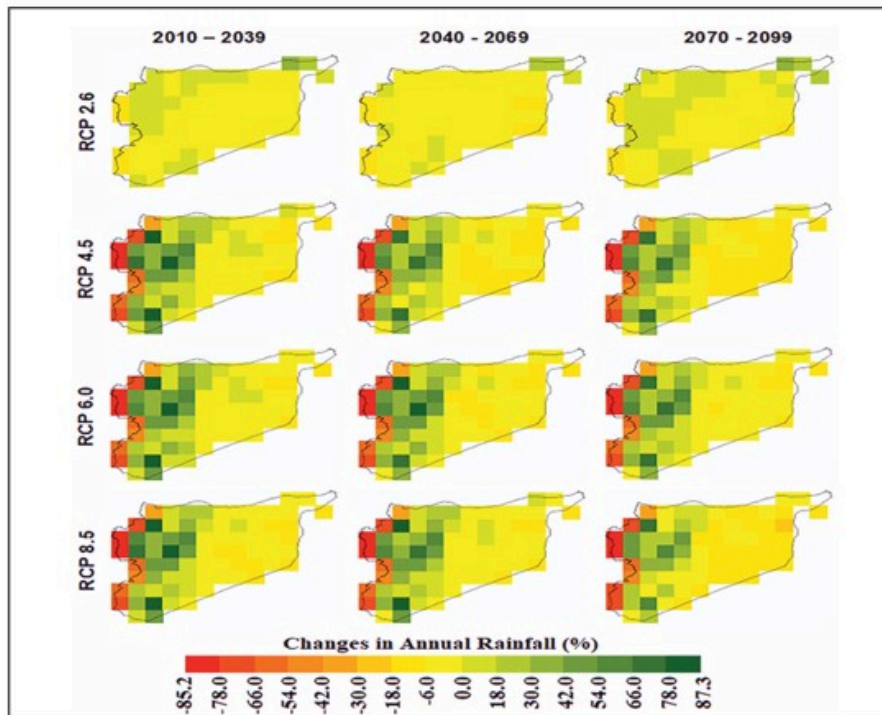


Figure 21: Projected changes (relative to the 1989–2008 reference period) in precipitation under RCP4.5 and RCP8.5 scenarios. *Source: Homsí, 2020*

Figure 21

See image above for figure legend.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1.docx](#)
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- [Table3.docx](#)
- [Table4.docx](#)