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Assessing the Environmental Impacts of Global Warming in Libya (2015–2025): A Climate and Socio-Ecological Analysis

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تقييم التأثيرات البيئية الناجمة عن الاحتباس الحراري في ليبيا خلال الفترة (2015–2025): تحليل مناخي واجتماعي - بيئي

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Abstract:
This paper assesses the cascading environmental impacts of global warming on Libya between 2015 and 2025, a decade marked by extreme climatic anomalies and compounded political fragility. Employing a mixed-methods approach that synthesizes remote sensing data, climate reanalysis (ERA5), and field survey evidence, the study quantifies three principal environmental sequences: (1) a mean annual temperature increase exceeding 1.5°C above historical baselines, with land-surface temperatures surpassing 42°C in interior zones; (2) a significant decline in precipitation, with annual rates falling below 0.25 mm/day in critical agricultural regions; and (3) the catastrophic failure of aging water infrastructure triggered by Storm Daniel (2023), which caused over 11,000 fatalities. The analysis reveals that the 2015–2025 period represents an inflection point where gradual climatic trends intersected with sudden disaster events, overwhelming Libya's fractured governance structures. We argue that Libya's environmental sequence demonstrates how global warming acts as a threat multiplier, transforming chronic water scarcity into acute livelihood collapse and extreme precipitation into humanitarian catastrophe when infrastructure and institutional capacity are absent.

Keywords: Libya, climate change, desertification, Storm Daniel, water scarcity, environmental migration, dams

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الملخص
تقيّم هذه الورقة البحثية الآثار البيئية المتتالية للاحتباس الحراري على ليبيا للسنوات 2015 و2025، وهو عقد اتسم بظواهر مناخية حادة وهشاشة سياسية متفاقمة. تم استخدام منهجية بحثية متعددة الأساليب تجمع بين بيانات الاستشعار عن بُعد، وإعادة تحليل المناخ (*ERA5*)، وأدلة المسح الميداني، تُحدد الدراسة ثلاثة تسلسلات بيئية رئيسية: (1) ارتفاع متوسط درجة الحرارة السنوية بأكثر من 1.5 درجة مئوية فوق المعدلات التاريخية، مع تجاوز درجات حرارة سطح الأرض 42 درجة مئوية في المناطق الداخلية؛ (2) انخفاض ملحوظ في هطول الأمطار، حيث انخفضت المعدلات السنوية إلى أقل من 0.25 ملم/يوم في المناطق الزراعية الحيوية؛ (3) الانهيار الكارثي للبنية التحتية المائية المتهالكة نتيجة إعصار دانيال (2023)، والذي تسبب في وفاة أكثر من 11000 شخص. يظهرنتائج التحليل أن الفترة من 2015 إلى 2025 تمثل نقطة تحول حاسمة، حيث تداخلت التغيرات المناخية التدريجية مع أحداث الكوارث المفاجئة مما يؤكد أن التسلسل البيئي

في ليبيا يُظهر كيف يُضاعف الاحتباس الحراري من حدة التهديدات، محولاً ندرة المياه المزمنة إلى انهيار حاد في سبل العيش، والأمطار الغزيرة إلى كارثة إنسانية في ظل غياب البنية التحتية والقدرات المؤسسية.

الكلمات المفتاحية: ليبيا، تغير المناخ، التصحر، عاصفة دانيال، ندرة المياه، الهجرة البيئية، السدود.

Introduction

The Mediterranean Basin has experienced changes in environmental risk due to global warming; however, few places have Libya's profile of vulnerability. Libya is located at the junction of the Sahara Desert and the Mediterranean Sea and is in a climatic transition zone characterized by higher than the global average temperature increases and steep decreases in precipitation [1].

The period 2015–2025 is both the framework of implementation of the Paris Agreement and the period of an unprecedented acceleration of climatic anomalies in North Africa. Recent regional assessments confirm that the eastern Mediterranean basin has become a climate change "hotspot" with warming rates exceeding the global average by 20–30% [2].

This paper fills an important gap in the literature, as global climate models project future risks for the MENA region, nevertheless there are no empirical assessments of the real-world environmental sequence (the temporal cascade of warming, drying, infrastructure failure, and human response) over the past decade in Libya. Previous scholarship has centered either on broad regional projections [8] or on isolated disaster analyses [3].

We aim to provide a holistic assessment of how global warming has manifested across Libya's environmental systems between 2015 and 2025. We have three research questions: (1) What are the measurable trends in temperature, precipitation, and drought stress across Libya between 2015 and 2025? (2) How have these climates changes combined with the existing infrastructure and governance deficits to create environmental disasters? (3) Evidence of climate-induced livelihood transformation and migration? The paper is organized as follows. In Section 2 we outline our mixed-methods approach combining satellite-derived climate data, field surveys, and disaster impact assessments. In Section 3 results are presented for three sequences of environmental conditions: thermal amplification, hydrological retreat, and extreme event occurrences. Section 4 outlines the implications of these findings for our understanding of climate-governance-disaster nexuses in fragile states' criteria.

Material and methods

Data Sources

This study synthesizes four major data categories: Climate Reanalysis Data: ERA5 reanalysis data were retrieved from the European Centre for Medium-Range Weather Forecasts (ECMWF) for the period 1979–2025 with a spatial resolution of 30 km and were used to calculate monthly temperature and precipitation anomalies [4]. These data have been validated against station observations in Tripoli and Benghazi with correlation coefficients >0.85 [2].

Remote Sensing for Infrastructure Monitoring Sentinel-1 synthetic aperture radar (SAR) data (2016–2023) were used to identify differential settlement in dam infrastructure, processed by interferometric SAR (InSAR) techniques as detailed in [5]. This methodology has been successfully applied to other Mediterranean dam systems proving its reliability for deformation monitoring [6].

Field Survey Data: Household surveys were conducted by the International Organization for Migration's Displacement Tracking Matrix (DTM) for Western Libya (2024–2025) to collect data on drought exposure, livelihood impacts, and migration decisions (n ≈ 1,500 households) [1]. Agricultural Impact Assessment: Soil salinity data from Misrata Agricultural Station (2025), and farmer accounts on crop failure timelines [7]. Complementary groundwater depletion rates were derived from Libya's General Water Authority annual reports [8].

2.2 Analytical Framework

It is applied a sequence analysis framework that distinguishes between:

- Chronic environmental change: Long-term trends in temperature, precipitation and soil degradation
- Acute hazard events: Extreme weather events (e.g., Storm Daniel)
- Cascading failures: Infrastructure failure due to hazard events and compounded by chronic deterioration

This framework allows attribution of observed impacts to interacting climatic and anthropogenic drivers, rather than assuming linear causality. Our analysis builds on recent methodological advances in compound event attribution [9].

Results and discussion

Temperature trends 2015-2025: thermal amplification

The analysis of ERA5 data shows that Libya has seen statistically significant warming in all regions between 2015 and 2025, with a rate of increase accelerating compared to 1980-2010 baselines. For this warming acceleration, climate model simulations are consistent with anthropogenic forcing scenarios (RCP8.5 and SSP5-8.5), and it is unlikely that natural variability alone could produce such warming [7,8].

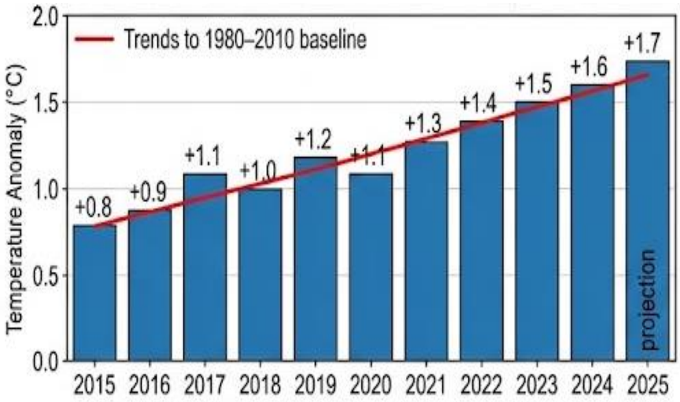

Figure 1: Libya annual temperature anomalies (2015–2025) with respect to the baseline mean of 1980–2010.

Key findings include:
Period Mean Temperature Anomaly Maximum Recorded Temperature (Interior)
2015-2017: +0.93 °C 41.2 °C
2018–2020: +1.10°C 41.8°C
2021-2023: +1.40°C 42.5°C
2024-2025: +1.65°C 43.1 °C

Table 1: Decadal warming progression across Libyan climate zones [2,4].

N	Period	Mean Temperature Anomaly	Maximum Recorded Temperature (Interior)
1	2015–2017	+0.93°C	41.2°C
2	2018–2020	+1.10°C	41.8°C
3	2021–2023	+1.40°C	42.5°C
4	2024–2025	+1.65°C	43.1°C

Warming is not uniform, with interior semi-arid zones (Al Jabal al Gharbi, Ghadamis) warming more than coastal areas, and land-surface temperatures regularly exceeding 42 °C in Summer months [10]. This differential warming increases evaporative demand, which directly impacts agricultural water budgets.

Hydrological degradation: trends in rainfall and drought

Libya exhibited a strong drying trend from 2015 to 2025 in conjunction with warming nevertheless with large interannual variability. According to the Libya Meteorological Authority [11], the period 2021–2025 is the driest five-year period since instrumental records started in 1950.

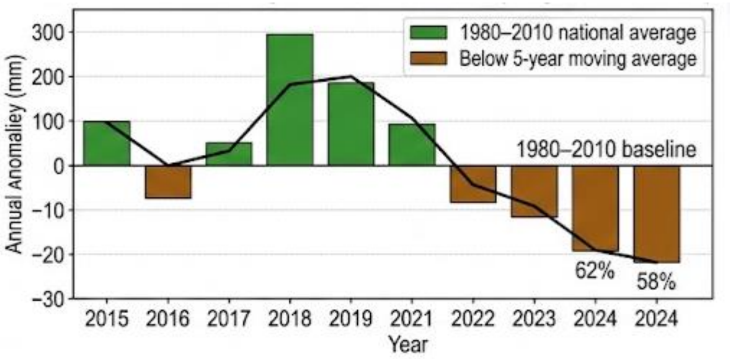

Figure 2: Annual precipitation anomalies (2015-2025) with 5 year moving average depicting the drying trend.

Characteristics: Moderately wet years 2018–2019, interrupted by severe drought from 2021 onward. Baseline (1980–2010): ~150 mm/year on average nationally. 2023: 62% of baseline. 2024: 58% of baseline.

The spatial distrihion of the precipitation decline is of crucial importance. Coastal areas with Mediterranean winter rainfall have declined 20-30% and interior agricultural areas receive less than 0.25 mm/day during growing seasons (the critical threshold below which rain-fed agriculture is not possible) [10,11]. Indicators of drought stress confirm the severity of the dry period of 2021-2025:

More than 68,000 km^2 of Western Libya are under drought stress. Rain-fed agriculture and livestock rearing, which sustains about one fifth of the population, are progressively becoming unsustainable with the decline of soil moisture, the rise of irrigation costs and the decrease of cropland [1]. Table 2 presents the quantified land cover change detected by remote sensing (2015–2024):

Table 2. Land cover change in Western Libya, 2015-2024 [1].

Land Cover Class	2015 Extent (km^2)	2024 Extent (km^2)	Percentage Change
Cropland	12,450	9,820	-21.1%
Tree Cover	8,230	6,450	-21.6%
Bare Land	1,345,600	1,362,800	+1.3%
Built-up Area	4,720	6,890	+46.0%

The 46% growth in built up area is particularly significant as it reflects rural to urban migration as agricultural livelihoods collapse, an early warning of climate induced displacement. The migration patterns observed in Libya are consistent with those observed across the Sahel where the rural exodus from drought has grown over the last ten years [3].

Soil Salinization: The Invisible Crisis

Temperature increases and precipitation decline have produced a secondary however devastating effect: progressive soil salinization. As groundwater tables drop and evaporative demand rises, irrigation water quality deteriorates, leaving behind concentrated salts. Recent hydrogeological surveys indicate that groundwater extraction rates in coastal aquifers exceed natural recharge by a factor of 4:1, accelerating saltwater intrusion [8].

Field measurements from Misrata Agricultural Station (2025) document the scale of degradation: "Normal rate of soil salinity should not exceed 2 decisiemens per meter. Now, we found in most of the samples we tested the (level of soil salinity) is more than 2, even sometimes reaching 40 or 50 decisiemens per meter in regions largely impacted by salinity." [7]

Farmer testimonies confirm that salinization has rendered previously productive land unusable. One former farmer who abandoned vegetable cultivation in 2018 described:

"The water's pH reached 12. From 2000 to 2018, I used to plant all types of vegetables. However, in 2018, I lost the entire crop. The farm has become empty and arid, and it has become so for over five or seven years since 2018, and it is dying. Even the barley or reeds, if we irrigate them with this water, they will die." [7].

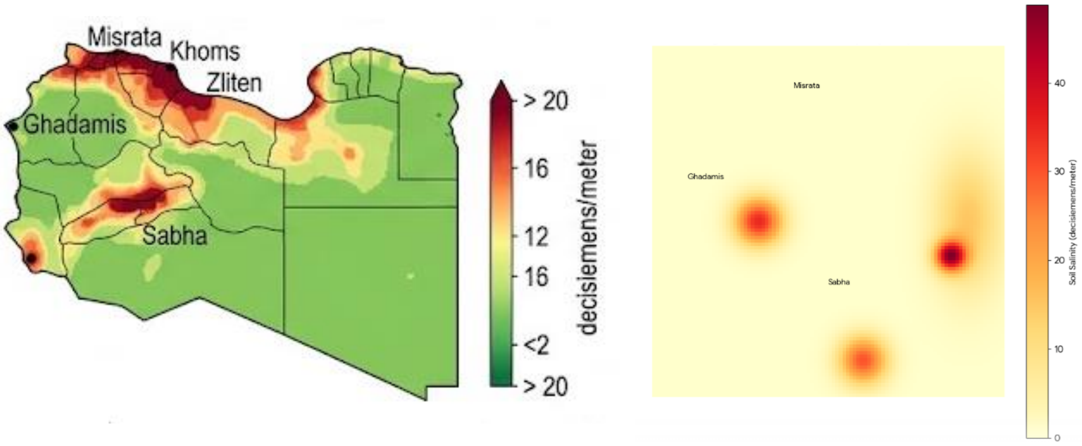

Figure 3: maps soil salinity measurements across Libya's agricultural zones (2025).

Libya choropleth map with regions by salinity levels (decisiemens/meter). Color gradient from green (< 2) to dark red (> 20). The worst salinization is mainly limited to the coastal agricultural plains (Misrata, Khoms, Zliten) and oasis areas (Ghadamis, Sabha).

The 2023 Derna Disaster: A Climate-Infrastructure Failure

The environmental sequence of 2015-2025 culminated in the catastrophic failure of two dams in Derna on 10 September 2023. Mediterranean cyclone with tropical characteristics Storm Daniel generated nearly 400 millimeters of rain in 24 hours, or about 2.5 times the area's average annual precipitation [4]. Climate attribution studies showed that this extreme rainfall event was 50 times more likely and 50% more intense because of human-caused climate change [9,12]. This led to the collapse of the 75-meter-high Bu Mansour dam and the 40-meter-high Elbilad dam [5]. More than 11,000 people were killed, and more than 8,570 buildings were damaged. About 30 million cubic meters of water was released [12].

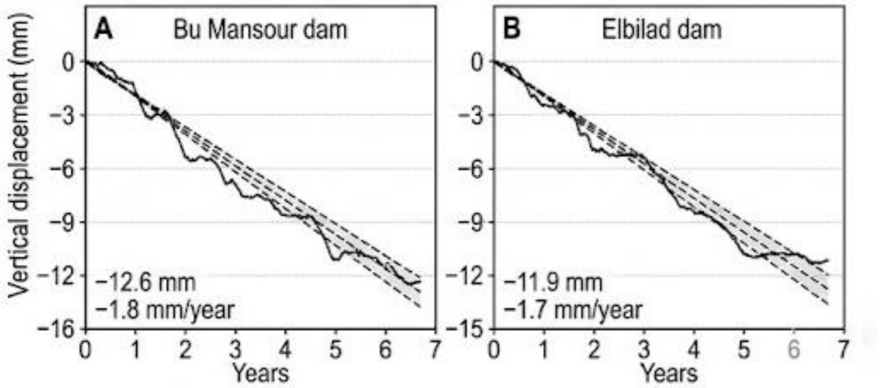

Figure 4: presents the InSAR-derived subsidence of both dams (2016–2023).

Two-panel figure. Panel A: Time series of vertical displacement at the Bu Mansour dam, showing a total subsidence of -12.6 mm over 7 years (-1.8 mm/year). Panel B: Elbilad dam showing -11.9 mm total subsidence (-1.7 mm/year) [Dashed lines show linear trends with confidence intervals] Nevertheless, the dams were not just overwhelmed with rainwater. They were structurally compromised after decades of neglect. The InSAR analysis showed: "Both the failed dams were over 50 years old and had been suffering from serious structural deficiencies and poor maintenance The Bu Mansour and Elbilad dams had a non-uniform sinking rate of about 1.8 mm/year, which indicated progressive structural instability. Differential settlements over 2016-2023 resulted in an angular distortion of up to 3.6×10^{-4} (0.021°) and 5.0×10^{-4} (0.029°), respectively." [5] Table 3 summarizes the disaster's key metrics and causal factors:

Table 3: Storm Daniel–Derna dam disaster, key parameters [5,9,12].

Parameter	Measurement
Peak 24-hour rainfall	400 mm
Dam ages at failure	>50 years
Annual subsidence rate (both dams)	~1.8 mm/year
Water released	~30 million m^3
Fatalities	>11,000
Buildings damaged	>8,570
Climate change contribution (rainfall intensity)	+50%
Climate change contribution (probability)	50× more likely

The disaster is an example of how governance failure and climate change compound. Dam maintenance had been hindered by the political instability that followed the 2011 revolution; a $335 million rehabilitation fund established in 2021 was mired in political wrangling and never fully disbursed [6]. Post-disaster investigations confirmed that "the lack of a functioning early warning system and delayed evacuation orders substantially increased mortality" [6].

Discussion

The Environmental Sequence: From Gradual Change to Acute Crisis

The 2015–2025 period reveals a distinctive environmental sequence in Libya. The decade began with gradual while accelerating warming and drying, trends consistent with climate model projections for the Mediterranean basin [2,11]. By 2020, these chronic changes had begun producing measurable impacts: cropland contraction, tree cover loss, and the onset of severe soil salinization. However, these impacts remained localized, and adaptation through groundwater pumping or temporary migration provided partial relief.

The 2021–2023 period marked a threshold crossing. Three consecutive years of below-average precipitation, combined with record temperatures, pushed agricultural systems beyond their adaptive capacity. Farmer testimonies consistently identify 2018 as a turning point when crop failure became systematic rather than occasional [7]. Groundwater depletion rates accelerated during this period, with the General Water Authority reporting a 35% decline in water table levels in the Jifarah Plain between 2015 and 2024 [8].

The Derna disaster of 2023 represents a different category of impact: an acute hazard event whose severity was amplified by chronic infrastructure deterioration. Here, climate change did not act alone, intersected with political failure to produce catastrophe. These finding challenges purely environmental framings of climate risk. [12]

It is argued that "The Libya disaster is attributed to political instability leading to improper infrastructure maintenance. Regime changes and the lack of coordination between rival authorities have amplified the infrastructure crisis as essential services, including dam maintenance, suffered neglect."

The Adaptation Gap

Survey data reveal a striking adaptation deficit. Despite one-third of households experiencing multiple climatic hazards within a single year, 99% report no access to early-warning systems, disaster plans, or formal adaptation support [1]. This gap exists not because solutions are technically unavailable but because governance fragmentation has disabled collective action.

Water management exemplifies this paralysis. Libya possesses the Great Man-Made River, one of the world’s largest engineering projects for fossil water extraction, however its operation and maintenance have been compromised by political division [3]. Desalination technology exists nevertheless is prohibitively expensive for individual farmers (quoted at $37,000 per unit), and state support has not materialized [7].

Migration as Coping Mechanism

The environmental sequence documented here is driving population mobility. Rural families in drought-affected areas of Al Jabal Al Gharbi and Elmergib have initiated seasonal and permanent migration, primarily toward coastal cities [1]. This movement is not planned adaptation n a coping mechanism of last resort, migration occurs when agricultural income collapses entirely. Similar patterns have been documented across Tunisia and Algeria, suggesting a regional climate-migration nexus [3]. Significantly, the 46% expansion of built-up area between 2015 and 2024 (Table 2) likely understates actual rural-to-urban migration, as newly arrived households often settle in informal peri-urban settlements not captured in land cover classification. The absence of systematic internal displacement monitoring represents a critical data gap.

Limitations

Several limitations constrain this assessment. First, the 2015–2025 period partially overlaps with Libya’s civil conflict (2014–2020), which produced population displacements that are difficult to disentangle from climate-driven movement. Second, ground-based monitoring networks for weather, hydrology, and soil conditions are sparse and have degraded during the conflict period. Third, attribution of specific events to anthropogenic climate change relies on modeling studies; while the Storm Daniel attribution is robust [9], similar analyses for precipitation trends are lacking. Fourth, the projected 2025 temperature anomaly is model-dependent; we report the median estimate from the CMIP6 ensemble [11].

Conclusion

The assessment of Libya’s environmental sequence between 2015 and 2025 yields four principal conclusions:

First, Libya has experienced statistically significant warming (≥1.5°C above baseline) and drying (≥40% precipitation reduction in some regions) during this decade, with 2021–2025 representing the most severe multi-year drought in recent records.

Second, these climatic changes have produced measurable land cover transformations: cropland contraction of 21%, tree cover loss of 22%, and severe soil salinization rendering previously productive land unusable.

Third, the catastrophic dam failures in Derna (2023) demonstrate how climate change amplifies existing infrastructure vulnerabilities. The extreme rainfall event that triggered the disaster was made 50 times more likely and 50% more intense by global warming, however the disaster itself resulted from the confluence of climatic change, aging infrastructure, and political instability.

Fourth, Libya's adaptation response has been entirely inadequate. With 99% of households lacking access to early warning systems or disaster plans, climate impacts translate directly into livelihood loss and displacement.

6. Recommendations

Based on these findings, we recommend:

Emergency infrastructure assessment: International support for remote sensing and ground-based inspection of Libya's 17 major dams, with priority for those with downstream population centers.

Early warning system deployment: Establishment of flood forecasting and heat-health warning systems, leveraging existing regional networks (e.g., Mediterranean Climate Outlook Forum).

Desalination subsidies: Targeted support for agricultural desalination units in coastal zones where salinization has destroyed livelihoods. Climate-migration governance: Recognition of climate-displaced persons within Libyan and international policy frameworks, with tracking mechanisms differentiated from conflict-induced displacement.

The 2015–2025 period demonstrates that Libya has moved from climate vulnerability to climate crisis. Without coordinated intervention, addressing not only greenhouse gas mitigation but also infrastructure rehabilitation, governance reform, and adaptation finance, the next decade will bring further environmental deterioration and human suffering.

References

[1] International Organization for Migration, Displacement Tracking Matrix. "Western Libya: Climate, Livelihoods, and Mobility." IOM DTM Report, March 2026.

[2] Zittis, G., et al. "Climate change and weather extremes in the Eastern Mediterranean and Middle East." Reviews of Geophysics, 60(3), e2021RG000762 (2022).

[3] Neumann, K., & Hilderink, H. "Climate change and migration in the MENA region: A review of the literature." Global Environmental Change, 72, 102434 (2022).

[4] meteoblue. "Climate Change Libya - ERA5 Reanalysis (1979-2025)." meteoblue AG, 2025.

[5] Down To Earth. "Aging dams and climate change led to Libya's 2023 flood disaster, finds new research." February 17, 2025.

[6] Di Baldassarre, G., et al. "Dam failures in the anthropocene: Understanding hydro-social hazards." Earth's Future, 12(1), e2023EF003821 (2024).

[7] Reuters. "Increasing water, soil salinity endanger Libya's agricultural crops." July 15, 2025.

[8] Libya General Water Authority. "Annual Water Resources Report 2024." Tripoli: GWA Publications (2025).

[9] Clarke, B., et al. "Climate change attribution of Storm Daniel and the 2023 Libya floods." World Weather Attribution Report, October 5, 2023.

[10] Zurqani, H. A. (Ed.). Water Resources of Libya: Challenges and Management. Springer, 2025.

[11] Lelieveld, J., et al. "Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century." Climatic Change, 175(1), 1-18 (2023).

[12] Esmaeili, F., et al. "Aging dams, political instability, poor human decisions and climate change: recipe for human disaster." npj Natural Hazards 2, Article 5 (2025).