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# Climate Change and Health: Enhancing Resilience in Fragile Systems

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## Abstract

Background: Climate change represents one of the most pressing public health challenges of the 21st century, with fragile and conflict-affected contexts experiencing disproportionate impacts. Libya, situated within the Eastern Mediterranean and North Africa climate hotspot, faces intensifying hazards including prolonged droughts, extreme heat, desertification, and catastrophic flooding. These environmental stresses converge with structural vulnerabilities—such as degraded infrastructure, weak governance, limited disease surveillance, and protracted political instability all of which undermine health system resilience.

Methods: This study employs an integrative review of peer-reviewed literature, gray reports, climate-health datasets, and comparative evidence from the wider MENA region to assess climate-sensitive health outcomes and systemic vulnerabilities in Libya.

Results: Findings indicate escalating risks of vector-borne and waterborne diseases, respiratory illness driven by deteriorating air quality, heat-related morbidity and mortality, food insecurity, and under-recognized mental health consequences. The 2023 Derna floods exemplify the compounded effects of climate shocks and governance fragility, highlighting critical deficiencies in preparedness and response. In the light of these findings, this paper advances context-specific adaptation strategies, including development of a National Health Adaptation Plan, investment in climate-resilient infrastructure, integration of mental health into emergency frameworks, expansion of disease surveillance systems, and mobilization of international climate finance.

Conclusion: Strengthening institutional capacity and embedding climate-health priorities into national policy are essential to safeguard public health, promote resilience, and mitigate the destabilizing effects of climate change in fragile health systems.

Key Words: Climate Change, Environmental Health, Libya, Public Health, Adaptation Strategies, Health System Resilience

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## Introduction

Climate change has emerged as the most urgent global health threat of the 21st century, manifesting worldwide through immediate and long-term health risks such as heatwaves, droughts, floods, vector-borne disease spread, food and water insecurity, and displaced populations.[1,10]

The WHO estimates climate change may cause approximately 250,000 additional deaths annually between 2030 and 2050, primarily from malnutrition, malaria, diarrhea, and heat stress.[4]

These outcomes result from complex pathways: rising temperatures and extreme weather worsen air pollution, increasing respiratory and cardiovascular diseases and premature mortality.[5]

Water scarcity and contamination increase risks of waterborne illnesses like cholera, especially where sanitation is inadequate.[5-7] Climate impacts on agriculture threaten food security, leading to under-nutrition and related health issues.[7-9] Mental health is adversely affected by psychological stress from extreme events, forced displacement, and uncertainty.[10]

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The Eastern Mediterranean and North Africa (EMNA) region, including Libya, is a climate hotspot.[11] By 2020, the southern Mediterranean warmed approximately 1.5˚C above pre-industrial levels, exceeding the global average of 1.0˚C.[12] Projections indicate regional temperatures may rise by 2.2˚C by 2040 and up to 4˚C by 2100 under high emissions scenarios.[11-13] Libya is already experiencing intensified hazards such as prolonged droughts, erratic rainfall, desertification, and extreme weather (Table 1). The 2023 Medicane storm caused catastrophic flooding in Derna, resulting in approximately 15,000 deaths and severe infrastructure damage.[15]

Table 1: Climate Hazards Risk Level Classification in Libya[14]

| Hazards | Risk Levels |
|---|---|
| Coastal Flood | High |
| Water Scarcity | High |
| Extreme Heat | High |
| Wildfire | High |
| Wadi Flood | Medium |
| Tsunami | Medium |
| Urban Flood | Low |
| Earthquake | Low |
| Landslide | Very Low |
| Volcano | Very Low |

These environmental stresses compound Libya's structural vulnerabilities: >95% desert terrain, <1% arable land, and dependence on the Man-Made River which makes up over 60% of the freshwater supply, threatened by overuse and contamination.[16] Libya imports over 75% of its food, increasing susceptibility to global supply disruptions exacerbated by climate events.[16] Libya's healthcare system, weakened by prolonged conflict and political instability, is ill-prepared for rising climate-sensitive health threats. Many facilities lack adequate infrastructure, equipment, and personnel.[5] The absence of a unified health information system and limited disease surveillance hinder timely responses. Less than 25% of the population has access to safe sanitation, exacerbating public health risks.[16]

Despite growing global attention to climate and health, Libya remains underrepresented in scientific literature.[5,16] Most regional studies emphasize environmental impacts or focus on relatively stable countries like Egypt, Tunisia, or Morocco.[11] This gap limits policymakers' ability to develop targeted, evidence-based adaptation strategies.

This study addresses these gaps by synthesizing evidence on climate-related health outcomes, evaluating Libya's health system vulnerability and resilience, and proposing context-specific adaptation and mitigation strategies. It examines pathways linking climate drivers to health challenges—including infectious diseases, heat-related illnesses, respiratory conditions, malnutrition, and mental health actionable strategies to enhance system-wide resilience. By situating Libya within the broader regional and global climate-health discourse, this research aims to support evidence-based policy planning and strengthen public health preparedness in one of the world's most climate-vulnerable contexts.

## Methods

A structured integrative review methodology was employed, following the IMRAD framework. Due to limited country-specific data and research, the review synthesized peer-reviewed literature, gray literature, policy documents, and climate-health datasets, supplemented by evidence from comparable arid and conflict-affected countries in the Middle East and North Africa (MENA) region.

Inclusion Criteria: Studies addressing climate-sensitive health outcomes (vector-borne diseases, heat illnesses, waterborne infections), environmental risks (drought, floods, desertification), and health system responses in arid or conflict-affected settings, particularly North Africa.

Exclusion Criteria: Studies unrelated to human health, duplicates, non-English/Arabic publications without translations, and research solely on economic/agricultural modeling lacking public health relevance.

Due to Libya's limited health surveillance capacity and conflict-related constraints, evidence from Tunisia, Egypt, Morocco, and Algeria was used to infer potential health trends.[5,16] Additional data from sub-national sources, NGOs, and humanitarian assessments were incorporated, though many lacked systematic health indicators or climate-health disaggregation.

Quantitative data scarcity precluded formal statistical analysis. A qualitative thematic synthesis was conducted across six domains: infectious diseases, heat stress and extreme weather, respiratory health, nutrition and food security, mental health, and health system infrastructure and resilience. Climate data—including temperature trends and projections—were sourced from Intergovernmental Panel on Climate Change (IPCC) reports, NASA, ECMWF, and the World Bank. WHO climate and health country profiles and climate risk indices contextualized Libya's vulnerabilities.[3,4-6]

This integrative approach consolidated scientific evidence, policy perspectives, and climate-health indicators, providing the most comprehensive assessment feasible under Libya's data constraints. Findings aim to inform national climate adaptation planning and strengthen public health resilience in climate-vulnerable, conflict-affected settings.

## Results

### Water Scarcity and Health Implications

Libya's reliance on non-renewable fossil aquifers via the Man-Made River is undermined by over-extraction, contamination, and prolonged droughts, reducing

water availability and hygiene, increasing dependence on unsafe water sources, contributing to cholera, dysentery, and giardiasis outbreaks, especially in under-served and displaced populations. Flood-related sewage overflows during the 2023 Derna flood exacerbated waterborne disease transmission. Other high-risk areas—Ghat, Kufra, and Zliten—face elevated cholera risk due to rising groundwater levels. Migrant influxes from sub-Saharan Africa further strain water and sanitation systems, increasing outbreak vulnerability.[5,15,16]

### Air Pollution and Respiratory Disease

Libya's air quality has deteriorated due to frequent sand-storms, unregulated industrial emissions, waste burning, and the increased use of diesel generators during power outages. Fine particulate matter ($PM_{2.5}$ / $PM_{10}$) and nitrogen dioxide ($NO_2$) concentrations regularly exceed the World Health Organization (WHO) air quality guidelines. In 2023, Libya's average $PM_{2.5}$ concentration (~30 µg/m³) was approximately six times higher than the WHO guideline value of 5 µg/m³.[17] Saharan dust intensified by desertification contributes significantly to respiratory illness. A 2017 dust storm in Tripoli and a 2021 sandstorm in Benghazi were linked to spikes in pediatric asthma admissions.

Chronic exposure correlates with rising bronchitis and Chronic Obstructive Pulmonary Disease (COPD) rates. Air pollution accounted for 11% of all deaths in 2016, causing an estimated 41–59 deaths per 100,000 population.[17–19]

### Heatwaves and Mortality Risk

Heatwaves have intensified, with summer temperatures often exceeding 45°C. Projections estimate an average temperature rise of +1.42°C by 2060, pushing annual means to 25.6°C.[20] The 2022 Tripoli heatwave (48°C) highlighted data gaps, as the lack of sensitive mortality surveillance precluded assessment of excess deaths. Vulnerable populations—elderly, outdoor workers, and those without cooling—are disproportionately affected. Regional models estimate 500–1,500 annual heat-related deaths in Libya, mirroring Algeria's experience.[21] Heat exacerbates pre-existing respiratory and cardiovascular conditions.[22,23]

### Extreme Weather Events and Disaster-Related Health Burdens

Climate-related disasters have surged in frequency and severity. The 2023 Medicane in Derna caused thousands of deaths, displacement, and infrastructure destruction. The 2024 Tarhuna floods damaged hospitals and caused fatalities among emergency personnel. Disrupted medical supply chains and facility closures delayed care. By 2050, Libya is expected to experience a 7% reduction in average annual precipitation, increasing flash flood risks in urban and rural areas.[20] These events magnify injury, disease outbreaks, and mental trauma risks, especially where emergency preparedness is weak.

### Health System Challenges

Libya's healthcare system is strained by climate shocks and longstanding vulnerabilities including conflict-driven destruction, governance fragmentation, and chronic underinvestment. Key vulnerabilities include:

1. Fragile Infrastructure and Workforce Shortages: Conflict and extreme weather have degraded facilities, causing unreliable electricity and water supply, compromising care continuity. Floods forced clinic closures and hospital incapacitation, delaying trauma care for thousands. Medical workforce shortages persist, with doctor-to-population ratios below WHO benchmarks, particularly in underserved regions. Energy demands forcooling strain power systems, causing outages that disrupt services and equipment maintenance[5].
2. Weak Surveillance and Early Warning: Libya lacks a comprehensive electronic disease surveillance system. Fragmented efforts impede outbreak detec tion and response, as seen after Derna floods with untracked diarrheal disease surges. Early warning systems for climate-sensitive diseases and extreme weather are absent or nonfunctional.

### Governance Fragmentation and Financial Constraints

Political instability and overlapping authorities hinder coordinated health governance. Climate and health remain low policy priorities. Preparedness is largely reactive, with limited heat-health plans, disaster management protocols, and risk-oriented communication. Budget constraints limit investments in resilient infrastructure, workforce training, and health-information systems. Flood-damaged transport networks disrupt medicine and vaccine delivery.[1] Although some activities are underway with international partners, Libya lacks an operational Health National Adaptation Plan (HNAP) and political divisions continue to stall climate-health preparedness.[8]

## Discussion

This study highlights the urgent, multidimensional threat climate change poses to public health in Libya, a nation facing environmental fragility, political instability, and a strained healthcare system. Findings align with global and regional trends showing climate change disproportionately impacts low-resource, conflict-affected settings.[1,4] Rising temperatures, reduced precipitation, and extreme weather compound health disparities and strain fragile health infrastructure.

Comparative evidence from the MENA region reinforces these observations. Egypt and Tunisia report increased respiratory illness and heat-related mortality linked to deteriorating air quality and rising temperatures. Unlike Libya, these countries have launched National Health Adaptation Plans and integrated early warning systems, mitigating some climate impacts. Libya's fragmented governance and lack of preparedness exacerbate health consequences of similar stressors.

Post-flood disease outbreaks in Derna illustrate the cost of inaction. Globally, waterborne disease spikes following extreme weather are well documented, yet Libya lacks contingency plans and ecological monitoring. Reports of increased scorpion stings in southern Tunisia due to ecological shifts raise concerns for similar unmonitored risks in Libya.

The 2003 European heatwave, causing over 70,000 excess deaths, demonstrates the value of preparedness measures like early warning systems and heat-health action plans.[24] Jordan and Egypt's climate-resilient

healthcare infrastructure and green hospital initiatives offer viable models for Libya.

Climate-related health threats in Libya mirror global risks. Vector-borne diseases like dengue and chikungunya have expanded in neighboring Egypt and Sudan, consistent with IPCC and WHO warnings that arid-region populations face heightened outbreak risks.[14,25,26] Mental health impacts are significant but under investigated. The 2023 Derna flood triggered acute psychological trauma and climate-related anxiety. Although Libya recently established a National Authority for Mental Health and Psychosocial Support, integration of mental health into climate adaptation remains minimal. Mental health and psychosocial support must become core components of public health emergency responses.
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More than a decade of conflict has left Libya's health facilities understaffed and under-resourced. Attacks on infrastructure and exodus of foreign medical personnel have eroded the capacity of the health system.[27] Lower development health information systems hinder disease surveillance and response. With less than 25% of the population accessing safe sanitation, vulnerability to waterborne diseases is compounded.

Climate change amplifies these systemic weaknesses. The 2023 Medicane flood exposed consequences of unregulated urban growth, aging infrastructure, and weak disaster preparedness. Without proactive adaptation, each climate shock risks further destabilizing Libya's public health system and fules politcal development.

## Conclusion

This study provides the first integrated assessment of climate change's public health impacts in Libya. Rising temperatures, water scarcity, air pollution, and extreme weather events contribute to a growing burden of climate-sensitive health conditions, including heat-related mortality, respiratory and vector-borne diseases, and food and water insecurity. These patterns reflect global trends but are particularly acute in Libya due to its arid climate, fragile infrastructure, and political instability.

Systemic vulnerabilities—including damaged health infrastructure, workforce shortages, inadequate surveillance, and fragmented governance—undermine Libya's capacity to respond. Without urgent adaptation efforts, these challenges will escalate, threatening public health and development goals.

Despite data limitations, findings highlight the urgent need to integrate climate resilience into national health planning by strengthening institutional capacity, expanding electronic surveillance, upgrading infrastructure, and embedding climate-health priorities in policy and budgeting. Context-specific, evidence-based reforms, combined with regional cooperation and international support, can lay the foundation for a climate-resilient, equitable healthcare system in Libya. Decisive leadership and sustained commitment are essential. The time for action is now (Table 2 and Table 3).

Table 2: Recommendations for Climate-Resilient Health Systems in Libya

| Recommendations for Climate-Resilient Health Systems in Libya |
|---|
| 1. Develop a national health adaptation strategy HNAP |
| 2. Strengthen disease surveillance and early warning systems |
| 3. Upgrade healthcare infrastructure for climate resilience |
| 4. Enhance health force capacity and emergency preparedness |
| 5. Improve community based risk communication and awareness |
| 6. Mobilize climate and health financing |
| 7. Promote regional collaboration and knowledge |
| 8. Institutionalize climate health governance |

Table 3: Policy Recommendations

| Policy Recommendations |
|---|
| Immediate Priorities:<br>• Decentralized Disease Surveillance: Deploy Mobile clinics with rapid diagnostic tools for flood-prone regions (e.g., Derna, Ghat).<br>• Heatwave Early Warning Systems: Partner with community leaders to broadcast alerts via SMS.<br><br>Long-Term Strategies:<br>• Climate-Resilient Infrastructure: Retrofit hospitals and health facilities with solar power and flood barriers. Double glasses, environment friendly low carbon footrpint Medical and electrical equipment and drugs and inhalers. Drawing on Egypt's Green Hospital standards and Jordanian Resistant and Sustainable Health Facilities.<br>• Mental Health Integration: Train primary care workers in Post-Traumatic Stress Disorder screening, leveraging Jordan's MHPSS frameworks. |

## Disclosure Statement

The author has no conflict of interests to declare.

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