

Pathway from water-conflict to water-peace in the Middle East and North Africa

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ABSTRACT

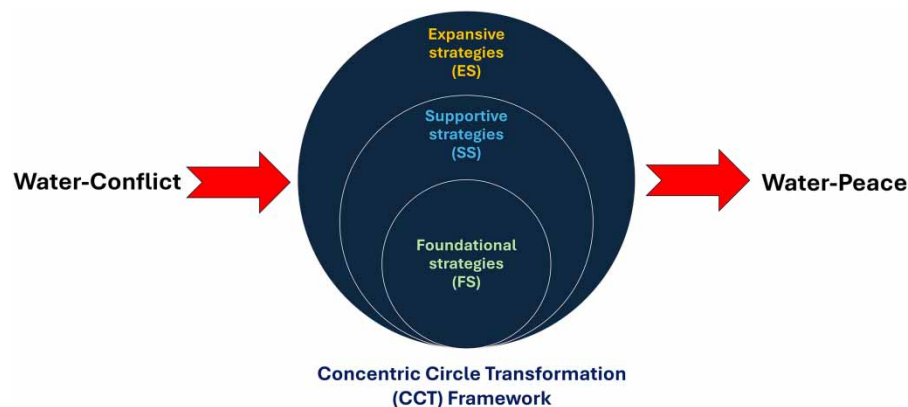
The Middle East and North Africa (MENA) region, with its arid and semi-arid climate, faces profound challenges in managing limited water resources. These challenges are further intensified by political tensions and socioeconomic inequalities, often resulting in water being an essential element in conflicts and tensions. Particularly during the last decade, the number of conflicts involving water has increased dramatically in MENA. This research explores the dynamics of water's role in conflicts, actors and scales of conflict across five fragile MENA countries, where it serves as a weapon, a catalyst, and a casualty. The analysis revealed a significant increase in the number of water-related incidents during the last two decades in these countries, with devastating implications on multiple social, economic, and security dimensions. The study suggests a concentric circle transformation (CCT) framework with three tiers of strategies: foundational, supportive, and expansive to help move from water-conflict to water-peace in MENA. These strategies, with examples of interventions, support transformation to water-peace by integrating soft interventions like empowering local communities, raising awareness, with hard interventions such as building resilient infrastructures and leveraging the power of innovative technological solutions. The framework offers scalable and adaptable solutions for regions facing similar challenges globally.

Key words: conflict, Iraq, Libya, Sudan, Syria, Yemen

HIGHLIGHTS

- Conflicts exacerbate water scarcity, triggering severe crises in the Middle East and North Africa (MENA).
- Water in MENA conflicts acts as a weapon, trigger, and casualty, driving instability.
- The new framework proposes strategies potential to promote transforming MENA's water-conflict into water-peace.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Throughout history, water has been a pivotal factor in the rise and downfall of many civilizations (Abate 1994; Cookson *et al.* 2019). The Middle East and North Africa (MENA) region notably marks the stage for both the earliest water conflicts and the establishment of first transboundary water agreements (Hatami & Gleick 1994; Sand 2018). Water scarcity and resource competition are critical challenges facing the MENA region, where

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arid and semi-arid conditions prevail. With limited freshwater resources and rapidly growing populations (Hameed *et al.* 2019; Maftouh *et al.* 2022), the region is experiencing increasing pressure on its water systems. Climate change further exacerbates this situation by intensifying droughts, reducing rainfall variability, and disrupting seasonal water availability (Fragaszy *et al.* 2020; Boloorani *et al.* 2024).

The MENA region is frequently mentioned as a prime example of a region where disputes over water resources might escalate into violent conflicts (Lonergan 1997). From 2012 to 2022, the number of water-related conflicts globally has quadrupled compared with their numbers from 2000 to 2011, mainly due to violence in the MENA region (Gleick & Shimabuku 2023). Over the past decade, MENA's water scarcity has worsened in parallel with escalated political unrest and armed conflicts. The political turmoil and associated violence from 2010 onward have destabilized several countries in the region such as Iraq, Libya, Syria, Yemen, and Sudan (Fraihat & Yaseen 2020; Barakat & Fakhri 2021; Msellemu & Kessy 2022).

Historically, water resources in the MENA region have been closely linked to socio-political dynamics, playing a central role in shaping the livelihoods of communities and the policies of states (Odhiambo 2017; Hejazi *et al.* 2023). In recent decades, the combination of over-extraction, pollution, and unsustainable management practices has pushed the region to the edge of a water crisis. This scarcity is not just an environmental issue but a geopolitical one, often contributing to disputes from micro- and meso-scales between communities and regions to macro-scales with disputes even between neighboring nations on transboundary water resources. The complex nexus between water scarcity and conflict has been widely documented, with water resources being weaponized, trigger conflicts, or targeted during times of political unrest (Gleick & Shimabuku 2023).

Politicizing water systems during water availability and abundance, rather than only during drought or scarcity, is a problem that is frequently disregarded. Although water scarcity is frequently cited as a conflict trigger, water abundance can also be weaponized as both offensive and defensive strategies (De Kraker 2015). Controlling floodwater management systems, including dams, levees, or drainage networks, can be used as a weapon in conflict zones to punish or target particular areas, disrupt livelihoods, and destabilize people. This underlines the need for protective measures irrespective of water availability and highlight for solution approaches that come from comprehensive analysis of the structure and dynamics of conflicts where water is involved (Nandalal & Simonovic 2003).

While many aspects of the nexus between water and conflict have been well studied, there is still a significant lack of comprehensive frameworks for interventions, especially in the MENA region where such efforts are desperately required. The structure of how water can be involved as a trigger, weapon, or casualty in conflicts is not fully captured by research in MENA, which frequently concentrates on discrete aspects of disputes involving water. An integrated approach that tackles complex dynamics is still missing. Developing and implementing such comprehensive frameworks is crucial, for instance, to changing the narrative of water as a source of conflict to one that promotes peace and collaboration, which will ultimately support regional stability in the long run (Gruen 2000; Nagheeb & Amezaga 2023; Döring *et al.* 2024).

Alleviating/minimizing the impact of conflicts on water resources or preventing water from being a target or a trigger in conflicts in the MENA region requires a multi-faceted approach that goes beyond traditional water management strategies. While technical (hard) solutions, such as building structures to improve water supply from conventional and non-conventional water sources (e.g., desalination, water reuse and rainwater harvesting), are critical, they alone are insufficient to foster this transformation where water scarcity intersects with socio-political issues (Gleick 2002; Medeiros & Sivapalan 2020). Soft strategies such as conflict resolution, water diplomacy, collaborative governance, sustainable water management, and capacity building are an integral part of the formula for peacebuilding, immediate recovery, and post-conflict rebuilding (Swain 2016).

To this end, based on a thorough examination of the water-conflict dynamics in MENA, this study seeks to establish a practical framework for alleviating and minimizing water-related conflicts in the region. This research contributes to the scientific discourse on the nexus between water, conflict, and peacebuilding in water-scarce regions, offering insights into how water resources can be managed to not only prevent conflicts but also foster long-term resilience in the face of climate change and socio-political instability.

2. MATERIALS AND METHODS

2.1. The MENA region and its grown water crises

MENA is one of the most water-scarce regions in the world (Al-Saidi *et al.* 2016). Its water resources are faced with interlinked challenges such as limited water resources, rapid population growth, and socioeconomic

development that all together contribute to the region's increasing water scarcity (Joffé 2016). Further, these challenges are compounded by external factors, including climate change impacts, political instability, and armed conflicts.

With an average renewable water resource of just 1,500 m³ per capita annually, the MENA region suffers from severe water scarcity when compared with other regions. According to Droogers *et al.* (2012), this is much less than the global average of 8,500 m³ per capita and far less than the averages for South America (47,000 m³), North America (20,000 m³) and Europe (11,000 m³). Water availability varies greatly throughout the MENA region; in Iran and Iraq, it can be over 2,000 m³ per capita annually, while in Jordan, Palestine, Yemen, and several Gulf countries, it is less than 200 m³ per capita annually.

Figure 1(a) and 1(b) shows how water stress is distributed geographically throughout the MENA region based on the ratio of total water demand to renewable surface and groundwater supplies that are available. Based on the baseline scenario, vast areas of the MENA region currently show high (40–80%) and extremely high (>80%) levels of water stress. Most of these areas are located in the Maghreb countries, the Nile Basin, the southern and northern Arabian Peninsula, and Iran. According to the optimistic future scenario, some areas facing severe water stress show signs of improvement by 2030, 2050, and 2080. Nonetheless, large areas in the region continue to experience severe levels of water stress, particularly in parts of the Arabian Peninsula and North Africa.

In contrast, the pessimistic scenario indicates that water stress in MENA will continue to worsen over the same time horizons, i.e., 2030, 2050, and 2080. While optimistic scenarios assume a more sustainable development pathway, slower rates of population expansion, and successful strategies of mitigating climate change, pessimistic scenarios assume strong economic growth combined with a heavy reliance on fossil fuels, which will exacerbate the effects of climate change and the scarcity of water. The projections in Figure 1 indicate that MENA's water scarcity is likely to continue and potentially worsen in the future, particularly under the business-as-usual and pessimistic scenarios, with potentially devastating implications. A drastic drop of 6–14% of the gross domestic product (GDP) is predicted by 2050, marking the region with the largest economic setback globally due to climate-induced water scarcity (World Bank 2017).

2.2. Data

This study primarily used data from the Water Conflict Chronology database (Pacific Institute 2024) to make an in-depth analysis of historical conflict incidents in MENA, where water is involved. The database provides a thorough record of cases where water resources were essential to conflicts, offering a unique dataset for analyzing the connections between water concerns and tensions.

The collection contains crucial information such as the date of each incident, the type of water dispute, and whether it involved intrastate or non-state parties. Furthermore, it indicates the country and region where each occurrence occurred, enabling a more complete understanding of regional patterns in water involvement in conflicts across the MENA region. The descriptive information in the database offers valuable insights into the manner in which water resources were involved in each instance. Examples of incidents include whether water was used as a weapon in a military operation, a cause of a conflict, or a casualty when water assets and capacities are targeted. This enabled conducting a comprehensive analysis of water-related occurrences in five selected fragile MENA countries, namely, Iraq, Libya, Sudan, Syria, and Yemen over a 24-year period (2000–2023). This period allowed drawn comparison and derives insights for two periods: pre- and post-2010. The year 2010 marks a pivotal point in the region's stability, as it has witnessed the onset of significant socio-political changes that reshaped the geopolitical and socio-economic landscape in the MENA region.

2.3. Methods

To develop a framework useful to lessen the degree of water involvement in conflicts and minimize the negative effects of tensions on water resources, this study used a multi-step methodology to examine the different water functions in conflicts throughout the MENA region. Data retrieval, classification, analysis, and the creation of a framework comprised the key elements of the methodological approach. The framework's applicability was then evaluated.

The first step involved data retrieval and analysis of information derived from the Water Conflict Chronology database. Each conflict's date, type, and nature are listed in this database along with the nation, area, and detailed incident descriptions. This study offers an examination of the conflict dynamics in the selected countries by

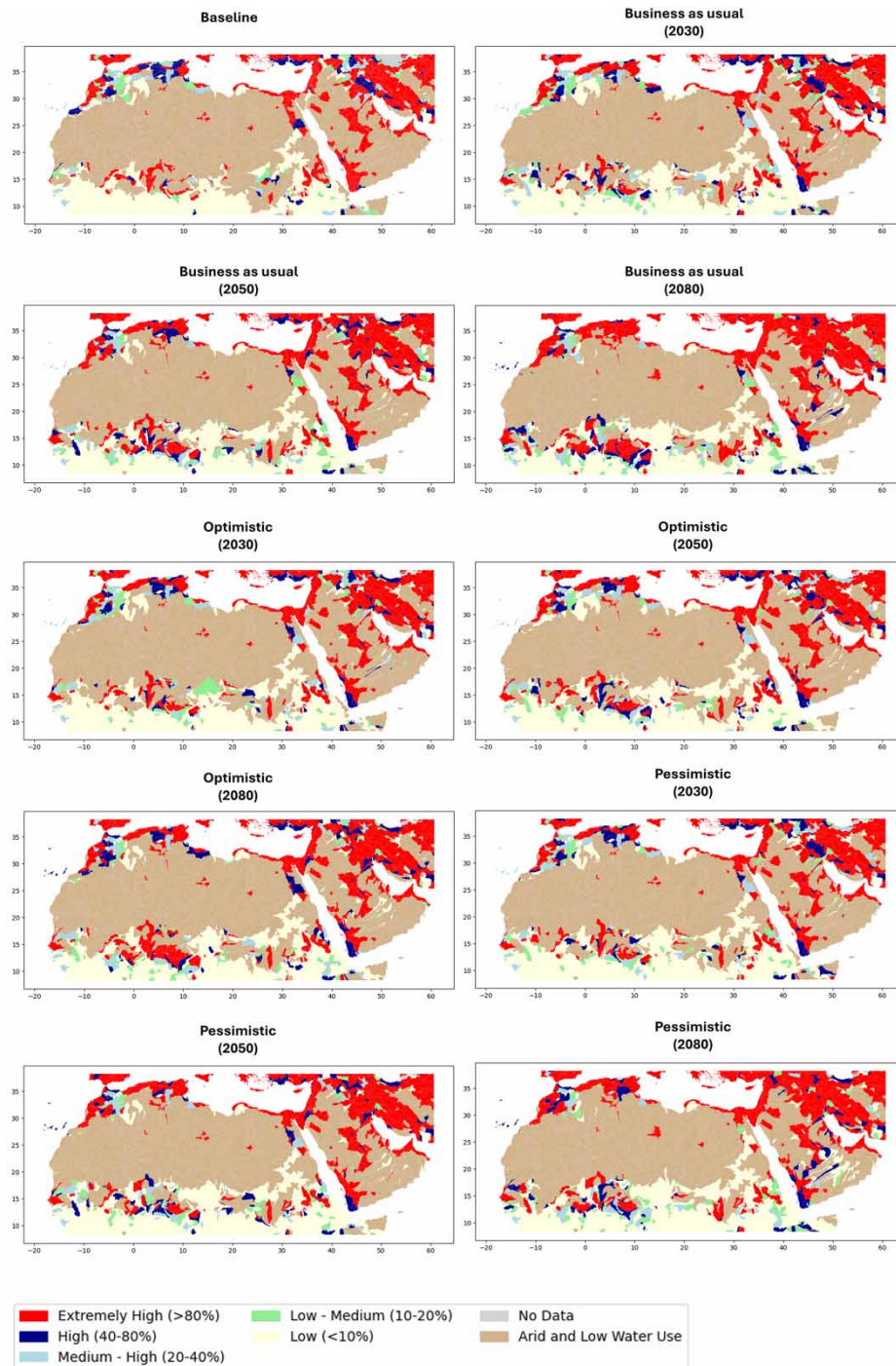


Figure 1 | Spatial distribution of water stress in MENA, measured as the ratio of total water demand to available renewable surface and groundwater supplies. This figure includes four sets of scenarios: baseline, business-as-usual (SSP3 RCP 7.0), and optimistic (SSP1 RCP 2.6) and pessimistic (SSP5 RCP 8.5) for the years 2030, 2050, and 2080. The maps were created by authors using data from the Aqeduct 4.0 Database (<https://www.wri.org/aqeduct>), maintained by the World Resources Institute (WRI).

classifying conflict instances according to their geographical scale and the actors involved. Accordingly, four types of conflict scales were considered: local, regional, national, and transboundary. Local conflict incidents, which are limited to certain regions, frequently involve disagreements over access to water resources between individuals or small groups, while regional incidents engage communities, regions or tribes. National conflicts, which are usually caused by government forces or militias for control of vital water infrastructure, affect greater areas inside a single nation and involve widespread disruptions to water supplies. Transboundary disputes arise

when one country's activities have a substantial impact on the water security of neighboring states, especially when those conflicts center on shared resources like rivers or aquifers.

The actors participating in water-related conflicts were divided into three categories: state, non-state, and mixed. Official government agencies, armed forces, and state-sponsored organizations are examples of state actors that have the power to control or interfere with water resources. Independent groups that function outside of governmental authority, such as terrorist organizations, militias, or tribes, are referred to as non-state actors. Conflicts that involve both state and non-state actors, including conflicts between government forces and militias or insurgents, are referred to as 'mixed actors'. A thorough assessment of the various types and causes of water conflicts in the selected countries is provided by this classification.

Individual instances were studied through a thorough analysis that followed the categorization. In order to comprehend the fundamental causes, dynamics, and effects of water conflicts, this phase entailed qualitative content analysis of incident descriptions. Finding recurrent themes, such as conflicts fueled by resource scarcity, the destruction of water infrastructure, or the use of water as leverage in larger geopolitical conflicts, received special emphasis. Critical elements that intensify conflicts and worsen water insecurity in the area were identified with the aid of this investigation.

Using the knowledge gathered from this analysis, a framework was created with an emphasis on fostering collaboration, long-term stability and reducing the negative effects on water resources. A paradigm for water-peace transformation that prioritizes preventive and adaptive actions was created by incorporating the lessons learnt. This strategy combines both hard and soft interventions, such as investing in resilient infrastructure and facilitating mechanisms to foster stakeholder discussion and collaboration to address underlying tensions before they become conflicts.

Detailed analysis of specific significant incidents of conflict was carried out to verify the framework's applicability. These instances help demonstrating how the suggested strategies and associated interventions could be used to defuse tensions and advance sustainable water management in actual situations. The framework was highlighted, for example, in situations involving pastoralists and farmers conflicts, where empowering local communities can contribute significantly to lower tensions and promote mutual confidence between disputing parties.

3. RESULTS AND DISCUSSION

3.1. Patterns and dynamics of water's role in MENA's conflicts

According to the data from the Water Conflict Chronology database (Pacific Institute 2024), the involvement of water in armed conflicts across MENA from 2000 through 2023 is on the rise (Figure 2). Among the five countries examined, Yemen records the highest number of conflicts where water is involved ($n = 163$), peaking in 2018 (Figure 2). These conflicts have led to widespread destruction of water facilities, depriving people of access to clean water. Iraq follows with 73 conflicts, and Syria with 40, both countries experiencing significant damage to their water infrastructure as a result of destructive armed conflicts. Sudan and Libya, with 28 and 20 conflicts, respectively, demonstrate comparatively lower water dependency or less intense conflicts over water resources compared with the other three countries. This categorization underscores the complex role water plays in conflicts in the MENA region.

Analysis of water-related conflicts in Iraq, Libya, Sudan, Syria, and Yemen between 2000 and 2023 shows clear trends in terms of conflict scales and parties. As different state and non-state actors are involved in these incidents, generally local-level conflicts predominated, with more than 97% of occurrences taking place on water resources located within the national boundaries (Figure 3(a)). A large percentage of incidents was caused by non-state actors, especially in Yemen and Sudan. Armed groups used water infrastructure as a weapon to obtain strategic advantage, especially in Syria and Iraq. In situations where water supplies were targeted during sieges or military operations, mixed actors – both state and non-state – also played roles. Conflicts between individuals, tribal groups, farmers, and pastoralists for access to water were the main cause of the high number of local conflicts in Yemen and Sudan (Figure 3(b)). Only a small number of occurrences, mostly in Syria, Iraq, and Sudan, have transboundary elements, notably due to disagreements over shared river basins like the Nile and Euphrates.

3.2. The triple role of water in conflicts

A closer examination of how water functions in armed conflicts in the MENA region reveals the prevalence of a threefold role: as a weapon, a trigger, or a casualty. Examples of the selected five countries over the past decade

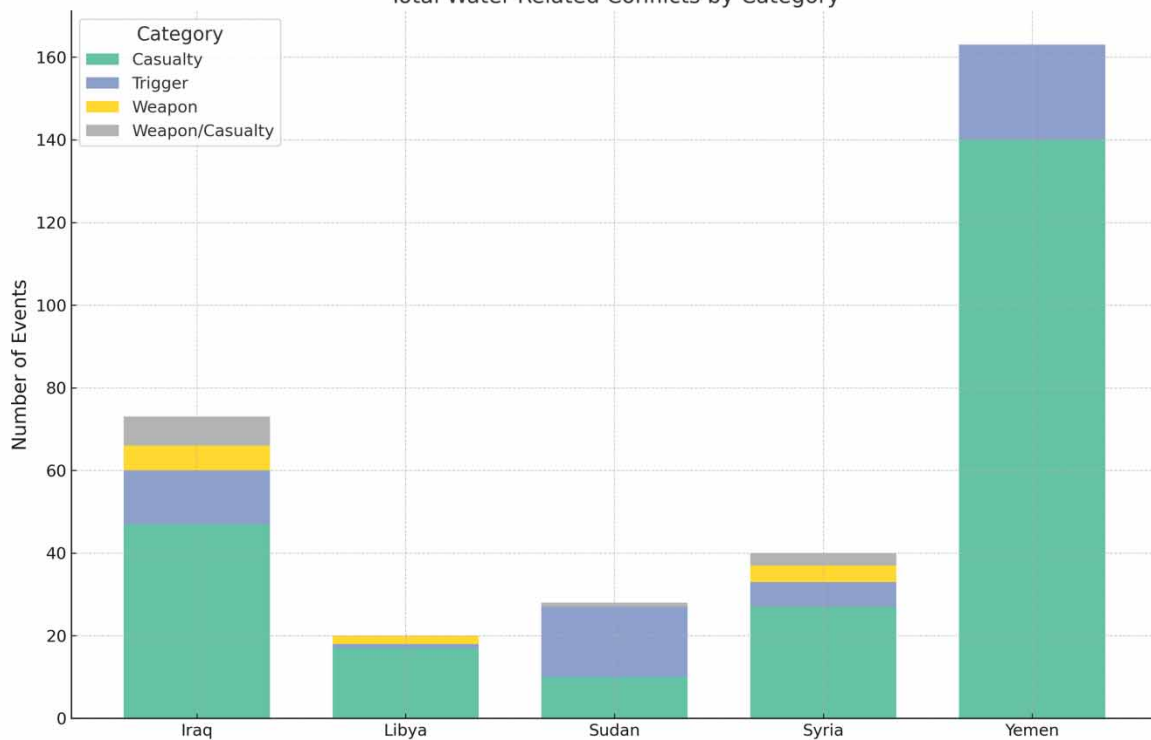
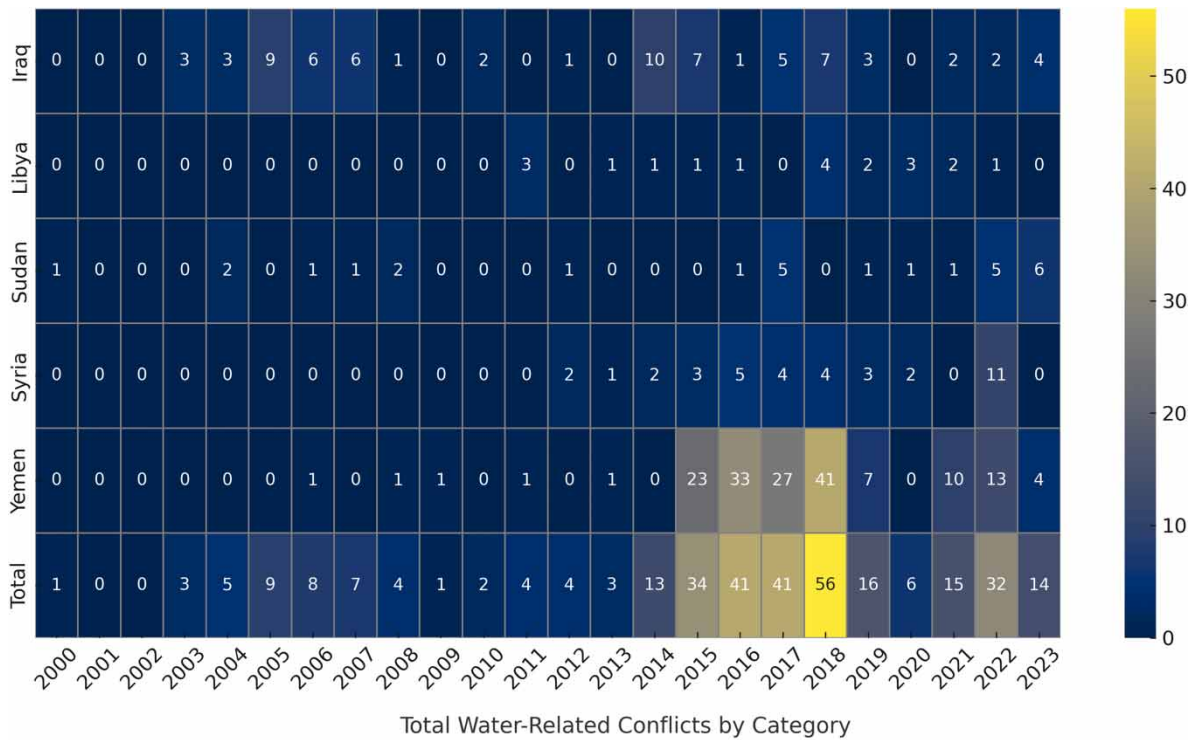


Figure 2 | Statistics on MENA military conflicts involving water visualized by the authors based on the data on water-related conflicts were sourced from the Pacific Institute's Water Conflict Chronology database (Pacific Institute 2024), covering the years from 2000 through 2023: heatmap of water-related events across five conflicted MENA countries (upper); bar chart categorizing the total number of events by the nature of water role (lower).

illustrate how disputes over water resources can ignite broader conflicts among opposing groups. Scarce water resources and competition for them can escalate internal conflicts within nations, leading to violent confrontation. In several MENA conflicts, water has been wielded as a weapon through tactics such as restricting access, diverting flow, contaminating water, or destroying infrastructure and water sources. This often includes

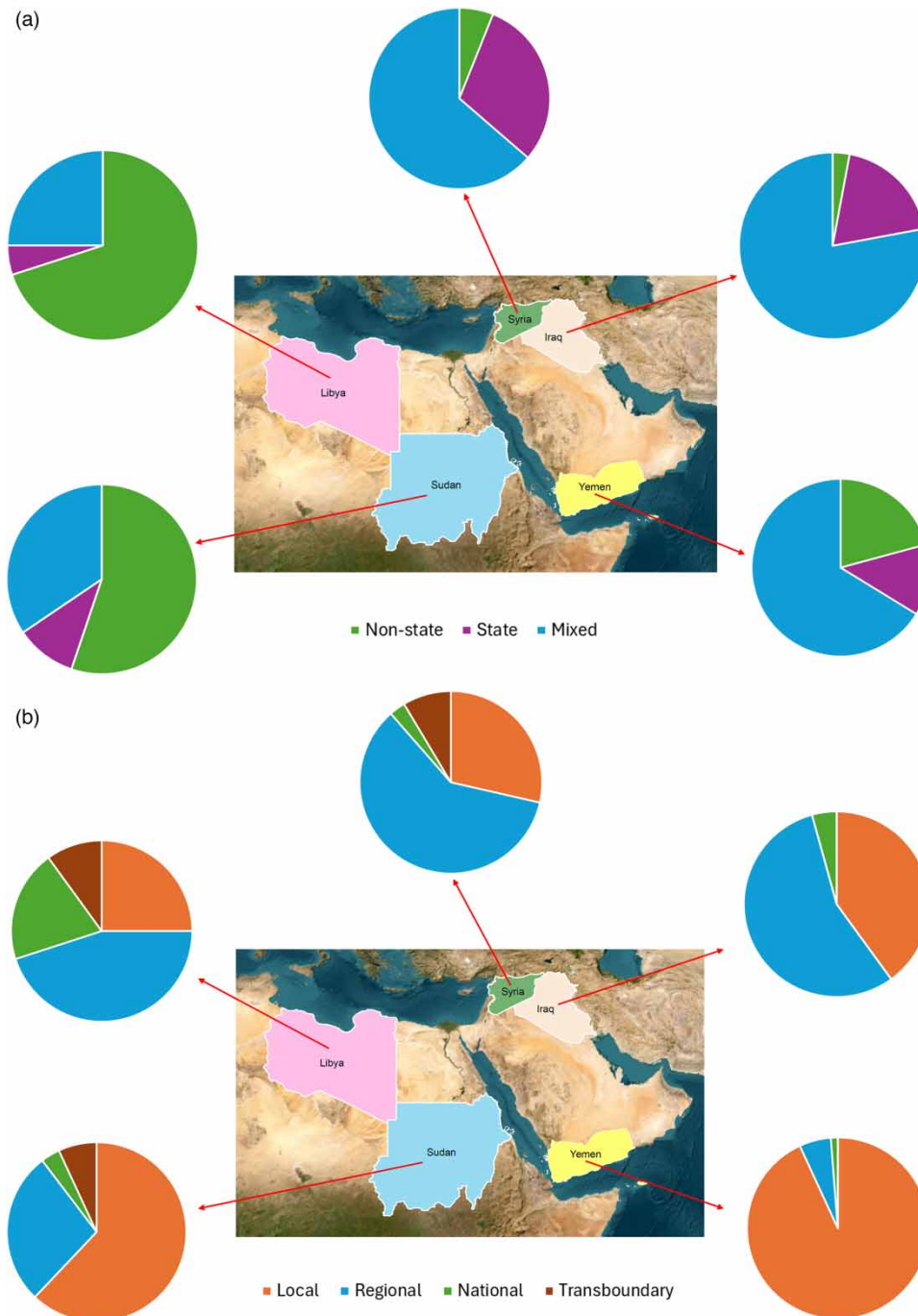


Figure 3 | (a) Statistics of the actors (non-state, state, and mixed) of the conflicts analyzed in the current research for the period from 2000 through 2023. (b) Statistics of the scale (local, national, and transboundary) of the conflicts analyzed in the current research for the period from 2000 through 2023.

direct attacks on water facilities and infrastructure or interference with water supply systems. The destruction of critical water infrastructure during conflict led to severe consequences on civilian populations, making water itself a casualty of warfare in these situations.

Water's role as a trigger for conflict is evident in MENA, especially in Sudan, which has experienced the highest number of conflicts triggered by water disputes ($n = 17$). This suggests that water scarcity and limited water resources significantly influence the dynamics of water-related conflicts within the country. This probably stems from competition over scarce water resources among various groups and regions. Documented evidence

shows that water scarcity has fueled violent confrontations among different groups (e.g. farmers and pastoralists) within the countries, further worsening internal instability.

Water as a weapon in conflict is clearly demonstrated by notable instances in MENA, particularly in Iraq ($n = 6$) and Syria ($n = 4$), indicating the strategic importance of water control in these countries' conflicts. Despite having the lowest frequency overall ($n = 12$) compared with the other two categories, i.e. trigger and casualty, these occurrences have resulted in serious harms on civilian populations and infrastructure. In both countries, conflicted parties have repeatedly employed water as a weapon by intentionally flooding areas and demolishing dams, resulting in widespread flooding and disruption of civilian life, infrastructure, and livelihoods. In one single case between January and April 2014, controlling the Falluja dam in Iraq and its operations by the Islamic State has resulted in flooding vast lands resulting in 12,000 families lost their homes and 200 km² of farmland damaged (Gleick 2019).

Water as a casualty of conflict is pronounced in the region, with Yemen witnessing the highest number of such cases ($n = 140$), representing over half of the total ($n = 241$) in this category among the five nations. This indicates the particularly destructive nature of conflicts in Yemen to water systems and infrastructure. The violence in Yemen's capital, Sana'a, in 2011 resulted in acute shortages of water and electricity, leading to the over-extraction of groundwater and depletion of aquifers. Furthermore, the catastrophic collapse of the Derna Dam in Libya in September 2023, triggered by a severe storm, underscores the consequences of inadequate maintenance amidst political upheaval. This event led to devastating floods, some of the most severe in recent memory.

3.3. Impacts beyond water availability

Conflicts exacerbate water contamination, for instance, through the breakdown and deterioration of water supply and sanitation systems in Iraq, posing significant health risks (Todd 2024). Yemen experienced the worst cholera outbreak in modern history due to the deterioration of its sanitation system under the ongoing political unrest and armed conflict. One million cases (Dureab *et al.* 2019) and thousands of deaths (Ng *et al.* 2020) had been reported between late 2016 and March 2018. Similarly, in the Gaza Strip, the destruction of sewage treatment plant has severely compromised water quality, leading to a high incidence of waterborne illnesses. As of 2018, around 93% of the groundwater in the strip was considered unsuitable for human consumption (Al-Hindi *et al.* 2021).

Natural ecosystems and habitats of living organisms are disrupted by infrastructure destruction and water source contamination, which threatens not only biodiversity but also food security. Water scarcity in Sudan has been made worse by prolonged hostilities that have resulted in substantial environmental degradation, including soil erosion and deforestation (Mohamed *et al.* 2016). Agricultural operations in the main irrigated and rainfed schemes in central Sudan are disrupted by conflicts, which exacerbates food insecurity and economic instability in the country.

The projected increase in water scarcity across river basins is likely to surge significantly due to pollution, mostly from agricultural and urbanization activities and practices (Wang *et al.* 2024). The MENA region's political unrest and continuous conflicts may make the condition of many water sources – which are already plagued by concerns of scarcity and contamination – even worse. The release of pollutants during armed conflicts would further compound existing challenges, compromising the quality of water in crucial rivers and aquifers. Apart from affecting agricultural yields and human health, this degradation will destabilize ecosystems already strained by climate change and other stressors.

3.4. Concentric circle transformation (CCT) framework

Water has traditionally been used as a weapon, a trigger for war, and a casualty in the MENA region with devastating implications. Effective strategies are, thus, imperative to protect water systems in the MENA region and mitigate the severe implications of conflicts over water. In the short term, addressing water-related conflicts requires immediate interventions throughout the region. For instance, increasing humanitarian aid to Yemen to ensure access to clean water is imperative. Strengthening the enforcement of international laws to safeguard water systems during conflicts is vital to reduce casualties and mitigate damage to infrastructure, particularly in Iraq, Syria, and Yemen. Enhancing availability and accessibility to improved water resources and establishing mechanisms for conflict prevention and resolution are for Sudan to avert further bloodshed.

In the long term, a comprehensive framework would be necessary for the MENA region's water future to boldly change from being a primary cause of conflict, weapon and casualty in conflicts to a major pillar in promoting peace.

Therefore, we present a concentric circle transformation (CCT) framework, a flexible and adaptable paradigm, with three different levels of strategies designed to maximize and promote the water-peace nexus's synergies. Each circle denotes a different degree of strategy. The CCT framework is organized around foundational strategies (FS) at the core, supportive strategies (SS) in the middle, and expansive strategies (ES) forming the outermost layer (Figure 4).

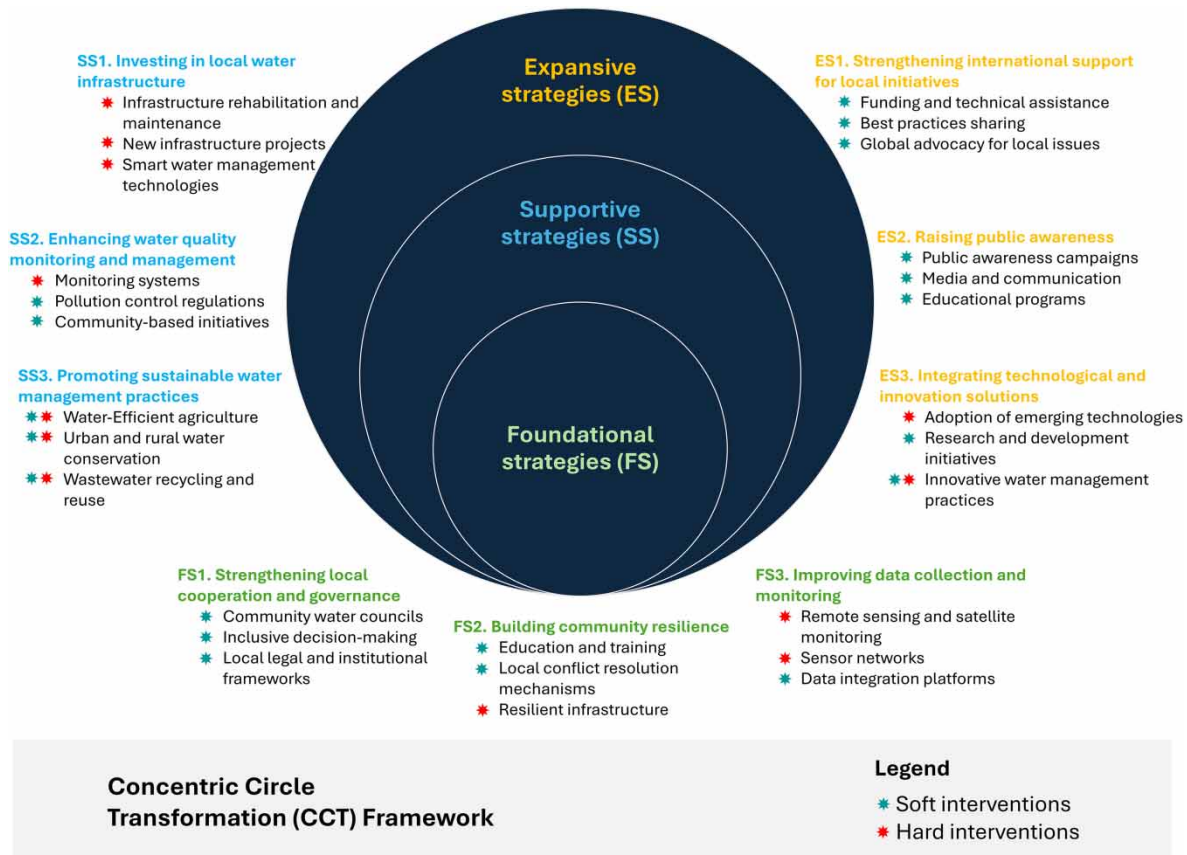


Figure 4 | Concentric circle transformation (CCT) framework for harnessing water-peace in the MENA region. It organizes strategies for transforming water-conflict into water-peace in the MENA region into three layers: foundational, supportive, and expansive strategies.

To foster and promote shift from water-conflict to water-peace, the CCT interventions can be divided into two main categories: soft interventions and hard interventions. Soft interventions that promote collaboration and increase social resilience include raising public awareness, involving the community, and fortifying Water User Associations (WUAs). In order to physically safeguard water resources, hard interventions concentrate on building resilient infrastructure, such as subterranean pipelines and robust water facilities. While numerous approaches may be used to reduce water scarcity and safeguard water infrastructure, these approaches can potentially work in concert in a number of ways. Combining these strategies maximizes the potential of the water-peace nexus synergies, tackles current issues while establishing a basis for long-term stability and resilience to climate change, and makes it possible for water to serve as a catalyst for cooperation and regional conflict resolution.

Foundational strategies (core circle) serve as the cornerstone for converting water-conflict into water-peace. Robust frameworks and inclusive decision-making processes are ensured through strengthening local governance and cooperation. Communities can better manage their resources when they have robust infrastructure, such as water delivering and treatment systems, early warning systems, dispute resolution mechanisms, and proper education. For well-informed decision-making and resource management, accurate and timely data collection and monitoring are essential.

Supportive strategies (middle circle) offer the necessary infrastructure and systems required to support the core strategies. Mobilizing financial resources into water infrastructure guarantees that local communities have the physical resources required for efficient water management. Improving the management and monitoring of

water quality supports the safety and sustainability of these resources. Encouraging environmentally responsible and sustainable local water management practices promotes effective and sustainable water use.

Expansive strategies (outer circle) build upon and intensify the effects of the foundational and supportive strategies. Strengthening international support for local initiatives brings in additional resources and expertise. Raising local public awareness ensures that the knowledge on best practices is shared and community is informed and engaged in sustainable water management practices. Integrating cutting-edge technological and innovation brings in creative solutions to support water management, conflict resolution, and sustainability efforts.

It is important to understand that, in contrast to technological developments in water management, public knowledge, community participation, and dispute resolution procedures play a fundamentally different role. Building trust, encouraging collaboration, and averting conflicts by communication and understanding are the main goals of public awareness campaigns and conflict resolution techniques. These interventions are crucial for both community-level resilience and rapid conflict de-escalation, especially in high-tension settings. These soft actions help to maintain social stability over the long run by establishing the importance of water as a common resource.

On the other hand, tackling the structural and technological difficulties of water management in areas that are prone to violence requires strong infrastructure, remote sensing tools, and early warning systems. By guaranteeing dependable access and effective usage, these hard interventions not only improve water security but also prevent water resources from being targeted or used as weapons during conflicts. By lessening the vulnerabilities that frequently lead to water-related conflicts, investing in such systems lays the groundwork for lasting peace.

Water disputes in MENA can be lessened by promoting and putting these interventions, among others, into action. Building with water for peace in mind will reduce tensions and advance harmony in addition to ensuring that everyone has equitable access to drinkable water, increasing agricultural productivity, and improving overall health. By acting proactively, the region can lessen the negative effects of armed and political conflicts on its essential and limited water resources, giving its population a more stable and secure future. Making water a pillar of stability is essential to MENA's continued development and security.

3.5. Viability illustration of the CCT framework

We examined certain significant water-related conflicts in Sudan, Libya, Iraq, Syria, and Yemen to demonstrate how the CCT framework can foster and promote a water-peace paradigm. To overcome governance shortcomings, prevent resource weaponization, and alleviate water scarcity, the CCT incorporates foundational, supportive, and expansive strategies.

(i) *Water conflicts between pastoralists and farmers in Darfur, western Sudan*

Conflicts between farmers and pastoralists over limited water resources in Darfur, Sudan, show how rivalry may turn violent, particularly during dry seasons. By guaranteeing equitable water distribution, fundamental interventions like bolstering WUAs aid in conflict resolution and foster collaboration. While early warning systems can stop disputes from getting worse by informing these groups of forecasts of climate conditions, enhancing preparedness, supportive strategies concentrate on improving water availability, such as building reservoirs and rainwater collection, have the potential to lessen resource rivalry. By educating communities and encouraging cooperation, expansive strategies, such as public awareness campaigns on sustainable water use, can ease tensions. When combined, these strategies can lessen disputes over water and promote regional stability.

(ii) *Water pollution crisis in Basra, southern Iraq*

A clear illustration of how environmental deterioration can spark conflict and intensify social unrest is the 2018 Basra, Iraq, disaster, in which tens of thousands of people were ill due to polluted drinking water. Widespread demonstrations that became violent were ignited by the fundamental problems of poorly run water systems and excessive salinity. The CCT provides multiple ways to reduce these root causes. Enhancing water management by giving local water associations the authority to guarantee fair distribution and upgrade infrastructure is one of the foundational strategies. While investing in strong water purification systems might reduce health hazards, supportive strategies on deploying mobile water quality monitoring equipment to identify contamination early is a crucial intervention. By encouraging regional cooperation and trust, expansive strategies like cross-border cooperation in managing shared water resources might stop contamination occurrences of transboundary

nature in the future. Furthermore, real-time solutions can be obtained by remote sensing for water quality monitoring, which lowers the likelihood of future emergencies.

(iii) *Weaponization of water in Syria*

The destructive conflict in Syria has provided a clear example of how water can be used as a weapon for tactical advantage. The intentional targeting of water resources to control territory and populations is demonstrated by events such as the 2014 restriction of water supplies to Wadi Barada and the 2017 flooding of Aleppo communities. The CCT provides a methodical way to lessen these effects. In order to stabilize water distribution and discourage its use in conflict, foundational strategies would place a high priority on reestablishing local councils, implement legal protections that classify water infrastructure as neutral, and establish community-led water management systems. Investing in robust infrastructure, like subterranean pipelines, to shield water sources from deliberate harm is one supportive tactic. To deter the use of water as a weapon, extensive strategies concentrate on utilizing public awareness campaigns and enlisting the help of reliable community leaders. It is also crucial to incorporate international legislation into the plan. The Geneva Conventions, which protect resources necessary for civilian survival, are broken when civilian water infrastructure is intentionally targeted. By guaranteeing responsibility and fostering long-term stability and resilience, the enforcement of these international legal frameworks in conjunction with technological cooperation can improve the conservation of water resources.

(iv) *Attacks on water infrastructure in Yemen and Libya*

The devastating political and security turmoil in Yemen and Libya has severely damaged water infrastructure, depriving millions of people of access to clean water. The 2017 airstrike on power lines in Dhamar and the 2016 attacks that cut off water to around 20 million people in Yemen show how crucial infrastructure has been lost to conflict. The CCT suggests a variety of strategies to minimize risks on water resources. Establishing local water committees to oversee shared wells, resolve disputes, and protect water sources is one of the fundamental interventions. To lessen reliance on delicate centralized systems, supportive strategies emphasize rainwater collection and the development of other water sources. Leveraging the power of sensor technologies that can monitor water networks and identify damage early, ensuring prompt repairs, expansive strategies make use of international cooperation to mobilize financial, technological, and human capacity support. Yemen and Libya can lessen the effects of violence on water infrastructure by strengthening infrastructure resilience and empowering local communities.

4. CONCLUSION

Water has become a source of conflict and instability in the MENA region due to an extraordinary water crisis that has been made worse by socioeconomic, political, and climatic factors. As a result of the deliberate and undeliberate destruction of water infrastructure and manipulation of water supplies during the conflicts in MENA, clean water access has become scarce for many people. This severe scarcity exacerbates humanitarian crises, leading to population displacement and adding strain to already fragile socioeconomic structures in numerous MENA nations. Predictions indicate a rise in the likelihood of water-related conflicts as anthropogenic pressures and climate change persist (Unfried *et al.* 2022; Kåresdotter *et al.* 2023), further diminishing water supplies. Consequently, there is a growing demand in MENA for coordinated, enduring solutions to address these pressing issues. A crucial step toward a water-secure future is understanding the dynamics of the water-conflict nexus to propose appropriate intervention for water systems safeguarding. This essential knowledge is helpful to construct a transformation pathway from water-conflict to water-peace in this region.

The research revealed how water is increasingly being weaponized, manipulated, and impacted in MENA, especially in nations like Iraq, Libya, Sudan, Syria, and Yemen. We highlight the urgent need for an integrated strategy to transform water-conflict to water-peace narrative by thoroughly analyzing these dynamics. Examples from this study demonstrate how water excess as well may be abused and turned into a weapon, in addition to conflicts connected to water scarcity.

The CCT provides a framework that divides tactics into foundational, supportive, and expansive strategies to solve this urgent problem. The main goals of foundational strategies are to ensure community involvement, data-driven decision-making, increase governance, and construct strong infrastructure. Financial investments, regional collaboration, and sustainable water management techniques are the main focuses of supportive

strategies. To increase the impact of peace-driven water management activities, expansive strategies focus on public awareness, technology advancements, and international collaboration. Our framework is scalable and context-sensitive and can be tailored according to the case specifics by addressing fundamental needs, offering supportive measures, and growing through global cooperation and technical advancements.

The CCT offers a methodical and flexible way to turn disputes over water into chances for peacebuilding. Both soft and hard interventions may be used. These interventions are not meant to be an exhaustive list, but they can offer some insight on what might be done in each specific case. Each case should be handled differently, considering the particular socioeconomic circumstances that are currently in place as well as the elements that are contributing to the conflict. In order to develop a balanced strategy that may optimize the potential of the water-peace nexus and transform water into a pillar for long-term peace and collaboration in conflict-prone areas, we stressed integrating hard and soft interventions. By addressing the underlying causes of water-related disputes, this all-encompassing strategy guarantees that actions are both proactive and reactive.

To conclude, we can reduce the likelihood of conflicts involving water, minimize their impact when happen, and advance regional stability over the long run by putting these multi-layered strategies into practice. Even if our framework tackles a lot of MENA necessary issues regarding water-peace transformation, there are a lot of barriers on the way, including funding, political will, and social support that need to be addressed. These limiting factors, and others, if addressed, have the potential to accelerate the adoption and implement the suggested strategies toward water-peace transformation in MENA.

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DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories. Aqueduct 4.0 Database: <https://www.wri.org/aqueduct> Water Conflict Chronology: <https://www.worldwater.org/conflict/map/>

CONFLICT OF INTEREST

The authors declare there is no conflict.

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