A social-ecological systems perspective on the impacts of armed conflict on water resources management: Case studies from the Middle East

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ABSTRACT

Armed conflicts disrupt social, environmental and economic processes. This includes water resources management and the provision of water services, with numerous implications for human security and environmental sustainability. Such impacts go beyond direct, immediately visible effects and can have far-reaching, long-term consequences. However, the understanding of these indirect conflict impacts in different social and political contexts is still limited. In order to address this knowledge gap, we build on the social-ecological systems framework to differentiate between direct and indirect conflict impacts and to analyze their effects on the water system. We then apply the framework to map direct and indirect impacts of armed conflict on water resources management, using empirical data from eleven cases in Iraq, Syria, Palestine and Yemen. This allows us to identify pathways in which conflict impacts are propagated through the water system. The results show the central role of financial mechanisms in upholding water resources management throughout conflict and the importance of enforcing international humanitarian law on the protection of civilian infrastructure. They also highlight the value of system-based approaches in revealing cumulative effects that can reinforce conflict impacts within the system, and in identifying potential obstacles for coping strategies employed by local populations throughout the conflict.

1. Introduction

Armed conflicts shape and disrupt social-ecological systems, and weaken their capacity to meet the basic needs of local communities (Barnett, 2006; Ingalls & Mansfield, 2017). Impacts of conflicts on water systems are particularly relevant for human security, as they can negatively affect other basic needs, such as public health (Ghobarah et al., 2003) and livelihoods (Weinthal & Sowers, 2019). Due to climate change, many conflict-affected countries, particularly in the Middle East and Africa, will further suffer from reduced water availability over the course of the 21st century. When water resources management is undermined by armed conflict, local populations lose a key climate adaptation strategy (ICRC, 2020; Vivekananda et al., 2014). The combination of violence, diminished livelihoods and insufficient climate adaptation capacity drives involuntary displacement, and long-term implications on human security can deter displaced populations from returning after the conflict ends (ICRC, 2020; Morales-Muñoz et al., 2020; UNHCR, 2019). The deterioration of water systems during armed conflict therefore has far-reaching and long-term consequences, both within conflict areas and beyond.

International humanitarian law prohibits the intentional attacks on water facilities that are essential for water service provision to civilian populations, and on dams or dikes that could lead to large-scale flooding if damaged. It also contains provisions on the protection of the environment in armed conflict, and requires military decision-makers to take possible collateral damage to civilian infrastructure and the environment into account under the principle of proportionality (Tignino, 2016). However, the implementation of these provisions faces multiple challenges, such as their applicability to intrastate conflicts and non-state armed groups, and the lack of effective enforcement mechanisms to deal with violations (Gleick, 2019). The assessment of possible collateral damages is complicated by the lack of adequate mechanisms to estimate civilian and environmental impacts of military operations, including on the water system (Sowers et al., 2017).

Conflict impacts on water systems go beyond the direct damage to physical infrastructure and human life. While such direct impacts are easier to monitor and quantify, indirect impacts of armed conflict can cause a higher civilian death toll, for instance due to malnourishment.

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and diseases (Wise, 2017). The assessment of both direct and indirect impacts is therefore needed (Al-Saidi et al., 2020; Weinthal & Sowers, 2020). However, the conceptual understanding and empirical evidence on such indirect impacts and knock-on effects is limited (InterAction & Stanford Health Policy, 2020; Zeitoun et al., 2017).

In order to address this knowledge gap, we use a systems approach to differentiate between direct and indirect conflict impacts and to study their effects on water resources management. We build on the social-ecological systems (SES) framework to analyze water systems in conflict settings and to map conflict impacts on different system components. While the SES framework accounts for the social, economic and political context of the system (McGinnis & Ostrom, 2014; Ostrom, 2009), it has rarely been applied to settings of political instability. We thus provide new conceptual and empirical insights on how SES function within the political context of armed conflict, and how system and context interact with each other.

Given the novelty of the conceptual approach, our goal in this paper is not to draw definitive causal conclusions on conflict impacts and system interactions. Instead, we aim to provide the first qualitative insights based on empirical data from multiple cases in four conflict-affected countries in the Middle East, namely Iraq, Palestine, Syria and Yemen. This first systematic assessment focuses on the Middle East for two reasons: First, the prevalence of political instability and armed conflict across much of the region provides ample examples of conflict-related water management challenges (Borgomeo et al., 2020). Second, the Middle East has received more attention than any other region within the scientific literature on water management in conflict settings (Schillinger et al., 2020), allowing us to build on previous studies in addition to our own empirical data. Insights from the Middle East can serve as a starting point for future large-N, quantitative research on the global scale.

Throughout the paper, we define an armed conflict as “a conflict in which the conflict parties resort to armed force or violence, leading to a situation of protracted confrontation which results in damage to property or human life” (Schillinger et al., 2020, p. 2, based on ICRC, 2008). Such a conflict may involve state or non-state actors, and take place between states or within the territory of one state.

In this paper, we first develop the framework for our analysis of water systems in armed conflicts. Then, we describe our methodology and data collection strategy. In the main section of the paper, we apply the framework to empirical data to identify pathways in which conflict impacts are propagated through the water system. Next, we discuss our results with regards to new insights on direct and indirect conflict impacts, the role of feedback loops and the influence of specific conflict conditions. The final section concludes the paper with key messages, implications for the humanitarian sector and directions for future research.

2. Analytical framework of water systems in armed conflict

2.1. Systems thinking and armed conflict

Conceptually, a system consists of interconnected components which, as a whole, serve a certain purpose (Ackoff, 1994; Meadows, 2008; Stephens & Hess, 1999). Systems thinking is an effective tool to understand the complexity that results from the interconnectedness of the components, particularly in the case of the human-environment interactions that characterize natural resources management. It can also be used to identify system vulnerabilities to external shocks as well as opportunities for positive change (Anderies et al., 2004; Holling, 2001; Richmond, 1993; Williams et al., 2017). In the context of armed conflict, systems thinking provides a useful approach to assess conflict impacts on different system components and to identify possible coping strategies.

Systems thinking particularly helps to analyze how interactions within the system and with related systems can propagate shocks, in this case conflict impacts (Rinaldi et al., 2001). Interactions between system components may form feedback loops that either reinforce or balance shocks to the system (Arnold & Wade, 2015; Meadows, 2008; Richmond, 1993; Walters & Javannick-Will, 2015). Such feedback loops are particularly relevant to understanding conflict impacts, as they can reinforce negative trends within the system and lead to vicious cycles that can cause lasting damage to the system (Sadoff et al., 2017).

In this paper, we use a systems approach to differentiate between direct and indirect conflict impacts, and to operationalize the terms with regards to system interactions. We define a conflict impact as ‘direct’ when a conflict-driven shock causes a disturbance in the given system component or interaction (Fig. 1a). We define a conflict impact as ‘indirect’ when the disturbance in question is caused by another conflict-driven disturbance in an interconnected system component (Fig. 1b), or by an interaction with a related system (Fig. 1c). Direct and indirect impacts are closely linked, and a direct impact can cause numerous indirect impacts depending on where in the system it occurs. This can lead to the propagation of conflict impacts across multiple systems or system components to produce a series of indirect impacts that are also referred to as ‘reverberating’ impacts (Sowers & Weinthal, 2021; Zeitoun & Talhami, 2016). Our definition of indirect impacts also includes coping mechanisms, as they occur in reaction to a conflict impact on a system component and lead to a change in system behavior.

2.2. Components of the water system

In order to apply our system-based definition of direct and indirect conflict impacts on water resources management, it is essential to use a water system model of interconnected components that reflects the environmental, social and political contexts of conflict-affected settings. We develop this water system drawing from the conceptual SES model by Anderies et al. (2004), which comprises four elements: 1) resource, 2) resource users, 3) public infrastructure, including both physical infrastructure and social capital in the form of institutional rules for the system, and 4) public infrastructure providers. We augment the model to a total of six components to incorporate relevant elements of conflict-affected settings. These changes are based on earlier studies on water resources management in fragile and conflict-affected settings, as outlined below and shown in Table 1.

This augmented model of water systems in armed conflict settings has three modifications to the original SES model. First, given the widespread damage to water and sewage facilities in armed conflict, we distinguish between physical infrastructure and institutions. The institutions component includes both the existing rules governing the water sector and their enforcement by relevant authorities, allowing us to account for changes in the institutional capacity of these authorities throughout the conflict (Donnelly et al., 2012).

Second, we analyze the operation and maintenance (O&M) of physical infrastructure as a separate component. Earlier studies identified several O&M challenges for water service delivery in conflict settings that go beyond direct infrastructure damage (Etienne & Nembrini, 1995; Pinera, 2012; Sikder et al., 2018; Zeitoun et al., 2017; Zeitoun & Talhami, 2016). This covers the operational capacity of both public and private water service providers, and the dynamics that can often be observed between them in conflict-affected settings (Pinera & Reed, 2009; Schillinger et al., 2020).

Third, we follow Zeitoun (2005)’s call for explicitly analyzing finances and other economic aspects of the water system in conflict settings, instead of treating them as a sub-category of operational or procedural issues. Conflict settings present unique challenges to economic planning and development, whose impacts on the water system should be accounted for (Barnett, 2006).

In addition to the components of the water system, we also consider

1 A diagram of the augmented water system model, including key interactions among the six components, can be found in the supplementary material.
interactions with related systems (Ackoff, 1994; Ostrom, 2007; Stephens & Hess, 1999). The water system interacts with multiple systems, such as agriculture, health, transport and land use. However, in the interest of limiting the scope of this paper, we focus on the interactions with the energy system. Electricity is a key prerequisite of modern water-delivery systems, for instance to power water and wastewater treatment plants, pumping stations, and desalination plants (Carrard et al., 2019; Porod et al., 2014; Younos, 2012). This makes the dependency on electricity one of the key vulnerabilities of the water system to shocks (Birkett, 2017; Etienne & Nembrini, 1995; FAO & World Bank, 2018; Zeitoun, 2005).

3. Methodology

We apply our analytical framework to conflict-affected water systems in the Middle East as a proof of concept and provide empirical insights on conflict impacts on different components of the water system. The empirical evidence originates from eleven cases across Iraq, Palestine, Syria and Yemen, which were selected to cover a variety of armed conflict contexts and water resource endowments. They include areas of both high and low intensity conflict, areas under state control and areas under the control of non-state armed groups, and areas under different degrees of economic embargos or sieges. This diversity of cases allows us to map a comprehensive set of conflict impacts on water systems and identify similarities and differences across different settings. Table 2 provides an overview of the cases. Detailed contextual information on all cases can be found in the supplementary material.

The case studies are based on primary and secondary data collected between December 2017 and March 2021. All case studies included secondary data from publicly available documents by governmental and non-governmental actors in each country and international organizations, as well as internal documents and survey data made available by relevant organizations. Primary data was collected via semi-structured interviews with stakeholders from local and national authorities, public and private water service providers, civil society organizations, international organizations and research institutes for case studies in Iraq, Palestine and Yemen, and by field observations in Palestine.

Note 2: Interview data for Yemen was collected by Musaed Aklan and Hanan Bahar in the context of a different research project in 2017 and 2018 and kindly shared for inclusion in this study.
Table 2
Overview of cases and relevant conflict situations.

| Case location | Study period | Conflict context | Conflict intensity |
|---------------|--------------|------------------|--------------------|
| Mosul, Iraq   | 2014-2017    | City occupied by ISIS between June 2014 and July 2017, before being re-captured by Iraqi military in extensive ten-month military operation | High |
| Kirkuk, Iraq  | 2005-2021    | Disputed territory between the Government of Iraq and the Kurdistan Regional Government, with local power dynamics influenced by the rise and fall of ISIS in Iraq | Low |
| Ramadi, Iraq  | 2013-2016    | City occupied by ISIS between May and December 2015 | High |
| Susiya, Palestine | 1995-2021 | Village located in Area C under Israeli administration, with demolition orders pending | Low |
| Ras al-Auja, Palestine | 1995-2021 | Bedouin community located in Area C in the Jordan Valley under Israeli administration | Low |
| Gaza, Palestine | 2007-2021 | Hotspot of armed violence in the Israeli-Palestinian conflict, and controlled by Hamas as de-facto authority | High |
| Aleppo, Syria | 2012-2016 | City divided into a government-controlled western part and an opposition-controlled eastern part between August 2012 and December 2016, with continuous fighting along the frontlines | High |
| Eastern Ghouta, Syria | 2012-2018 | Opposition-controlled area under siege by the government between April 2013 and April 2018 | High |
| Sana’a, Yemen | 2014-2021 | City under control by Houthis movement since September 2014 and regular target of airstrikes by the anti-Houthi coalition | High |
| Hudaydah, Yemen | 2014-2021 | City under control by Houthis movement since October 2014, with pro-government military operations attempting to re-capture the city since mid-2018 | High |
| Aden, Yemen | 2015-2021 | City contested between the Yemeni government and southern secessionist forces | High |

*a* Study periods refer to the period examined in each case study, which does not necessarily cover the entire conflict. Supplementary material includes details on the start and end point of each case.

*b* Conflict intensity is rarely consistent. Cases of high conflict intensity may also include periods of low intensity, but are characterized by repeated outbreaks of high intensity fighting.

We placed great emphasis on the triangulation of data, since data collection in conflict settings is difficult and individual pieces of data might be unreliable (Barakat et al., 2002; Cronin-Furman & Lake, 2018). Within each case study, data was, as much as possible, collected and verified from different, independent sources. Conflict impacts were included in the analysis only if they could be identified in multiple cases, or if there was strong evidence in one case. The conflict impacts presented in this paper should therefore not be seen as an exhaustive list, but as the first step towards the systematic analysis of relevant processes.

4. Conflict impacts on water system components

The following sub-sections present empirical insights on how armed conflict affects each water system component directly and indirectly. We provide illustrative examples from the cases to show different facets of a specific conflict impact. Examples are chosen based on the strength of evidence for the incident in question and the added illustrative value. A comprehensive list of all conflict impacts and the corresponding cases can be found in the supplementary material. Each sub-section additionally includes a figure that summarizes all individual conflict impacts on the system component at hand, distinguishing between direct and indirect impacts. Like the six system components, these figures should be considered as parts of a whole and viewed in combination with each other.

4.1. Water resources

We identify three main categories of conflict impacts on water resources: 1) pollution of water resources, 2) limitations to the accessibility of water resources, and 3) impacts on the availability of unconventional water resources (Fig. 2).

4.1.1. Pollution of water resources

There is no shortage in sources of pollution related to war, however, water pollution due to insufficiently treated wastewater is particularly common (Faour & Fayad, 2014; Mason et al., 2011; Weinhäupl & Sowers, 2019; Zeitoun et al., 2014). Such water pollution has two main causes. First, damage to sewage networks, pumping stations and wastewater treatment plants causes leakages prior to treatment. This was reported, for instance, following the destruction of infrastructure in Aleppo (REACH, 2015), Eastern Ghouta (SAMS, 2015) and Aden (GIZ, 2018a). Second, electricity shortages in conflict settings limit wastewater treatment to basic methods, such as sedimentation. With limitations on the operation and capacity of treatment facilities, untreated or insufficiently treated wastewater is discharged directly into the environment. Examples for this include the Gaza Strip, where untreated wastewater is pumped into the Mediterranean Sea and local wadis (UN OCHA, 2020) and Ramadi and Mosul, where untreated and insufficiently treated wastewater is discharged into the Euphrates and Tigris rivers, respectively (UN-Habitat, 2019; UN-Habitat, 2018).

Local issues of pollution can be exacerbated during times of conflict when environmental regulations are not enforced as strictly as they would be during times of peace. Kirkuk, for instance, has suffered from widespread industrial pollution as the local oil industry has been effectively unregulated for decades while the governorate’s status remains disputed (Oxfam, 2017). The pollution of surface waters with waste, a problem in many Middle Eastern countries, is exacerbated by the destruction of infrastructure and the subsequent dumping of debris in the environment, often alongside rivers (UNEP, 2017). The lack of institutional capacity to enforce regulations against such pollution is coupled with limited funds for clean-up.

4.1.2. Accessibility of water resources

Mobility constraints during conflict directly affect the accessibility of water resources. Such constraints can result from security concerns, when areas of active fighting should be crossed, or checkpoints controlled by conflict parties. Inhabitants of villages north of the IS-controlled area surrounding Ramadi would usually wait until night to go down to the Euphrates River and nearby water installations under the cover of darkness, out of fear of getting shot by ISIS fighters.

Large-scale infrastructure such as dams can be used by conflict parties to control water resources to intentionally limit the access for downstream users or to release large amounts of water to cause flooding in downstream areas. Numerous examples exist on this ‘weaponization’

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3 Interview with a local government official in the Gaza Strip (September 2018).
4 Interviews with a government official in Mosul and a government official in Ramadi (February 2021).
5 Interviews with a government official in Mosul, a government official in Ramadi and a representative of a local civil society organization in Ramadi (February 2021).
6 Interview with a local academic in Ramadi in (February 2021).
of water infrastructure in the conduct of ISIS in Iraq and Syria (King, 2015; von Lossow, 2016), including in Ramadi, which was affected by ISIS’ control over the local Ramadi Barrage (Alkhshali & Smith-Spark, 2015; Middle East Monitor, 2015) and their control over the Tabqa Dam further upstream in Syria (Paletta, 2016). The manipulation of river flows also affects water quality, as a lower flow increases the concentration of pollutants and the water accumulated upstream of the dam can carry pollutants from flooded land into the river.

In protracted, long-term conflicts, access to water resources can also be restricted by conflict parties that introduce and enforce regulations for areas under their control. In ‘Area C’ of the West Bank, the Israeli civil administration uses diverse types of regulations to limit or prohibit the access of Palestinian communities to different types of water resources. Physical access to surface water resources, such as springs or the Jordan River, is restricted by the demarcation of land as closed military zones with restricted access or as nature reserve with limitations on infrastructure development and permitted economic activities (Ma’an Development Center, 2014). Access to groundwater resources is limited by strict regulations on water infrastructure development, creating significant obstacles and delays to the construction of new wells in Area C (EWASH & Al-Haq, 2011; Selby, 2013).

The overextraction of groundwater in the absence of effective regulatory oversight during conflict can impede water access. This effect is particularly visible in the Sana’a Basin, where the groundwater table has been steadily dropping due to overpumping from unauthorized wells, leading to a decrease in water production quantities and an increase in water production costs as wells need to reach deeper to access the aquifer. While this had already been an issue prior to the conflict, its onset and the take-over of the area by the Houthi movement have intensified the problem (UNICEF & Oxfam, 2016).

4.1.3. Unconventional water resources

Unconventional water resources, such as treated wastewater, rainwater harvesting and desalinated seawater, can offer significant additional supply in water scarce regions like the Middle East. A decrease in the production capacity can therefore have severe implications for the overall water availability. As the large-scale production of unconventional water resources requires a large amount of electricity (Weinthal & Sowers, 2020), unreliable electricity access can severely obstruct the operation of facilities. Wastewater treatment and desalination plants in the Gaza Strip, for instance, have struggled to remain operational during a prolonged electricity crisis (UN, 2017). Damage to water facilities further aggravates the situation; in Yemen, both major desalination plants were destroyed in recent years (World Bank, 2020).

Small-scale, decentralized solutions that are independent from

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7 Interviews with a government official in Ramadi and a local academic in Ramadi (February 2021).
8 Interview with a local academic in Ramadi (February 2021).
9 Interview with a representative of a local civil society organization in Ras al-Auja (May 2020).
10 Interview with a government official in Ramallah (October 2018).
11 Interviews with a government official in the Gaza Strip (August 2018) and a representative of the public service provider in the Gaza Strip (September 2018).
4.2. Physical infrastructure

We distinguish four key ways in which armed conflict affects physical water infrastructure: 1) the destruction of existing water facilities and networks, 2) obstacles to the repair of damaged infrastructure, 3) limitations to the construction of new infrastructure, and 4) the development of informal infrastructure (Fig. 3).

4.2.1. Destruction of infrastructure

The use of explosive weapons during battle, particularly in urban areas with high infrastructure density, causes extensive damage to water infrastructure (Boer et al., 2020; Zeitoun & Talhami, 2016). Water and sewage networks are especially vulnerable as they are usually located underneath streets and can be damaged by the operation of heavy, armored vehicles and by airstrikes on road networks or vehicles. Furthermore, damage assessments of underground water networks usually cannot be conducted via remote sensing, as opposed to surface infrastructure. Repairing all damages to the water network, however, is an important step in the restoration of water services (UN-Habitat, 2017)12.

Infrastructure damage is particularly devastating for key facilities that form a bottleneck in the system. Examples of such impacts include the damage to the Khormaksar pumping station in Aden, which disconnected the Aden Peninsula’s sewage network from its wastewater treatment plant (UN-Habitat, 2020b) and the destruction of a water main in East Mosul which cut off water to half a million people during the Battle of Mosul (AJ Jazeera, 2016; Tawfeeq & Abdelaziz, 2016).

Active fighting is not the only cause of infrastructure damage. A perpetual lack of maintenance, misuse of equipment and intermittent power supply also wear down water facilities and cause lasting damage. While water infrastructure in Mosul and Ramadi suffered heavy damage during the battles to liberate both cities from ISIS, the provisional operation and lack of equipment maintenance under ISIS caused additional damage (UN-Habitat, 2016)13. In the Gaza Strip, intermittent electricity supply causes reduced equipment efficiency and increased rates of malfunction in water facilities, as repeated power cuts wear down equipment such as pumps, generators and control panels14.

4.2.2. Repair of damaged infrastructure

Both direct and indirect infrastructure damage is compounded by impediments to the repair process. Several factors can limit the access to damaged water facilities for repair crews, including security concerns due to active fighting, the location of the facility in territory controlled by an opponent, and access restrictions imposed by a conflict party. When the Al-Khafsa Water Treatment Plant near Lake Assad, the source of 90% of Aleppo’s water supply, was hit by an airstrike in 2015, access to the plant for repair work was complicated by the fact that the area was controlled by ISIS. Government engineers were eventually allowed to access and repair the plant under the supervision of the International Committee of the Red Cross (ICRC) after an agreement with ISIS was reached (Hourani & Adams, 2015; World Bank, 2017). A similar situation occurred in 2017, when the plant went offline due to a technical malfunction and IS did not allow repair teams to enter the facility (UN OCHA, 2017). International organizations like the ICRC also help facilitate access to water facilities within the ‘no go’ zone along the border between the Gaza Strip and Israel. Clashes along the border regularly further complicate access for repair crews15.

A lack of construction materials and equipment can significantly delay both the repair of damaged infrastructure and the construction of new infrastructure. Such lack of materials can be caused by a breakdown of the economy and thus local production, or by embargos or import restrictions that limit the access to ‘dual use’ materials, i.e., materials that can be used for both civilian and military purposes. Martin and Klawitter (2017) estimate that 70% of construction materials and other items required for the rehabilitation of water facilities in the Gaza Strip are considered as dual use items by the Israeli authorities and therefore difficult, if not impossible, to import.

4.2.3. Construction of new infrastructure

The construction of new large-scale infrastructure, to close capacity gaps or to replace outdated or destroyed facilities, rarely happens in conflict settings. When the security situation becomes stable enough for construction projects, planning and implementation are often hindered by a lack of funds or an unwillingness to spend available funds on water infrastructure investments. In Iraq, the budget of the Ministry of Water Resources, which includes funding for rehabilitation and construction of water infrastructure, was cut from USD 1.7 billion in 2014 to a mere USD 50 million in 2017 to allocate more funds to the fight against ISIS (UNEP, 2017; von Lossow, 2018)16.

Conflict-related regulations can obstruct the construction of new infrastructure, as previously mentioned in the context of limitations to the access to water resources in the Israeli-Palestinian conflict. In the West Bank, regulations by the Joint Water Committee17 and the Israeli Civil Administration have repeatedly been cited as major limitations to Palestinian infrastructure development (Selby, 2013; UNEP, 2020). While infrastructure development in the Gaza Strip is primarily restricted by the lack of access to materials (Martin & Klawitter, 2017), an Israeli permit is required for infrastructure projects close to the border with Israel, which can take years to obtain18.

4.2.4. Development of informal infrastructure

As public water infrastructure becomes dysfunctional due to damages and lacking repair or maintenance, local populations may construct their own small-scale infrastructure. In ISIS-controlled Mosul, neighbors came together to dig their own makeshift wells as water services started to deteriorate. While the water was visibly unsuitable for drinking, it was used for domestic purposes, including personal hygiene19. Neighborhood wells continued to be an important source of water throughout the time of ISIS control and during the Battle of Mosul (Tawfeeq & Abdelaziz, 2016; Zuccino & Solomon, 2017), and were the primary source of water for domestic uses in most of the city in the aftermath of

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12 Interviews with a local government official in Mosul and a representative of the public service provider in Ramadi (February 2021).
13 Interview with a local government official in Mosul (February 2021).
14 Interview with a representative of the public service provider in the Gaza Strip (September 2018).
15 Interviews with two local government officials in the Gaza Strip (September 2018).
16 Interview with a representative of a local civil society organization in Mosul (February 2021).
17 The Joint Water Committee was established as bilateral committee between Israelis and Palestinians in the Oslo Peace Process, tasked with water resources management in the West Bank. While both sides were supposed to be equal within the committee, critics have pointed out that the unequal power dynamics between Israelis and Palestinians have turned the JWC into an Israeli tool of dominating water infrastructure development in the West Bank. See also Zeitoun (2007); Selby (2013).
18 Interview with a local government official in the Gaza Strip (September 2018).
19 Interviews with a representative of a local civil society organization in Mosul and a local government official in Mosul (February 2021).
the battle (Lafta et al., 2018). In Aleppo, a network of wells existed across the city before the conflict, but most of them had not been used for decades. Local populations restored them as a way to cope with the lack of public water supply (ICRC, 2015a; World Bank, 2017). In both cities, wells were usually outfitted with motorized pumps and required expensive fuel to operate. Water was rarely treated and not suitable for consumption.

4.3. Operation and maintenance

Armed conflicts affect the O&M of water service provision in four main areas: 1) availability of qualified staff, 2) access to consumables and spare parts, 3) lack of electricity and fuel to power water facilities, and 4) emergence of informal service providers to fill gaps in public service delivery (Fig. 4).

4.3.1. Staff availability and qualification

The prevailing security situation directly affects the availability of staff, who might flee from areas of high conflict intensity, sustain injuries or suffer from mental trauma (Etienne & Nembrini, 1995). Staff members might also be unable to reach their assigned duty stations due to security concerns or having to cross frontlines, such as in Aleppo, where the mobility between the eastern and western parts of the city was extremely limited during periods of high conflict intensity (UN-Habitat, 2014). By the time ISIS established control over Ramadi, most public sector employees had left the city, leaving it to ISIS to find staff to operate the key water facilities20. In Mosul, remaining public sector employees were given the choice to continue working under ISIS; some accepted, others were replaced by ISIS loyalists21.

As public utilities and governmental agencies face financial hardship due to the conflict, salaries are often not or only partially paid, which can push qualified staff members to look for other employment opportunities. When public sector salaries stopped coming in Sana’a, many employees turned towards the private sector where employment was much more profitable. Other local utilities in Yemen faced similar issues, particularly in areas not controlled by the Yemeni government (World Bank, 2020)22. Formal training opportunities for staff are also rarely available; an assessment of local utilities across Yemen showed that since the onset of the conflict, staff training programs have almost completely stopped due to a lack of funds (GIZ, 2018c).

4.3.2. Access to materials

Consumables such as water treatment chemicals are crucial for system operation, while spare parts are needed for both routine maintenance and repair to damaged facilities. Similar to construction materials, access to chemicals and spare parts is determined by local

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20 Interviews with a government official in Ramadi and a representative of the public service provider in Ramadi (February 2021).
21 Interview with a local government official in Mosul (February 2021).
22 Interview with a representative of the public service provider in Aden (January 2018).
production and available transportation routes, including restricted imports. Access to water treatment chemicals is particularly difficult, as many of them are considered dual use items due to their potential use as chemical weapons, most notably chlorine (Zanders, 2019). Restrictions on access to equipment, chemicals and fuel drive up prices, such as in Eastern Ghouta, where transport routes into the besieged area were limited to one highly regulated government checkpoint and smuggling tunnels controlled by different armed opposition groups (PAX & The Syria Institute, 2016; Turkmani et al., 2015; UN HRC, 2018).

4.3.3. Power supply

In most cases, insufficient electricity access is a key limiting factor for the operation of water facilities, and subsequently water service provision. Power outages usually result from damages to electricity infrastructure, fuel shortages, or insufficient operational capacity of the power utility. However, in some cases, electricity was also deliberately cut by conflict parties, for instance when the Iraqi government cut the power supply from the Mosul Dam to ISIS-controlled Mosul in 2015 (UN-Habitat, 2016)23. Later, during the Battle of Mosul, ISIS deliberately cut electricity to water facilities to interrupt water service provision to neighborhoods near the frontlines. This forced residents to move to other areas of Mosul under ISIS control, allowing ISIS to use these civilians as human shields during their retreat (Tawfeeq & Abdelaziz, 2016)24.

In the absence of reliable electricity supply, fuel-powered generators are commonly used to keep water facilities operational. However, fuel usually becomes a rare and expensive commodity in conflict areas, driving up the cost of water service provision. Additionally, generator malfunctions become a risk factor. Having difficulties to access fuel within the besieged Eastern Ghouta, communities devised creative solutions to ensure access to water from their wells. Next to hand pumps, some wells were outfitted with seesaws that children could play on while also pumping water (UN HRC, 2018).

4.3.4. Rise of informal service provision

As public water service provision deteriorates during the conflict, spaces open up for alternative, informal service providers. While regular water service provision via the municipal network continued in most parts of government-controlled western Aleppo, an extensive informal water market developed during the conflict in eastern Aleppo, including private actors and civil society organizations (UN-Habitat, 2014; World Bank, 2017). The existence of an informal water market prior to the conflict significantly improves the informal service capacity during conflict. An analysis of the water tanker market in Sana’a and Aden

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23 Interview with a local government official in Mosul (February 2021).
24 Interview with a government official in Mosul (February 2021).
during the Yemeni war showed that in Sana’a, where tankers were already commonplace to serve informal settlements before the conflict, informal service provision was much more structured than in Aden (Abu-Lohom et al., 2018).

Informal service providers play a vital role to fill the water supply gap during conflict, but there are concerns due to a lack of regulation regarding their operation. This pertains to both the quality of water and the price charged for water. The consequences are high prices for low-quality water, often excluding poor segments of the local population from access (DFID, 2019; Pinera & Reed, 2009; UNICEF & Oxfam, 2016).

4.4. Finances

As shown in relation to other system components, the cost of water service provision increases during conflict, particularly due to high fuel prices and the cost of repairs to damaged infrastructure. At the same time, public utilities often struggle with cost recovery and the payment of recurring expenses, including salaries and maintenance work, due to reduced monetary inflows. Focusing here on these inflows, we divide conflict impacts into two categories: 1) decreasing utility income due to high rates of non-revenue water or low bill collection rates, and 2) volatile financial support by external actors (Fig. 5).

4.4.1. Utility income

Conflict settings often report an increase in non-revenue water, i.e., water that is provided to the network, but is not billed to customers. Leakage from the damaged or neglected supply network and other water infrastructure is the main reason for this increase in non-revenue water. Dysfunctional water metering and water theft further exacerbate the problem. For instance, non-revenue water recorded by the utility increased from 41% in 2014 to 55% in 2017 in Aden (GIZ, 2018a), and from 35.3% in 2014 to 54.9% in 2015 in Hudaydah (Water and Environment Centre et al., 2017).

Bill collection rates are low in most conflict-affected areas, which can result from an insufficient capacity of the utility, especially in cases where billing and collection are done manually, or from the inability or unwillingness of customers to pay their bills. Municipalities in the Gaza Strip reported collection rates as low as 15% in 2018. In opposition-controlled eastern Aleppo, approximately 65% of residents did not pay their water bills in spring 2015. This was caused by not only a lack of means or willingness of the residents, but also the break-down of financial services, as there were no functioning banks from which customers could send transactions. The resulting income loss mainly affected the public utility, as private service providers generally charged in cash upon delivery (REACH, 2015).

While private water service providers seem to have fewer problems with bill collection, their customer base is restricted by the high price of service provision. On the one hand, this high price is due to additional costs of the service provision, e.g., to transport water from the nearest filling point to the customer. In Ras al-Auja, water costs 3.5 NIS/m³ at the local filling point, however, the water price increases to between 30 and more than 100 NIS/m³ for the community, depending on whether users have access to their own mode of transportation (GVC Italia & UNICEF, 2010). On the other hand, the lack of regulatory oversight on the informal water market, especially when combined with a lack of alternative water sources, allows service providers to charge very high prices (REACH, 2014; UNICEF & Oxfam, 2016). A study of water service provision in Sana’a showed that the water provided by private tankers was on average five times more expensive than municipal water, with peak prices as high as ten times the municipal tariff during high conflict intensity and low fuel availability (Aklan et al., 2019).

4.4.2. External financial support

Given the limitations to cost recovery, many utilities in conflict settings depend on external financial support to pay salaries and maintain service provision. In most cases, such financial support is provided by the national government or by international organizations, both of which can be problematic in volatile conflict settings.

Government support to areas under the control of opposition groups can be severely limited. In Aden, the utility receives some financial support from the internationally recognized Yemeni government to cover regular expenses including salaries (GIZ, 2018a; UN-Habitat, 2020a), while the utility in Sana’a, under control of the Houthis, does not receive any support from either the Yemeni government or the Houthis (GIZ, 2018b). In Kirkuk, the long-standing dispute over the governorate has restricted the financial support from either government (Oxfam, 2017).

When financial support by the government is impossible or insufficient, international humanitarian organizations and development agencies can intervene. Such interventions usually take place within emergency projects and short funding periods to minimize the financial risk in the case of conflict escalation. Additionally, funds are often available for repairing damaged water facilities or constructing new facilities, but not for long-term O&M. The Gaza Strip is a microcosm of challenges related to international financial support, including ‘no contact’ policies enforced by many international organizations towards Hamas, institutional pluralism and donor fatigue. Such challenges can cause a disconnect between internationally funded projects and the local needs and development plans (Barakat et al., 2018; UN OCHA OPT, 2010). The ‘competition’ between conflicts over the limited amount of humanitarian aid available further disadvantages protracted conflict areas, as funds are allocated towards new crises in other countries.

4.5. Institutions

We identify two main ways in which armed conflicts affect institutions in the water system: 1) the lack of enforcement of existing regulations and standards, and 2) changes to the institutional structure of the water sector and the introduction of new regulations in areas controlled by non-state actors (Fig. 6).28

It is noteworthy that while the institutions component is directly affected by conflict in several ways and plays a role for indirect impacts on most other system components, we did not identify any compelling evidence for indirect impacts on institutions.

4.5.1. Enforcement of regulations

While government authorities are preoccupied with the armed conflict happening within their territory, the monitoring and enforcement of laws related to the environment is usually deprioritized. In our set of cases, this comes in addition to an already low awareness of environmental issues among large parts of the population and a relatively weak position of environmental agencies within government structures. The result is a de-facto absence of regulations related to the water system, with previously mentioned examples including the insufficient enforcement of environmental regulations in Kirkuk, and of water resource allocations and service provision standards in Sana’a.

27 Interviews with a representative of the local service provider in Aden, a representative of the local service provider in Sana’a and a government official in Sana’a (January 2018).
28 Interviews with a government official in the Gaza Strip (April 2018) and three local government officials in the Gaza Strip (September 2018).
29 Interview with a representative of an international organization in the Gaza Strip (June 2018).

25 Interviews with two local government officials in the Gaza Strip (September 2018).
26 Interview with a representative of a local civil society organization in Ras al-Auja (May 2020).
The enforcement of state policies in areas under the control of non-state actors is additionally limited as state law enforcement is either withdrawn or denied access (Walch, 2018). This includes areas that are controlled by non-state actors for a long period of time, such as the Gaza Strip under Hamas rule and many areas controlled by the Houthi movement in Yemen, as well as areas that are held by non-state actors for a relatively short period of time, including cities held by ISIS.
4.5.2. Changes to the institutional structure

Upon gaining control over new territory, conflict parties often appoint their allies to local leadership positions as part of a patronage system and to consolidate their control, and might even make changes to local governance structures. After taking control of Mosul, ISIS drastically changed the set-up of the city’s administration, including changes to the role of the municipality in providing basic services and receiving taxes (UN-Habitat, 2016) and the replacement of high local government officials with ISIS loyalists.

When the Houthi took control of Sana’a, they also placed loyalists in political leadership positions, but made limited changes to city administration, leaving the water sector largely unaffected (UN-Habitat, 2020b).

Over time, non-state actors with territorial control can introduce more elaborate new institutional structures in parallel to state structures, which may interfere with previously established water management and governance processes. For instance, since Hamas took control of the Gaza Strip, structures characterized by institutional pluralism have developed, such as separate water sector development plans, abstraction licensing processes and taxation schemes (Nashashibi & Gal, 2019).

4.6. Resource users

We discern three main conflict impacts on water resource users, including water use for domestic, agricultural and industrial purposes: 1) shifts in local water demand, 2) limitations to the ability or willingness to pay for water services, and 3) impacts on consumer choices, which often serve as a coping mechanism to deal with the deterioration of public water supply (Fig. 7).

4.6.1. Shifts in local water demand

Conflict-driven migration causes significant shifts in domestic water demand at different scales, from refugee streams at the international level to internally displaced persons (IDPs) at the sub-national level. Such shifts are particularly problematic if they occur within areas of high conflict intensity where the water system is unable to accommodate the increased demand in the host area. This especially applies to areas from which emigration is almost impossible, such as areas under siege in the Syrian civil war (ICISyria, 2018), and to areas where IDPs stay in rented accommodations rather than IDP camps, such as many cities across Yemen (GIZ, 2018c; World Bank, 2020).

Changes in economic activity due to the ongoing conflict affect the water demand from agriculture and industry. Given its high share in water consumption, the agricultural sector plays a particularly important role. While agricultural abandonment can reduce the pressure on local water resources (Müller et al., 2016), shifts towards water-intensive cash crops as a new source of income can cause the opposite, as observed with increasing qat cultivation in Yemen (DFID, 2019; ICRC, 2015b).

4.6.2. Payment for water use

The lack of paying water users was previously identified as a key driver of financial difficulties, particularly for water utilities. Armed conflicts generally cause economic hardship and high unemployment, and can lead to systematic de-development in the long run (Moyer et al., 2019; UN, 2017). Consumers in Yemen have continued to incur debts with the local utilities while unable to pay their water bills, with no plan on how to repay them in the future (GIZ, 2018c). Lacking financial means for water services also restricts the access to informal water service providers, which usually charge high prices and do not share the mandate of public service providers to supply water to as many users as possible (UNICEF & Oxfam, 2016). Dissatisfaction with the quality or reliability of water services can further deter water users from paying their bills, even if they have the financial means.

4.6.3. Consumer choices

Faced with a deteriorating public water supply, customers are forced to find alternative sources. Depending on the local situation, choices may be limited by affordability, accessibility and quality of water, as well as the users’ capacity for water storage to cope with intermittent water supply. Aleppo provides an example for such choices. The city’s municipal water supply was subject to strict rationing from early on during the civil war, long before conflict-related infrastructure damage severely deteriorated public service provision. Limited on-site storage capacities forced households to identify alternative sources of water early on (World Bank, 2017). These alternative sources were usually lower quality (e.g., boreholes) or significantly more expensive (e.g., water trucks) than the municipal water supply. As neighborhoods in eastern Aleppo suffered extensive damage due to fighting, some households had to rely on the limited humanitarian assistance as their primary source of drinking water (REACH, 2015).

Prioritizing water from specific sources for different uses is an important strategy for households to cope with the varying quality of these sources. Inhabitants of ISIS-controlled Mosul would generally use their storage capacity to store as much water from the municipal network as possible. While this water was only provided infrequently and had poor quality due to insufficient treatment, it was the highest quality water available to households and would only be used as drinking water. The water from neighborhood wells was used for all other domestic needs. While this usage pattern often led to skin conditions due to the use of well water for personal hygiene, it also reduced the risk of other water-borne diseases linked to the consumption of the heavily polluted water.

5. Discussion

5.1. Direct and indirect conflict impacts

Across all water system components, we identified a total of 58 individual conflict impacts, visualized by the arrows in the six figures. Approximately 38% of these were classified as direct conflict impacts and 62% as indirect conflict impacts, comprising of 53% interactions between components of the water system and 9% interactions between the energy system and a component of the water system. In addition to these basic figures, we can also draw several insights as to which components of the system are most vulnerable to indirect and indirect conflict impacts or play a key role in propagating shocks through the system.

On the one hand, physical infrastructure, finances and institutions are most vulnerable to direct conflict impacts. Major direct impacts on these components and the wider system take the form of infrastructure destruction, limitations on the access to construction materials, physical access restrictions and an overall weakened financial and institutional capacity, particularly in areas under the control of non-state actors. On the other hand, water resources emerge as most vulnerable to indirect conflict impacts. A deterioration in any other part of the water system can negatively affect the local water resources, particularly through pollution. Considering indirect conflict impacts within the water system, a deterioration in finances, physical infrastructure and O&M affect other components most significantly. Therefore, these components would be the most effective points of action to slow down the deterioration of

30 Interview with a local government official in Mosul (February 2021).
31 Interview with a Yemeni academic in the Netherlands (January 2018).
32 Interview with a representative of the public service provider in the Gaza Strip (September 2019).
33 Interviews with a government official in Mosul and a representative of a local civil society organization in Mosul (February 2021).
34 Details on the classification of conflict impacts per system component can be found in the supplementary material.
water systems during conflict.

It should be noted that the classification as direct or indirect conflict impact according to our system-based definition depends on the specifications of the system model used, particularly with regards to related systems. The model we used in this paper to trial the approach only considers one related system, the energy system. The addition of other systems, e.g., to explicitly include transportation or local production capacities as prerequisites of the water system, would change the classification of some impacts from direct to indirect across systems.

Within the water system, it could also be useful to distinguish between formal and informal elements of certain system components. This particularly applies to infrastructure and service provision, as the development or expansion of informal mechanisms is an important coping strategy in conflict settings. While such strategies are reactions to conflict impacts on the water system, they are also affected by the conflict and might have limited feasibility or even a net negative effect due to their interaction with other conflict impacts. This includes, for example, unregulated water quality and pricing for private service providers, which can have significant health implications and limit the water access for poor community members, and the pollution of local water resources, which limits the safe use of water from informal infrastructure, such as neighborhood wells. Additionally, informal mechanisms developed over the course of the conflict might become permanent, especially in the case of protracted conflicts. As an area emerges from conflict and formal water management processes are restored, it is crucial to understand how formal and informal elements of the system interact and might complement each other (Pinera, 2012).

5.2. Feedback loops and cumulative effects

The most commonly described vicious cycle for water systems in fragile settings centers around service provision, payments for services and funding available to the utility: insufficient operational capacity of the service provider leads to a deterioration of water services, for which water users become unwilling to pay, leaving the utility with fewer funds to run operations and causing a further deterioration in service quality (Davis et al., 2014; Diep et al., 2017; Walters & Javernick-Will, 2015). In our system model, this includes the components O&M, resource users and finances. This feedback loop is as important during conflict as it is during times of peace. In conflict settings, however, the main financial driver of this loop is not the consumers’ willingness to pay, but rather their shift from formal to informal service provision. As users receive less water from the public network, they turn to alternative sources, paying private service providers rather than the public utility. The resulting decrease in utility income leads to a further deterioration of services in the absence of funds to cover expenses and maintain its water facilities. This loop is particularly problematic in cases where private service providers rely on the public network and filling points to maintain their service, rather than having their own water sources.

Additional financial stress on water utilities is caused by feedback between infrastructure damage and the utility’s finances: Damages to the public water network, whether they are direct or indirect, increase...
leakages from the network and thus non-revenue water, decreasing the utility’s income and the funds available for infrastructure maintenance and repair. External investments in infrastructure repair can counter this feedback loop.

In addition to the feedback loops, negative trends can also be reinforced by the interplay of certain conflict impacts to cause cumulative effects (Zeitoun & Tallhami, 2016). Once again, the repair of infrastructure damage provides an example. Several factors limit the repair process, including access restrictions, a lack of materials and insufficient funds. The severity of infrastructure damage is exacerbated by each of these limitations, prolonging the negative effect on other components of the water system. Another example is the concurrence of water resource pollution and a limitation on water treatment capacity, for instance due to infrastructure damage, insufficient treatment chemicals or lack of electricity. The consequential lack of clean drinking water has severe health implications, particularly in areas where households struggle to access or afford fuel to boil water before consumption.

5.3. Influence of the conflict setting

There are common phenomena to water resources management in armed conflicts, reflected in the conflict impact categories we identified throughout our analysis, e.g., pollution of water resources or lack of qualified staff. However, different individual conflict impacts can cause these phenomena. The conflict impacts most relevant in a given case, particularly in the case of direct impacts, depend on the conflict characteristics, such as the duration and intensity of the conflict and the territorial aspirations of conflict parties, and on the pre-conflict status of the water system.

Considering the influence of conflict intensity, many direct impacts in high-intensity conflict settings are related to active fighting, be it in terms of destruction or access limitations due to security risks. In low-intensity conflicts, impacts on socio-political and economic elements of the water system are more pronounced, as conflict parties are able to divert attention to other issues next to active fighting. Additionally, construction projects are more likely to be considered during periods of low conflict intensity due to the lower risk of destruction, making infrastructure development an important target of potential conflict impacts. As conflict situations become protracted, issues related to the operational, financial and institutional capacity of the water system gain importance over infrastructure damage and access limitations. These issues are often due to indirect impacts, reinforcing feedback loops and cumulative effects within the water system. In such cases, the repair or reconstruction of water infrastructure will not be sufficient to restore water services or curtail the pollution of water resources.

Some of the individual conflict impacts we identified are specific to certain types of conflict settings. Water systems in territories under the control of insurgent groups often face challenges related to the access to finances, being cut off from national government support and many international donors. Potential institutional pluralism between state governance structures and insurgent governance structures as well as a lack of enforcement of state policies and regulations additionally complicate institutional processes within the water system. Among the cases we analyzed, these most notably occur in the Hamas-controlled Gaza Strip and the Houthi-controlled area in Yemen, including both Sana’a and Hudaydah. Water systems in areas that are under siege by another conflict party or subject to an international embargo particularly struggle with the access to construction materials, consumables, such as water treatment chemicals, and fuel. This puts an additional strain on the operational capacity of water service providers in these areas. Notable examples from our set of cases include Eastern Ghouta in Syria and, again, the Gaza Strip.

Lastly, the status of the water system prior to the conflict plays a key role in determining its resilience to different conflict impacts. Decentralization and redundancy of critical infrastructure can limit the impact of infrastructure damage and avoid the kind of large-scale failures that we identified in Aden and Mosul. The cases of Aleppo and Sana’a show the value of pre-conflict access to alternative water sources and informal service provision, providing local populations with familiar strategies to cope with a deterioration of public water supply. While water utilities are very likely to struggle financially throughout prolonged conflict irrespective of their prior situation, Sanogo (2019) suggests that financially decentralized utilities are in an advantageous position. Longitudinal studies of water systems before and during armed conflict should further explore these phenomena to provide more insights on how to improve system resilience to conflict-related shocks before the fact.

6. Conclusion

While indicators such as infrastructure damage and loss of human life are important to monitor the impacts of armed conflict, they only show a part of the picture. Indirect impacts and reinforcing effects within and between systems are crucial in understanding the wider effects of conflict on livelihoods and human security. In this paper, we built on the SES framework to define and analyze direct and indirect impacts of armed conflicts on water resources management, using empirical evidence from eleven case studies in Iraq, Palestine, Syria and Yemen. We created conceptual insights on how SES function in disruptive conflict settings and showed the value of system-based approaches to the study of direct and indirect conflict impacts, emerging feedback loops and other cumulative effects.

We identified three key dynamics within the conflict-affected water system that are of relevance to the humanitarian sector. First, our findings highlight the central position of insufficient finances in the deterioration of water systems in conflict settings, particularly related to the lack of funds for operative expenses in service provision and for infrastructure maintenance and repairs. Both of these dynamics drive reinforcing feedback loops. This indicates a need to re-evaluate the ways in which financial support is provided to conflict-affected areas and water systems, especially via predominantly short-term humanitarian aid. Second, the destruction of critical infrastructure causes significant direct and indirect impacts, ranging from the immediate interruption of water services to environmental impacts, an additional financial burden on local actors, and security risks for repair crews. In many cases, the destruction of water facilities during active fighting is also the trigger for the initial deterioration of water management and service provision early in the conflict. Our analysis therefore supports the urgent calls for conflict parties to adhere to international humanitarian law on the protection of civilian infrastructure during armed conflict (Geneva Water Hub, 2019). Third, our results emphasize the importance of safeguarding water quality, which, in a conflict setting, is threatened by many potential indirect impacts. The pollution of water resources, combined with insufficient treatment capacity, easily leads to large-scale humanitarian crises that can far outlive the conflict itself, including grave impacts on public health, food security and the environment.

This paper provides a first assessment of conflict impacts on water resources management and water service provision from a systems perspective. Further research is essential to increase our understanding of these impacts and their long-term implications on civilian life. Such research can include quantitative studies based on a large-N design, studies on specific elements or interactions of the water system during armed conflict, and studies on conflicts outside of the Middle East. More differentiated analyses can create additional insights on prevalent conflict impacts on specific disadvantaged groups, such as IDPs, women and children.

Lastly, although many of the case study areas are prone to drought or flooding due to extreme weather events and climate change, our analysis did not focus on the impacts of armed conflict on water-related disaster response and risk reduction. While the issue of disasters in conflict-affected settings has recently received scholarly attention (Mena & Hilhorst, 2021; Peters, 2021), more research is yet needed on the...
implications of weakened water systems for the vulnerability to water-related hazards in armed conflicts.

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**CRedit authorship contribution statement**

Juliane Schilling: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. Gül Özerol: Conceptualization, Formal analysis, Funding acquisition, Investigation, Supervision, Writing – original draft, Writing – review & editing. Michiel Heldeweg: Supervision, Writing – original draft, Writing – review & editing.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Appendix A. Supplementary material**

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