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Review

Water Conflicts: From Ancient to Modern Times and in the Future

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Citation: Angelakis, A.N.; Valipour, M.; Ahmed, A.T.; Tzanakakis, V.; Paranychianakis, N.V.; Krasilnikoff, J.; Drusiani, R.; Mays, L.; El Gohary, F.; Koutsoyiannis, D.; et al. Water Conflicts: From Ancient to Modern Times and in the Future. *Sustainability* **2021**, *13*, 4237. https://doi.org/10.3390/su13084237

Academic Editor: Julio Berbel

Received: 16 March 2021
Accepted: 4 April 2021
Published: 11 April 2021

Abstract: Since prehistoric times, water conflicts have occurred as a result of a wide range of tensions and/or violence, which have rarely taken the form of traditional warfare waged over water resources alone. Instead, water has historically been a (re)source of tension and a factor in conflicts that start for other reasons. In some cases, water was used directly as a weapon through its ability to cause damage through deprivation or erosion or water resources of enemy populations and their armies. However, water conflicts, both past and present, arise for several reasons; including territorial disputes, fight for resources, and strategic advantage. The main reasons of water conflicts are usually delimitation of boundaries, waterlogging (e.g., dams and lakes), diversion of rivers flow, running water, food, and political distresses. In recent decades, the number of human casualties caused by water conflicts is more than that of natural disasters, indicating the importance of emerging trends on water wars in the world. This paper presents arguments, fights, discourses, and conflicts around water from ancient times to the present. This diachronic survey attempts to provide water governance alternatives for the current and future.

Keywords: water conflict; water policy; water tension; water violence; water management; water crises; water arguments; water politics; water mafia; water scarcity

1. Prolegomena

"If roads lead to civilization, then water leads to peace."
Shimon Peres (1923–2016)

> *"Anyone who can solve the problems of water will be worthy of two Nobel Prizes–one for peace and one for science."*
>
> John F. Kennedy (1917–1963) National Water Commission Hearings (1966).

1.1. Water Conflict Chronology

During the history of humanity, numerous water conflicts, accidental and/or deliberate, have been reported, and in some instances, water has even been used as a weapon of war. Most have taken place in the eastern Mediterranean region, but with varying intensity of the dominating cultures in the region. Whereas the Minoans and Mycenean's supposedly refrained from active participation in these conflicts, the city–states of Mesopotamia occasionally engaged in fierce competition over the regional resources [1]. The palace economy of the Aegean region and Anatolia that characterized the Late Bronze Age disintegrated, transforming into the small, isolated village cultures of the Greek Dark Ages. During that time, the cultural collapse of several civilizations (e.g., the Mycenaean, the Kassite's in Babylonia, the Hittite Empire in Anatolia, the Egyptian new Kingdom, several states in Levant, and a period of chaos in Canaan) were highly involved in water related conflicts [2].

1.2. Water Governance

Water is a natural resource produced at unpredictable, unstable, and uncontrollable rates. That is why, rightly so, Article one of the Council of Europe Directive (EU/60/2000/EU) Water Resources Management Directive stipulates that: water is not a commercial product like any other but, instead, a heritage which must be protected, defended, and treated as such. However, beyond that, it is necessary to ensure the quality of the water supply, even in cases of "emergency", such as the one that the world is going through. That is why in most of the States, such as the USA, Germany, Japan, and the Scandinavian countries, the control of the water supply services are under public and/or municipal control.

The amount of water that is today economically available for human use for all uses is about 4600 km^3/yr, which corresponds today to about 600 m^3/inh.yr [3]. Total water demand is expected to increase from 4600 today to 5500 km^3/yr in 2050 [4]. This increasing scarcity is made more complicated because almost half the globe's land surface lies within international watersheds. There are 263 rivers around the world that cross the boundaries of two or more nations and untold number of international groundwater aquifers.

Recently, both water quantity and water quality have been reduced, emphasizing water scarcity. [5,6]. As a result [7]: (a) over two billion people live in regions experience high water stress and the number is expected to increase in the future. (b) Over one billion people do not have access to clean and safe drinking water. (c) Five to ten million people die each year from water-related diseases or inadequate sanitation. (d) Millions of women and children spend several hours collecting water from an average distance of 6 km and polluted sources. And (e) Twenty percent of the world's irrigated lands are salt-laden, affecting crop production and food safety.

In addition to water scarcity, many water systems worldwide are transboundary (e.g., rivers, lakes, and groundwater aquifers). Such transboundary or cross-border water systems can always be a cause for competition among the countries that share them. This is reflected in the English language, as the word rival, which has the meaning, "*I am competing*", has its root in the Latin word rivalis, which means sharing the same river with someone else. Moreover, riparian countries are often competitors for the river they share, and this has often created a crisis in the relations between different states.

More than 40% of the world are within stress zones water, while a total of 263 basins are recorded worldwide to be transboundary (Africa 59, Europe 69, Asia 57, North America 40, South America 38), and 39 countries, whose rivers flow at least halfway across the borders of these countries [8]. Based on these data, the appearance of hydrological interdependence is highly increased.

Nowadays, water conflicts around the world appear to be much more complicated compared to ancient times. In a chronologic perspective, one can argue for five eras of water conflicts, each singled out by its distinct features: (a) prehistoric times (ca 3500–1150 BC), (b) historical time (ca 750 BC–330 AD), (c) medieval times (ca 330–1400 AD), (d) early modern and modern times (ca 1400–1900 AD), and (e) contemporary times (1900 AD-present). A comprehensive review of the history of water conflicts is necessary to enhance our understanding of the causes, the means, and their consequences. Such information is necessary in order to prevent future conflicts by developing appropriate water governance frameworks. "*Study the past, if you would divine the future*", Confucius (551–479 BC).

This review is organized as follows: section one introduces the theme and elements of the review, followed by sections two–five, explaining the distinct histories of water conflicts from prehistoric times to present in a chronological and geographical perspective. Section six discusses the potential emerging trends and future challenges. Finally, in section seven, the epilogue–concluding remarks are highlighted.

2. Water Conflicts in Prehistoric Times (ca 3200–1150 BC)

Turton et al. [8] reported that Laozi (6th or 4th BC), an ancient Chinese philosopher, wrote: "The sage's transformation of the world arises from solving the problem of water. If water is united, the human heart will be corrected. If water is pure and clean, the heart of the people will readily be unified and desirous of cleanliness. Even when the citizenry's heart is changed, their conduct will not be depraved. Therefore, the sage's government does not consist of talking to people and persuading them, family by family. The pivot (of work) is water".

Water Conflicts in the Eastern Mediterranean during the Bronze Age

One of the very early examples of the use of water as a weapon comes from the Sumerian myth, recounting the deeds of the goddess Ea, who punished humanity's sins by inflicting the Earth with a great flood. According to the myth, the patriarch Utu spoke with Ea, who warned him of the impending flood and ordered him to build a large vessel filled with all life seeds [9].

Water conflicts in the Mesopotamian region included: (a) Sumerians (of the Lagash city) in the early Dynastic period fighting against the cities of Ur, Uruk, Larsa, Akshak, Umma, and others (ca 2500 BC). (b) During the early Dynastic period, Sumerians (of the Umma city) fought against the Lagash and others (ca 2294–2230 BC). (c) From ca 1800 to 1750 BC, several wars took place between: (i) the Sumerians (Larsa) against the cities of Babylon, Der, Uruk, and Isin; (ii) Babylonians against Elamites and Sumerians (Larsa); and (iii) Babylonians against Elamites. (iv) From ca 1750–1500, several wars took place between the Assyrians and Hittites against the Babylonians, Hurrians, and Amorites in the region. (v) Conflicts between Mehrgarh and Indus valley (2500–1900 BC). (vi) From ca 1500 to 1250 BC, Egyptians fought with Libyans, Persians, Phoenicians, and others. And (vii) The Battle of the Hydaspes was fought in 326 BC between Alexander the Great and King Porus of the Paurava kingdom on the banks of the Jhelum River (known to the Greeks as Hydaspes) in the Punjab, Pakistan) [7,10].

The history of the Middle East conflict had been tied to water. These disputes ranged from conflicts over access to adequate water supplies to intentional attacks on water delivery systems during wars. For example, a water conflict occurred in the Tigris and Euphrates river valleys during the last 5000 years. Around 1790 BC, a continued water dispute led Hammurabi (1792–1750 BC), the Babylonian king, to include several laws in the famous "*Law Code of Hammurabi*" pertaining to the negligence of irrigation systems and to water theft. Hammurabi created laws, which were enforced in his kingdom, and supposedly ensured farmers' participation in the construction and maintenance of infrastructure and a fair distribution of irrigation water to avoid conflicts [11].

3. Water Conflicts in Historical Time (*ca* 750 BC–330 AD)

3.1. Water Conflicts in Archaic, Classical, and Hellenistic Periods

Sargon II, the Assyrian king (from 720 to 705 BC) destroyed the irrigation network of the Haldians after his successful campaign in Armenia. Sennacherib of Assyria attacked Babylon in 689 BC as revenge for his son's death and destroyed the water supply canals to the city. In 612 BC, a coalition of Egyptian, Median (Persian), and Babylonian forces destroyed Nineveh, the capital of Assyria, by diverting the Khosr River to create a flood [5].

In the challenging climate of the Eastern Mediterranean, agricultural societies faced erratic winter precipitation and summer droughts. In the southeastern part of mainland Greece and the isles of the Aegean Sea, where most city–states evolved during the archaic age, farmers had to develop strategies to counter the adverse effects of droughts and potential food crisis [12]. From the early 6th century Athens, the reforms of the magistrate Solon clarified the right of neighbors to collect water, if they, beforehand, had been unsuccessful in making access to groundwater on their property. Undoubtedly, this stipulation prevented some conflicts in the local communities in rural Attica.

Another type of conflict between neighbors emerged in the 4th century Athenian forensic speeches, where litigations against individuals for causing water to inflict damage on the property found its way into the courtrooms. Here, in a speech by Demosthenes, one country dweller allegedly caused damage by diverting excessive rainwater into his neighbor's property (Demosthenes 55, Against Callicles). A similar situation and the ambition to prevent farmers to divert water across the land of neighbors motivated the lawgivers of 5th century Gortyn, Crete, to accept a law regulating and preventing the negative effects of leading water across the land of neighbors [13].

From an early date, it appears that the Greeks of the archaic period possessed knowledge of how to perform intentional contamination of the water supply of enemies. According to later Classical, Hellenistic, and Roman evidence, part of the arsenal of the early city–state was to use poisonous plant extracts or by disposing of animal carcasses or liquid waste in wells or tanks of opponents. A typical example is the fortified Phocian city of Kirrha, near today's Itea, which controlled access to Delphi from the Corinthian Gulf. According to Polyaenus, a writer of the 2nd century AD, the attackers added roots of *Hellebore* spp. plant (Figure 1) to the spring from which the water came.

Figure 1. The *Hellebore* spp. plant [14].

Polyaenus also gave credit for the strategy—not to Cleisthenes, but to General Eurylochus—who had advised his allies to gather a large amount of *Hellebore* spp. from Anticyra, where it was abundant (Polyaenus, Stratagems 6.13). The war lasted 10 years [13]. Kirrha was besieged by land and sea, but eventually succumbed only when the besiegers poisoned the springs that supplied the city with the poisonous plant. It is also possible that Alexander the Great died after drinking wine containing *Hellebore* spp. roots [14]. Several examples from the Classical literature of the fourth and fifth centuries suggest that access to water was an endemic challenge to armies in the field. Herodotus, in his ninth book, related the instance where the invading Persians, under general Mardonius, prevented the Greeks from access to water (Herodotus, 9.41.2; 9.53.2).

Thucydides' narrative of the siege of Pylos in 425 BC clearly stated that the Spartan garrison gave in because of lack of food and water in "the desert island" (Thucydides, 4. 26), and Xenophon in his Hellenica referred to several instances, whereas cutting off the opponents of the water supply was a well-proven strategy (Xenophon, Hellenica, 3.1.7). Moreover, he explains how water could be used to undermine the fortifications of a besieged city (Xenophon, Hellenica, 5.2.6), and how access to water became a priority to an army on the march (Xenophon, Hellenica, 6.2.29). The fourth century author Aeneas Tacticus advised city–states facing invasions and sieges to contaminate the local water supply, i.e., water in lakes, to deprive enemies from exploiting the resources of the land (Aeneas Tacticus, Poliorcetica, viii, 2).

Examples of water contamination occurred during the Peloponnesian War in five years (430–426 BC). In the second year of the war, in 429 BC, the Spartans probably contaminated parts of the main water supply network and/or cisterns or water supply wells in Piraeus, which were the main sources of water supply for the wider region, including Athens. Historical data show that the contamination of the water caused by the Athenian plague during the summer of the second year of the war was probably due to salmonella (*Salmonella enterica* Typhi), by using feces, rotten vegetables, or corpses [15,16]. Thucydides states that the plague, from the polluted water, first struck Piraeus and then Athens:

> *"Ες δὲ τὴν Ἀθηναίων πόλιν ἐξαπιναίως ἐσέπεσε, καὶ τὸ πρῶτον ἐν τῷ Πειραιεῖ ἥψατο τῶν ἀνθρώπων, ὥστε καὶ ἐλέχθη ὑπ' αὐτῶν ὡς οἱ Πελοποννήσιοι φάρμακα ἐσβεβλήκοιεν ἐς τὰ φρέατα· κρῆναι γὰρ οὔπω ἦσαν αὐτόθι. ὕστερον δὲ καὶ ἐς τὴν ἄνω πόλιν ἀφίκετο, καὶ ἔθνῃσκον πολλῷ μᾶλλον ἤδη."*
>
> It is translated as [17]:
>
> *"He suddenly fell in Athens. He first appeared in Piraeus, where it was reported that the Peloponnesians had poisoned the wells (Piraeus did not yet have fountains) and then spread to the upper city, where too many began to die"*
>
> [Thucydides, 2. 48 2].

Thucydides reflected that in the midst of the calamity, some remembered, of course, other prophecies, but also the following oracle, which, as the elders said, was once sent to him: *there will be a Doric war and an infection with it.*

> *"ἐγένετο μὲν οὖν ἔρις τοῖς ἀνθρώποις μὴ λοιμὸν ὠνομάσθαι ἐν τῷ ἔπει ὑπὸ τῶν παλαιῶν, ἀλλὰ λιμόν, ἐνίκησε δὲ ἐπὶ τοῦ παρόντος εἰκότως λοιμὸν εἰρῆσθαι· οἱ γὰρ ἄνθρωποι πρὸς ἃ ἔπασχον τὴν μνήμην ἐποιοῦντο."*
>
> It is translated as [17]:
>
> *"Many quarrels took place then, because others said that the oracle did not speak of an infection [disease] but of famine [hunger], but the prevailing opinion was that the right one was an infection because people interpreted the oracle according to their diseases."*
>
> [Thucydides, 2. 54.3]

At the time of Alexander's expedition, the Indus valley was characterized by fertile lands, and comprised of the territory of five rivers, namely Indus, Jhelum, Ravi, Chanab, and Satluj. It was these rivers and their resources that caused the wars and conflicts, not only historically, but today too. The main reasons of wars in the Indus valley were delimitation of boundaries, waterlogging (dams and lakes), and diversion of rivers, running water, food, and political distresses. One of the earliest water conflicts in the Indus valley was recorded in the famous Goutama Buddhar Kappiyam (Mauryan Empire *ca* 300–200 BC): *a conflict over the sharing of Rohini river water between the Sakyan and Koliyan, India;* According to Guhan [18]:

"When the Sakiyas and Koliyas waged a terrible war;
About sharing the river Rohini,
Blood, gushing like a spring, flooded the waters,
The Buddha, coming to know of it,
Did what was needful;
To end the long-drawn discord and;
To bring both sides together.
All shall be well if good men try."

The Battle of the Hydaspes was fought in 326 BC between Alexander the Great and King Porus of the Paurava kingdom on the banks of the Jhelum River (known to the Greeks as Hydaspes) in the Punjab region of the Indian subcontinent (modern-day Punjab, Pakistan) (Figure 2). The battle resulted in a Greek victory and the surrender of Porus. Large areas of the Punjab between the Hydaspes (Jhelum) and Hyphasis (Beas) rivers were absorbed into the Alexandrian Empire, and Porus was reinstated as a subordinate ruler [19].

Figure 2. War Elephants Depicted in Hannibal Barca Crossing the Rhone (Jhelum River) [19].

Alexander's decision to cross the monsoon-swollen river, despite close Indian surveillance, in order to catch Porus's army in the flank, has been referred to as one of his "*masterpieces*". Although victorious, it was also the costliest battle fought by the Macedonians. The resistance put up by King Porus and his men won the respect of Alexander, who asked Porus to become one of his satraps. The battle is historically significant for opening up the Indian subcontinent to Ancient Greek political (Seleucid, Greco–Bactrian, Indo–Greek) and cultural influences (Greco–Buddhist art), which continued to have an impact for many centuries [19].

3.2. Water Conflicts in Roman Times

The Roman army used water, both as an offensive and defensive weapon, including diversion of water, thus preventing besieged populations from its most vital resource. Moreover, the Roman army deterred from using poisonous materials to pollute the water supply of adversaries.

Frontinus [20] in 97 AD became the Curator Aquarum of Imperial Rome at the time of Emperor Nerva. He was able to subdue the warlike tribes of Siluri and Ordovices settled in the region of present-day Wales. Thanks to these experiences, combined with a definite talent for writing manuals, Frontinus wrote a treatise on military topics, De Re Militari, now lost except for the four books, Strategematica [21], containing a large collection of military anecdotes, including strategies implemented by the great Generals of the past, not only Roman, listed by specific topics.

The third book of *Strategematica* deals explicit with siege techniques, for which the theme of water, widely covered, plays a fundamental role. Particularly, the seventh chapter dealing with the "*De-fluminum-derivatione-et-vitiatione-aquarum*" or "*On diverting streams and contaminating waters*", which illustrates how water can be an instrument of war, which a good Roman General must take into account in the planning and management of a military campaign. Later on, we will refer specifically (but not only to), the categories and the examples taken from the text of Frontinus.

Frontinus also considered the important role of water supply of a fortified city under siege. Frontinus in his book quotes two examples of military operations implemented by the Roman army (Frontinus *Strategematica* Book III, 7). The first is about the war against the Pirates, which the Romans engaged between 80 and 60 BC, and in particular, the operations conducted by the General Publius Servilius Vatia [22] about 75 BC in Cilicia, in the Anatolian peninsula. The military campaign ended with the capitulation, after siege, of the city of Isauria, which was a hideout for fugitive pirates. This result was achieved by diverting the river that flowed through the city, which in fact was taken by thirst. For his brilliant conduct, Publius Servilius, nicknamed for this reason Isaurico, received a triumph in Rome in 74 BC. For his merits (L.A. Florus, *Rerum Romanorum* Liber I, 41, 5). The second example is from Gaius Julius Caesar's account for the Gallic wars (Commentarii de bello gallico). The incident took place towards the end of the military campaign in Gaul, after the defeat of Vercingetorix at Alesia in 52 BC. A group of Gauls escaped from Alesia and chased by the Roman troops found refuge in the city of Uxellodunum in Aquitaine in the South of France. The Roman army immediately besieged the city. Due to the prolonged siege, Julius Caesar decided to have a tunnel dug to drain the water from the sources feeding the city, writing about it: "*... ad-postremum-cuniculis-venae-fontis intercisae-sunt, atque-aversae.-Quo-facto-exhaustus-repente-perennis-exaruit-fons* . . . " or "*... At last, the water streams were cut off, and diverted from their course, therefore the flow of the water suddenly stopped* ..." (J. C. De bello Gallico, liber VIII, 43). At this point, the city had to capitulate and life was spared to the insurgents who had surrendered, although was amputated the hand that had raised his sword against Caesar.

A few years later, in 47 BC, towards the end of the Civil War, Julius Caesar found himself in a similar situation when besieged in the royal palace in Egyptian Alexandria. In fact, the troops of Ptolemy XIII had contaminated the freshwater supplies with seawater and, thus, seriously threatened the efforts of the besieged to withstand the siege. Caesar overcame this offensive action by having two deep water wells dug within the perimeter controlled by the Romans (J. C. De bello Alexandrino, Ch. 5–9). This solution allowed them to resist until the arrival of the allied troops led by Mithridates of Pergamon. The two armies joined, defeated the Egyptians, and thus ended the Alexandrian campaign.

Hence, and perhaps not surprisingly, the fifth century AD, Flavius Vegetius, paid attention to the fact that the besieged must still be able to access water in sufficient quantity and adequate quality in order to resist. He recommended the excavation of new wells within the city, the construction of reservoirs using existing structures, the fortification of water points located outside city, to be essential knowledge and preparations of the besieged (Vegetius, De re military, IV, 10). This was especially true in regions affected by water scarcity, such as the lands adjacent to the Dead Sea in Palestine, where the fortress of Masada (originally the royal palace of Herod the Great) was located [23]. This structure, high above the surrounding terrain (Figure 3), had been equipped with vast warehouses, *"... in the most appropriate areas, many cisterns to collect and distribute water in abundance, almost competing with nature to make this fortification even more impregnable a place that was already inexpugnable"* (Josephus, Jewish War, VII: 176).

Figure 3. Water cisterns in the fortress of Masada used for harvesting and storage of rainwater.

After the destruction of Jerusalem in 70 AD by the future emperor Titus Flavius Vespasian, the Jewish rebels fled from Jerusalem, occupied Masada, and were eventually besieged by the Roman army. Moreover, the besieging troops, since they could not relay on a quick surrender by the rebels due to a possible depletion of water and food, were forced to conduct challenging assaults using numerous soldiers and war machines.

Another episode quoted by Frontinus refers to a military action during the Iberian wars (143 BC) when Quintus Caecilius Metellus Macedonicus was governor of Hither Spain. During a military operation against the Celtiberians, Metellus was able to defeat the enemies by ransacking their camp located in a valley. He decided to divert a water stream located at an elevation higher than the enemy camp, and then suddenly release the water with dramatic effects. This caused panic among the enemies who were overwhelmed by the Roman troops, which had secretly prepared for the sudden assault.

The water also served to hinder the construction of tunnels designed to pass under the walls or make them collapse. One of the systems used was to flood the moats around the fortifications. Even Julius Caesar used this technique in Gaul (J.C., De Bello Gallico, VII, 72) when he arranged to divert a surface stream to fill the moat surrounding the military camp from which he besieged the city of Alesia [24] (Figure 4). The effectiveness of moats against tunnels made by the besiegers was somehow codified by Flavius Vegetius in the fourth century AD (Vegetius, De Re Militari, Liber IV, 5).

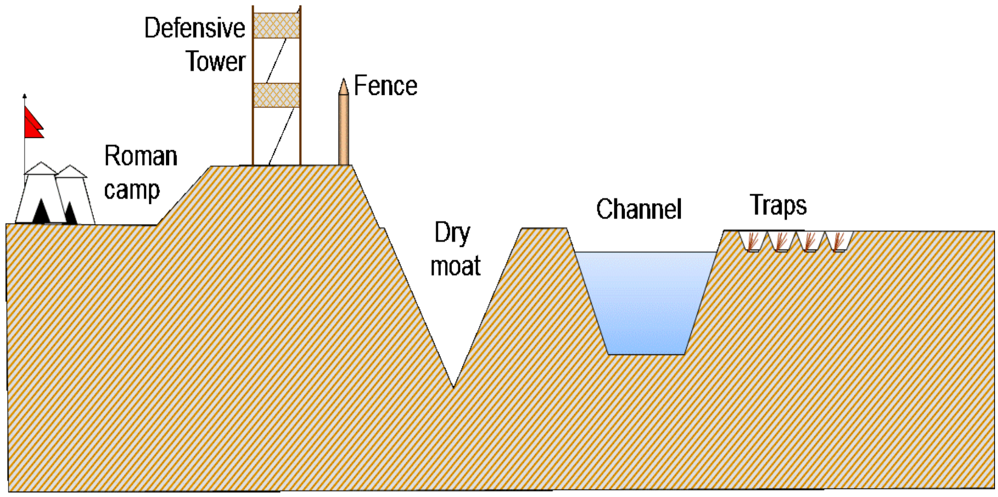


Figure 4. Scheme of the fortifications of the Alesia's Roman camp (drawing by R. Drusiani, based on the description of Julius Caesar—Bellum Gallium, Book VII, 72).

4. Water Conflicts in Medieval Times (ca 330–1400 AD)

In late antiquity, Roman armies in the field experienced the hardships of campaigning against adversaries capable of exploiting the destructive effects of flooding. Thus, deliberate flooding of lowlands represents a strategic defensive option to slow the advance of invading enemy armies. This became very evident to the Romans in 363 AD when, during the military campaign against the Sassanids, they were thwarted near the present day city of Tikrit (Iraq) by the flooding caused by the Persians who had opened the dams of the irrigation system (A. Marcellinus, Rerum gestarum libri, Book XXIV, 2, 10–11).

This type of military action has been used throughout the ages in different regions of the world. More recently, in the twentieth century, we have seen the implementation of this strategy with a devastating result, when tens of thousands of Chinese lost their lives when the levees of the Yellow river were demolished to stop the advance of the Japanese in 1938 during the Sino-Japanese War [25].

The city of Naples, which in 536 AD was on the Goths' side, was besieged by the General Belisarius (Procopius, Bellum Gothicum, Liber I, 9), represented in Figure 5, and was conquered thanks to the stealthy entry of 400 soldiers through an underground tunnel intended to take water to the city. Soon after, also in the same campaign, General Belisarius, but this time as the besieged, was able to foil the attempt of the Goths led by their king, Vitige, to enter Rome through the aqueduct Virgin built completely underground, and for this reason not cut off by the Goths. In fact, a sentry had noticed the presence of Goth explorers who were inspecting the tunnel, which was immediately blocked (Procopius, Bellum Gothicum, Liber I, 19).

After this last failed attempt, the Goths, after a year of unsuccessful siege of the city, withdrew to the north in March 538 AD. It is interesting to note that almost 1000 years later, in 1442, the Spanish nobleman Alfonso of Aragon exploited his knowledge of the writings of Procopius of Caesarea to gain access to the city of Naples. After a brief search near the Porta Carbonara, he followed the same route used by Belisarius, a branch of the ancient Greco-Roman aqueduct of the Bolla to enter the city of Naples sided with the Angevins, which the Aragon king had sieged [26].

In March 624 AD, at Bader battle, Muslims also used water as a weapon in Al-Madinah, the west part of Saudi Arabia, to resist the army of non-Muslims, Quraish, who came to destroy the city. Muslims occupied the Bader well outside the city and prevented them from entering the city; this helped Muslims to gain a victory [27].

In 1187, at the Horns of Hattin, Sultan Saladin could defeat the Crusaders by preventing them access to water. He filled all the wells along the way with sand and ruins; all sources were used to supply the enemy army with water [28].

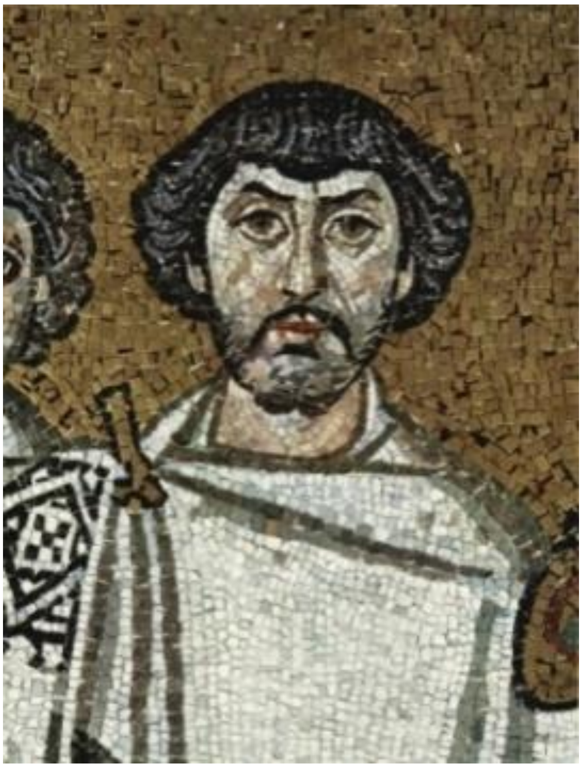


Figure 5. Representation of Byzantine General Belisarius (mosaic in the Basilica of San Vitale in Ravenna, Italy).

Medieval Central and Western Europe experienced significant changes in the political order of society, whereas the basic economy still rested on agriculture. The emergence of the medieval city and its growing importance towards the end of the period as a commercial and political center further encouraged the development of new socioeconomic trends. Still, however, princes, the nobility, and the church expanded control over most parts of the European continent and its resources.

Medieval city outlines south of the old Roman region, facing the Germanic and Slavic cultures to the north and east, were partially developed for city development. Some of the key elements of Roman water management, such as aqueducts, continued to work for centuries and ensured the city populations a steady water supply. On the one hand, warfare among northern Italian city–states in the 13th through the 15th centuries often targeted the water supply of cities. This included Orvieto, where the conflict between Braccio Fortebraccio and the pope led to severance of Orvieto's aqueduct in 1419–1420 [29].

On the other hand, the overall impoverishment of the population in medieval England, and local rights to use water causes for transportation, resulted in little improvement in advanced water technology and engineering. Moreover, few external military threats meant that little was done to construct and uphold sophisticated water defenses [30]. Stealing of water and, thus, violation of private water rights became endemic to large parts of medieval Europe, including the cities of Germany and Italy [31]. However, to some degree, inhabitants worked together to counter the negative effects of threats, such as fire, hygiene, and environmental pressure, thus preventing conflicts over water from evolving and escalating [32]. Scandinavia, on the contrary, with abundant access to fresh water, saw little conflict over water rights [33].

5. Water Conflicts in Early and Mid-Modern Times (ca 1400–1900 AD)

In 1503, Leonardo da Vinci collaborated with Niccolò di Bernardo dei Machiavelli, an Italian Renaissance diplomat, philosopher, and writer, best known for *The Prince* (*Il Principe*). However, this rare case of collaboration between geniuses of the first order proved to be an utter fiasco. Their plan was to divert the Arno River, depriving Pisa of water and, thus, compelling its surrender to the besieging Florentines. It ended up yielding a lot of mud, at high cost to Florence and the careers of its planners. Leonardo left town, never to work there again, and Machiavelli was soon driven out from politics [34].

In pre-Columbian times, controlling available water resources was a key factor in accumulating political and social powers, which led to recurring and intensive conflicts, particularly in the Basin of Mexico [35,36]. Since colonial times, the fights surrounding water have been intensified by introducing activities of water consumption. These activities have led to increased competition, and demand to access water sources to develop urban settlements, water-powered industries, fishing, mining, and irrigation [37–40]. A project that took around three centuries (1607–1900) to complete was called El Desagüe (The Drain) in the Basin of Mexico. The Drain involved complex networks of tunnels—large channels to drain wastewater and runoff of floodwater from the Basin of Mexico [18,36,41–44].

As a result of this project, the ecology of the basin was affected the desiccation of the lake and the demise of pre-Columbian settlements [45]. Therefore, there were social confrontations between Spaniards and Indians on one side and between the colonial authorities and the Spanish Crown on the other side [36–48].

In 1642, the Chinese governor of the city of Ming was hoping to use floodwater to break a six-month siege the city had endured from peasant rebels led by Li Zicheng [49]. The Huang He's dikes breached, but the floodwater destroyed Kaifeng [50]. More than 300,000 of the 378,000 residents were killed by the flood and ensuing peripheral disasters, such as famine and plague [51]. If treated as a natural disaster, it would be one of the deadliest floods in history.

After this disaster, the city was abandoned until 1662, when it was rebuilt under the rule of the Kangxi Emperor in the Qing dynasty. Archaeological research in the city has provided evidence for the 1642 flood and subsequent occupation in 1662 [52]. It remained a rural backwater city of diminished importance thereafter and experienced several other less devastating floods.

In 19th century, in Paris, some methods were introduced to direct water supply at homes. One of them was the fixed fee (free tape), without measuring water consumed. In this method, the subscriber paid a fixed fee based on the number of users (people and animals), number of engines (steam engines), garden area, and number of taps. The second method delivered water by using a gauge (constant volume of water per day). In 1876, a third method, the water meter, was developed. These methods, however, led to conflicts among the different actors. In the free-tap method, the main conflict involved the problem of selling water by some users to other subscribers.

In the case of gauge, the main source of conflict was frauds linked to the shape and size of the diaphragms in the gauges. Some subscribers changed the diaphragm's diameter to withdraw more water. Although the water meter ended the above-mentioned conflicts, it generated some new ones. For instance, the meters could not measure small flows. Therefore, some costumers kept their taps barely opened, and this opportunistic behavior was undetected by the system.

In 1887, a court in Paris ruled that these types of illegal connections were not only a cheat on the quantity of the water delivered, but also considered as theft from public sources. The metering system also raised new conflicts between landlords and their tenants. Before water metering, landlords were not concerned about the volume of water consumed by their tenants, since it was not reflected on their own bills. However, with the new method, landlords were concerned about limiting the water volume consumed by their tenants. However, up to today, the metering system has largely remained a water measuring system for various water users [53].

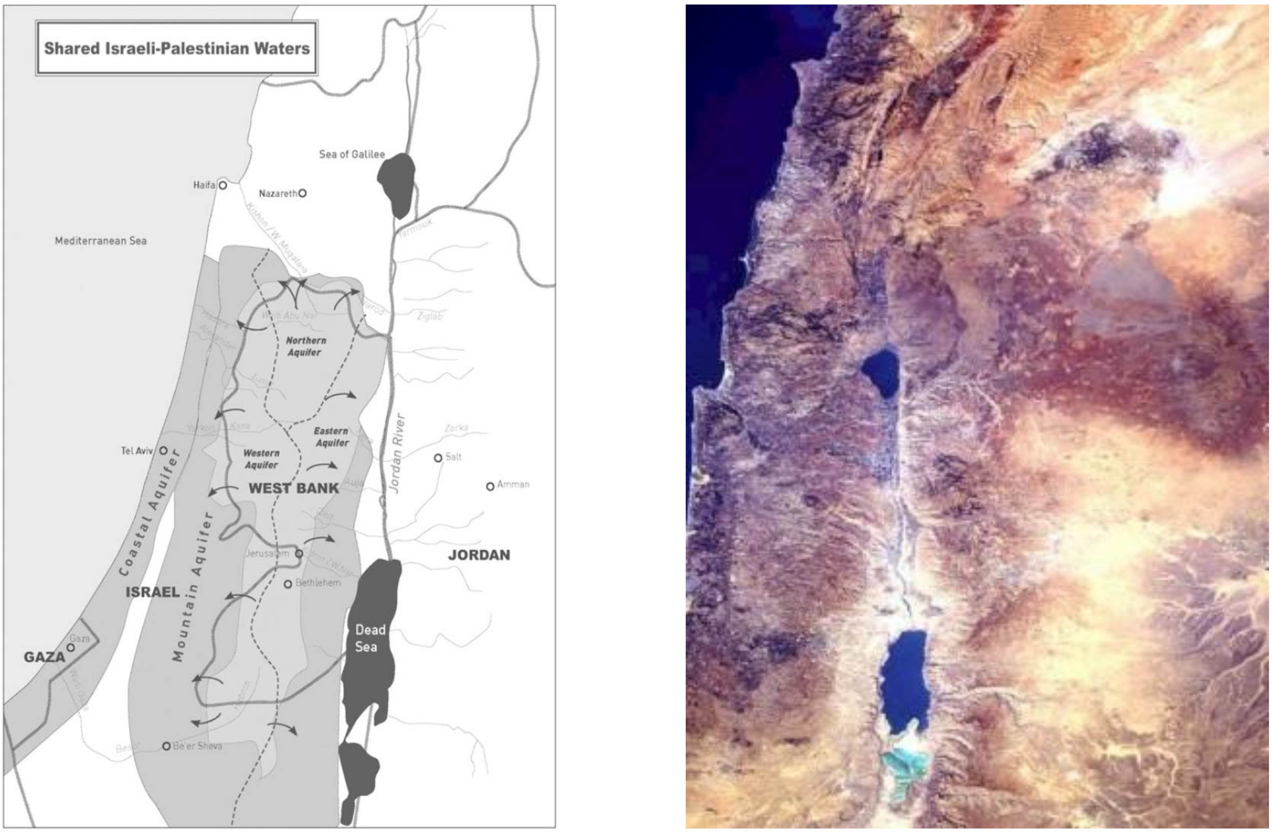
6. Water Conflicts in Contemporary Times (1900 AD–Present)

Water security has always been an essential element while assessing the development of civilization. With modern irrigation technology and infrastructure, the importance of water has been largely downplayed in recent history. However, dwindling supplies, potential effects of climate fluctuations, and a rising population have again brought water to the forefront of future development and risk analysis. In the future, water will again play an important role in the same countries that housed great ancient civilizations determining power-sharing strategies and political alliances.

Interstate conflicts: water conflicts can occur on the intrastate and interstate levels. Interstate conflicts occur between two or more neighboring countries that share a trans-boundary water source, such as rivers, seas, or groundwater basins. For example, the Middle East has only 1% of the world's freshwater shared among 5% of its population. Intrastate conflicts take place between two or more parties in the same country. An example would be the conflicts between farmers and industry (agricultural vs. industrial use of water).

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the current interstate conflicts occur mainly in the Middle East (disputes stemming from the Euphrates and Tigris Rivers among Turkey, Syria, and Iraq; and the Jordan River conflict among Israel, Lebanon, Jordan, and the State of Palestine), in Africa (Nile River-related conflicts among Egypt, Ethiopia, and Sudan), as well as in Central Asia (the Aral Sea conflict among Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, and Kyrgyzstan).

The Jordan River basin area, including parts of Lebanon, Syria, Israel, Jordan, and the West Bank, is primarily an arid region (Figure 6).



(**a**) (**b**)

Figure 6. Jordan River basin: (**a**) shared Israeli–Palestinian waters and (**b**) a satellite picture [53].

The river originates in Lebanon and has a total average flow of 1200 million cubic meters per year. The patterns of water use, overuse, and territorial political issues result in disagreement over water distribution. The increase in population has led to significant challenges in managing limited water supplies. Without a legitimate water-sharing agreement, the countries of Syria and Israel have taken over the water supplies. The construction of reservoirs on the Yarmuk River has reduced the discharge into the Jordan River. The Mountain Aquifer underneath the West Bank is a point of conflict between Israelis and Palestinians. Issues include the domination of groundwater supplies by the Israeli state and settlers and the walling off of Palestinian access to water supplies. Even while Israel and Jordan were legally at war, water officials from both countries met several times a year at so-called "*Picnic Table Talks*". As a result, when the Jordan–Israel Peace Treaty was signed in 1994, it was possible to include a well-developed annex acknowledging that "*water issues along their entire boundary must be dealt with in their totality*" [54,55].

The Euphrates–Tigris Basin is shared among Turkey, Syria, Iraq, and Iran to comprise parts of the Tigris basin. Disputes for water rights go back to antiquity, and until today, no agreement has been reached between the riparian countries. The wider region is characterized by high water stress, and climate fluctuations is predicted to further deteriorate this situation [54–56]. In addition, the area faces severe problems of water quality degradation due to sea level rising, agricultural drainage, and uncontrolled wastewater discharge. The recent decision of Turkey to construct the Ilisu Dam and other smaller projects, to decrease its dependency to oil, is likely to renew the disputes. Currently, bilateral agreements have been reached, but they fail to address the whole problem, considering all of the riparian countries and addressing, effectively, the problem of water quality degradation [54–56]. Iran, for example, is absent from all agreements regarding the distribution of water in the Tigris–Euphrates Basin, except the 1975 Algiers Agreement with Iraq. A multilateral agreement among all riparian countries is crucial for the sustainable management of the basin, to ensure its socioeconomic and ecological stability [54–56].

Another water conflict concerns the Nile Basin. The Nile Basin expands over eleven countries; it is characterized by strong conflicts over water allocation among riparian countries. Currently, the water needs of these countries are barely met; this situation will likely exacerbate in the future due to climate fluctuations and the growing population. In addition, the new development plans in Ethiopia and Sudan will further reduce water flow downstream [54–56]. The Nile Basin Initiative (NBI), founded by 9 out of 10 riparian countries in 1999, has strengthened the cooperation among countries for water rights. However, the planning of the largest hydroelectric dam (Grand Renaissance Dam) on the Nile by Ethiopia reignited disputes among Egypt, Sudan, and Ethiopia. In 2015, the three countries reached an agreement for the management of the Grand Ethiopian Renaissance Dam. The lack of water rights to the Nile water for the other nations, however, provides evidence that the disputes over the Nile water have not ended. For instance, Ethiopia, Kenya, Uganda, Rwanda, Tanzania, and Burundi signed, in 2010, the Entebbe agreement, asking for the redistribution of the Nile water, considering their own rights [54–56].

Theoretically, Afghanistan is characterized by high-water potential, but the lack of water infrastructure has resulted in severe water shortage. The Helmand River, which covers 40% of the country, is shared with Iran, and historically has resulted in strong disputes between the two countries. The flow and distribution of water between the two countries is regulated by a 1973 treaty; currently, Iran receives more water volumes than described in the agreement. Since the commencement of the construction of the Kamal Khan Dam in the Helmand River, disputes have become more intense. Iran argues that the Kamal Khan Dam construction will accelerate the ecological degradation in its water-stressed southeastern region [54–56]. On the other hand, Afghanistan states that the construction of the dam and its operation is consistent with the 1973 water treaty. Poor water management in the basin, the need to ensure a minimum ecological flow to maintain downstream wetlands, climate fluctuations, and the growing population are expected to escalate this dispute in the near future. The countries must find ways to cooperate that ensure sustainable development of the basin and efficient water use [54–56]. In February 2021, the two countries (i.e., Afghanistan and Iran) agreed to commit to a new survey at the Helmand catchment and to reconsider water rights based on the 1973 treaty.

The Mekong River Basin has witnessed an enormous expansion of dam construction for energy production, especially in China and Laos. This growth has led to diplomatic tensions with the countries located downstream of the dams, which face potentially negative impacts (greater floods or seasonal water scarcity). The Mekong River Commission (MRC) has failed to resolve these tensions due to the lack of enforcement and China's opposition to join MRC as a full member. In fact, China is trying to form alliances with the downstream countries though alternative institutional mechanisms, offering assistance for dam construction downstream in the Lower Mekong Basin [54–56].

Rising water demand in India, especially within its agricultural sector, is set to almost double the existing water supply by 2030. Regional disparities of water distribution between Pakistan's Sindh and Punjab provinces could instigate severe internal tensions in the future.

Conflicts over the water distribution of the Indus River date back to the 19th century, but at that time, these were conflicts between the provinces of the Indian sub-continent, which were supposed to be resolved by British India. British India was able to resolve the first major dispute in 1935 through arbitration by the "Anderson Commission". When irrigation demand increased over the next few years, a new dispute emerged, which was resolved in 1942 by the "Rao Commission". With the partition of united India, the Indus Basin was also divided between India and Pakistan in 1947 [54,55], which left the control of Pakistan's irrigation water in the hands of India, geographically. Therefore, water conflicts between the two nations started soon after independence in 1948, when India claimed sovereign rights over the waters passing through its territory and diverted these waters away from Pakistan. This illegitimate control of rivers threatened war when India refused Pakistan's proposal of neutral arbitration to settle the conflict. Later on, the World Bank offered its neutral services to resolve the conflict, and both India and Pakistan agreed [54–56].

The proposal of joint use and development of the Indus Basin as a single water resource was refused in 1952 over the concern of national sovereignty by both, which lead to the division of the Indus and its tributaries. According to this proposal, India was offered three eastern rivers (Ravi, Beas, and Sutlej), while Pakistan was offered three western rivers (Indus, Jhelum, and Chenab). India was also supposed to provide monetary funds to construct canals and storage dams to replace Pakistan's irrigation supplies from the eastern rivers to western rivers. However, India refused to pay for the construction of storage dams, which was then settled through external finance with the help of the World Bank. Since the Indus Waters Treaty (IWT) was signed in September 1960, many controversies have arisen over the design and construction of different projects on both sides of the basin, some of which have been resolved, and others yet to be resolved [56].

From December 2001 to June 2002, India vocally considered pulling out of the treaty, as one of the steps at hitting back at Pakistan for its alleged support of terrorist outfits targeting India [57,58]. In turn, Pakistan stated that it would be prepared to use nuclear weapons over a water crisis [56]. Among other regional experts, a senior Pakistani diplomat confirmed that water has become the core issue between India and Pakistan [59,60].

Within countries—water conflicts: in the 1990s, in Barcelona, adding different water taxes, such as wastewater collection and treatment charges into the municipal water bills, led to the "*water war*" of Barcelona. That event emphasizes that water must be considered a universal service and should be accessible to everybody. This case also indicates how water policies are based on demand to propose environmental and economic gains, while the water policies must also address distributional impacts. During the early 1990s, in Barcelona, the domestic water fee per cubic meter on average rose 108%.

Discontent with the increasing municipal water fee led to a tax revolt. Some non-governmental organizations (NGOs) and neighborhood community groups proposed to pay only water charges, but not the added taxes. Barcelona was impacted by the tax revolt of 2.6 million people. The opponents prepared a platform against high domestic water bills. Retired people and single people also joined the tax revolt. The protests had a strong penetration in municipalities and green NGOs [61,62].

The other violation, in terms of the equity principle, was that larger families (>4 members) had to pay more than small families. In fact, the block-rate structure did not consider the number of members in each family. In 1995, several families complained in the Catalan Higher Court of Justice that the families denounced the unfair conditions regarding large families. In 1997, the Catalan Higher Court of Justice ruled that water bills must be modified with respect to family size.

Finally, the Catalan Administration decided to modify the taxes to ease the impact of water bills for less income families. The regional government eliminated the additional 20% wastewater tax paid by domestic consumers in Barcelona. They modified the tariff based on the location of households, number of used taps, and apartment size. They also agreed to subsidize part of the charges for poor and large families. In 1999, they introduced progressive tariff structures for charges and taxes. They considered substantial increases for those subscribers with the largest consumptions. However, problems regarding fairness and efficiency still loom large. These problems are the objects of tension and conflict between consumers, public administrations, and community groups.

Today, to internalize the charges of environmental improvement, there is institutional consensus. However, spreading the charges evenly across consumers is not the best option to agree on the popular scale. One reason for social opposition may be a general belief that water should be subsidized as a public good. Therefore, a public effort is required to justify Catalan citizens about the value of water to avoid future fights. Despite certain progresses, increasing block tariffs, as well as a high level of fixed costs, may raise the water conflicts in terms of equity. Sometimes, environmental conservation and protection are not necessarily understandable for social justice. Therefore, more sociological efforts are needed to modify water taxes and tariffs [63].

Yemen is one of the water-scarcest countries, with an average water availability of about 120 m^3 per capita/year [64]. Grievances over poor water management, rising inequality, and livelihood losses have led into growing public protests. Water disputes have increased the pressure on the state, and have weakened its capacity to deal with other pressing issues [65]. The already weakened state became increasingly unable to deliver basic goods and services to its people, thereby losing its legitimacy, leaving a vacuum to the benefit of insurgent militants [63].

Dispute over water in the Cauvery river Basin in India, between the Indian states Karnataka and Tamil Nadu, has resurfaced in recent years due to the prevalence of droughts. The consequences include legal battles and violent protests against decisions to alter water allocation between the two states.

Droughts, livestock prices, and armed conflict in Somalia have been associated with severe socioeconomic impacts. Regional and temporal variations in violent conflict outbreaks have been linked to drought severity [66]. Intensive droughts result in massive selling of livestock, decreasing prices, and lowering rural incomes. The lack of employment alternatives may push them to join armed groups, which offer cash revenues to their fighters.

In 2000, the privatization of the drinking water supply in city Cochabamba, Bolivia, resulted in an outbreak of violent protests known as the "*Water War of Cochabamba*". These protests canceled the privatization of the drinking water supply and public access to water received new legal backing. However, the decreasing water supplies resulting from climate influences, over-consumption, and technological deficiencies continue to heavily strain the city of Cochabamba.

In the Pangani River Basin in Tanzania, migration has led to intensive water conflicts between pastoralists and farmers. The main drivers of water conflicts include rapid population growth and increasing livestock, which generate additional demands for water, as do the irrigation systems, reducing water flow for other uses, such as power generation, land alienation, resulting in poor water rights management. Measures to resolve some of these water conflicts include the improvement of irrigation systems, so they do not waste water, and application of environmental impact assessment techniques wherever new projects are introduced in the basin [67].

Use of water as a weapon: there have also been conflicts in which water was not the main target, but was one of the weapons used in a war scenario [68]. This aspect will be examined with reference to the area of the Mediterranean Sea, mainly in the old times. In this area, there are many examples of water or water infrastructure utilization in conflicts over a couple of millennia. This is somehow described in treaties concerning the so-called "*Art of War*" with the contribution of literate, historical, and military commanders; we can divide it in three periods. Ancient Greece with Aeneas Tacticus and Thucydides (5–6 BC), the rule of Rome from the Republic to the Empire with Julius Caesar and Sextus Julius Frontinus (1 Sec. BC–2 Sec. AC), until the era of the Byzantine Empire, with its most important strategy writers, such as Publius Flavius Vegetius and Maurice Emperor (4–6 century AC). Several water wars and conflicts occurred during and after the English Era (1848 AD) among Pakistan, India, Nepal, Bhutan, and Bangladesh. The Indus Valley was, historically, rich in water resources, with very rare water conflicts. However, the Indus Valley was the center of wars and conflicts, historically, and a game-changer of the governing power in the past and the present.

In recent history, the practice of using poisonous materials was generally abhorred at an international level, as stated by the Fourth Geneva Convention signed in 1949. Nevertheless, during the second half of the twentieth century, this practice has been adopted in some cases, especially in regional conflicts.

In 1938, in China, Chiang Kai-shek ordered the destruction of flood-control dikes of the Huayuankou section of the Yellow River, to flood areas threatened by the Japanese army. West of Kaifeng, dikes were destroyed with dynamite, spilling water across the flat plain. Even though the flood destroyed part of the invading army and mired its equipment in thick mud through Wuhan, the headquarters of the nationalist government was taken by the Japanese in October 1938 [34]. The flooded waters covered an estimated area between 3000 and 50,000 km^2, and killed anywhere from (an estimated) tens of thousands to one million Chinese residents [69].

7. Potential and Emerging Trends

One of the basic purposes of this paper rests on the unassailable assumption that we can tell something about the future by looking at the past, or, in simplest words, it looks at what we could learn from the past. By accepting this fact, questions revolve around new approaches, measures, means, technologies, and policies.

By definition, a discussion of the future cannot have the same empirical background as a historical study, since the data just do not yet exist [55]. A potential approach is to consider past practices and technologies in combination with today's existing knowledge. Yet, cutting-edge developments and recent trends might suggest possible changes for future water conflicts, if one examined them within the context of this study. Potential changes in the strategies we will adopt, to deal with or prevent future water conflicts are: public health issues, updated methodological approaches of negotiation, improvements in water availability, and water use efficiency.

7.1. Domestic and Transboundary Water Conflicts

One area of focus in the past regarded the risk of wars between countries arising from water issues. Actually, this discussion was motivated from the 1995 speech of the United Nation (UN) Secretary-General Ban Ki-moon in Stockholm, where he stated, "The wars of this century have been on oil, and the wars of the next century will be on water... unless we change the way we manage water". However, this phrase was isolated from his speech, as he stated in a subsequent commentary [70]. In recent history, no wars have ended between countries due to water conflicts, despite the 310 river basins shared by more than one country, and the identification of hotspots of water conflicts [54,71].

For instance, Peek [63] identified four hotspots of water conflicts during the period 1990 to 2008: (i) between Tajikistan and Uzbekistan as a result of the Rogun Dam construction in the Amu Darya River, which impacted irrigation potential in Uzbekistan. (ii) Among Cambodia, Thailand, Vietnam, and Laos, because of the Don Sahong Dam. (iii) Between Turkey and Iraq due to the impacts of the Ilisu Dam on the Tigris River, which damaged ancient structures in Mesopotamian. (iv) Among Ethiopia, Egypt, and Sudan, due to the Renaissance Dam on the Blue River, which affected the decreasing water flow on the downstream areas.

Today, however, most of these conflicts have been attenuated or even resolved. The relations of Tajikistan and Uzbekistan have greatly improved in recent years, signing several cooperation agreements; according to their leaders, there are "*no remaining unresolved issues*". Following a period of acute tension (1980 to 2000), relations between Turkey and Iraq significantly improved, enabling the reactivation of cooperation in water management of the Tigris and Euphrates basins [72]. Currently, new negotiation basins have been initiated. Regarding the water conflict among Ethiopia, Egypt, and Sudan due to the construction of the Renaissance Dam, an agreement was eventually reached with the involvement of the USA. The construction of Don Sahong (and other ongoing) dams will greatly impact the Cambodian economy, particularly in fishery and agriculture. However, in the recent years, the tension has been attenuated, and collaborations in the field of energy between Ethiopia, Egypt, and Sudan have been developed. Furthermore, the increasing worldwide concern on the impacts of dams in the ecology and biodiversity of the region will contribute to the development of fair agreements regarding the waters in this region.

There are additional examples of successful cooperation between countries in the management of transboundary waters, despite bad relationships (e.g., Israel, Jordan). In recent history, no case of war had its roots in water availability. These examples allow us to safely conclude that such events have a very low risk of occurring in the future, even for countries with bad relations [73]. Despite increasing pressure of water resource availability that will possibly ensue in coming decades, in case of occurrence of droughts, the intensity of water conflicts may revive temporarily. Gathered experience for negotiating and managing transboundary waters, new frameworks for solving water conflict, technological innovations, and involvement of international institutions or countries will attenuate these tensions and will contribute to the fair share of water resources. Predictions of armed conflict come from the media and from popular, non-peer-reviewed work [73].

Within-countries, water conflicts over competing groups for water access and control may have serious consequences. There are several examples of fights between groups, on issues other than water, within one sovereign state. According to a common survey by the World Health Organization (WHO) and the United Nations International Children's Emergency Fund (UNICEF), the average annual number of people killed globally due to water conflicts (75,000) was more than death from natural disasters (63,000), from 1980 to 2015 [74].

Some communities fight not only against water resources and dams, but also against mines and other natural sources. Social communities and NGOs mobilize against the projects that damage local water quality and quantity. Social groups are fighting for socio-environmental and water justice. Their struggles can be considered as a response to the growth of global economy metabolism. The neoliberal policy considers water as a commodity. In addition, private water operators aim to prepare profits rather than global water rights and environmental protection. However, the increasing trend of water withdrawal is not only due to neoliberalism, but also due to state capitalism [55,75].

7.2. Public Health Issues

One of the most significant challenges for humanity is providing people with safe drinking water, an issue that has not been resolved yet in many developing countries around the world. It has been estimated that about 1 billion people have no access to clean water, leading to the death of more than 50 million people annually. Cholera and many other pathogens threaten the lives of more than half of all infected people [76,77]. Such waterborne diseases can be avoided or reduced by advanced drinking water treatment technologies; however, the cost of water treatment is commonly prohibited in developing countries [78,79]. This can be overcome by applying early warning and prevention methods at the sources [80,81] and implementing cost-effective sanitation systems, combined with on-site household sanitation systems, especially for rural areas [82]. It is worth mentioning that some of the problems, in terms of health risks from pollution caused by non-point sources (i.e., nitrates and phosphates used in agriculture, pesticides, etc.), have a great impact in both groundwater and surface water. Water supply is sometimes compromised due to the presence of these pollutants, which can be considered a source of water conflict.

Evidence suggests that waterborne pathogens will continue to be a critical issue for human health, attributed to several underlying factors, such as increasing urbanization, climate extreme events, increasing water reuse practices, conflicts, disasters, traveling, ecosystem disturbance, lack of awareness and education, and social-economic status [83–85]. None of these factors acts individually, but on the contrary, there is a strong synergy between them, which limits the understanding of the onset and progression of diseases. To overcome the problem, we need a robust methodological approach concerning the relations among the critical factors and their contributions to pathogen dispersion and transmission of diseases [85]. It is also critical to increase our understanding of the mechanisms and environmental pathways connecting pathogens to human hosts, which is still a significant challenge due to scale (temporal or spatial)-dependent processes [85–87], and pathogen diversity, which that implies a divergent response to environmental changes [88–90].

Another critical point is how governance and policymakers perceive and manage the challenge of protecting human health, which determines the relevant practices to deal with it, mainly by implementing relevant policies and targeted measures. For example, in the urban health sector, the effort is mainly focused on improving coverage and expanding the provision of health services, which means that the activity is primarily driven by managing the current incidents and the potential pathogen outbreaks [84]. What is essential, however, is to reverse this perception and focus equally on sanitation and environmental hygiene issues preceding healthcare, such as better housing, integrated water supply, sanitation, food quality regulation, and wastewater and solid waste management, which might be more effective than following the modern approach to health care delivery and tackling material poverty [84].

The World Health Organization (WHO) recognizes antibiotics and antibiotic resistance, found in wastewater treatment units, as the most critical public health issue for the 21st century [90]. It is necessary to implement effective tertiary treatment methods [89–94], and elucidate the practices/mechanisms/processes driving Acquired Immunodeficiency Syndrome Resource Group (ARG) transfer sources to the environment (aquatic and soil), and from the environment to animals and humans [95–97], and of the role of other anthropogenic activities to antibiotics and ARG spreading [95]. The Coronavirus Disease 2019 (COVID-19) pandemic, despite the lack of a direct link with water resources, has revealed the severe weaknesses of modern societies regarding their abilities to withstand such extreme situations, and has raised awareness about the need for taking appropriate measurements to prepare our societies to withstand similar events in the future by strengthening their resilience.

Water resources contamination with microbial or chemical agents was always one of the deepest fears of societies. Despite the sophisticated technologies employed in the developed world for the treatment of water intended for potable use, and the intensive monitoring schemes of water quality, contamination of the urban water distribution networks needs more attention. Unfortunately, urgency plans have not yet developed that realistically consider extreme events, even for most developed societies. Developing countries remain even more vulnerable to such events due to lack of resources for developing relevant infrastructure. Such situations will inevitably lead to great tensions among citizens and high death tolls.

Consequences, however, are not limited in urban environments. Intentional contamination of water supplies or breakout of (new) waterborne diseases can expand the crisis to the agri/food systems with huge societal consequences. We recommend that governments in developed and developing countries, in conjunction with well-respected organizations and institutions (WHO, UESCO, UN) must cooperate and develop relevant initiatives that can effectively address such crises, making progress for more sustainable and resilient water systems. A pioneering effort to this direction is the emergency water supply plan—Organization for the Development of Crete S.A. (OAK S.A.). That plan was recently made public, and is pioneering, if not European, certainly at a national level.

Κάλλιον το προλαμβάνειν ή το θεραπεύειν, i.e., "*It is better to prevent or cure it*", Hippocrates (460–370 BC). These plans are considered the most effective means of continuously ensuring the safety and acceptance of water supplies for the intended use. They must incorporate assessment of the risk, considering all the necessary steps in the water supply from the catchment to the final user, followed by the implementation and monitoring of risk management control measures, with emphasis on high-risk hazards. Such methodologies have been recently applied to drinking water (Stockholm framework) and effluent reuse [98–100]. Threats to public health can also result from damages in infrastructure due to failures or the prevalence of extreme events, and they can generate tension between citizens for access to water.

7.3. Use of Non-Conventional Water Resources as a Means to Mitigate Water Competitions and Conflicts

In the next 30 years, it is estimated that the world's population will increase from 7.3 billion today to 9.7 billion. Moreover, by 2030, roughly 60% of the world's population will be living in urban areas. At the same time, the UN anticipates that, by 2030, 60% of the world's population will live near a coastal region, creating even more urban sprawl than what already exists [101,102]. Meanwhile, the available fresh water on earth will remain the same (not distributed evenly). Thus, given the difficulties of developing new water sources and the high percentage of non-revenue water around the world megacities, most water municipalities have to recognize that the development and use of non-conventional water sources can play a vital and crucial role in helping to alleviate water shortage problems.

Fundamentally there is a tendency to increase the use of non-conventional water resources. The reuse of reclaimed wastewater, generated by wastewater treatment plants (WWTPs) and food industries, particularly in agricultural production [102–104], seems ideal for water-scarce problem areas (e.g., Mediterranean basin), promising to reduce user competition for water and relieve pressure on water resources. Developments in (cost) effective, and environmentally and climate-friendly treatment technology is a critical factor in favor of increasing water reuse in these areas [89,91], but they need further political and economic support to address regulatory issues and social-economic constraints [100–106]. An excellent example of this is the legislative initiatives and reuse guidelines proposed by the European Union (EU) [103], which have been adopted in conjunction with other relevant EU policies (e.g., the introduction to the circular economy concept and adaptation to climate change) [103]. In these guidelines [103], among others, the emerging pollutants (e.g., pharmaceuticals and antibiotic resistance genes) are of concern due to their potential to introduce to the trophic chain and harm biodiversity and human health [93]. However, so far, there are no criteria for these substances and, therefore, they need to be accessed and elaborated further before incorporating national legislation [91].

Many researchers have confirmed that rain harvesting (RH) can provide water in urban/suburban, industrial, and rural areas [107–118], promising to save freshwater, a potential that may reduce tensions and competition among users. It is considered a low health risk, cost-efficient, and an environmentally friendly technology [119–121], a fact that has allowed its expansion in many developing and developed countries (EU, USA, UK, Japan, South Korea, Australia, and Africa) [116]. Experience indicates that RH requires advances in the domains of technology [116,122], urban and water planning [121,123], policy [116,124], assessment of economic impacts [125,126], and health risks [122].

Desalination is a technology with a wide range of applications in urban and agricultural areas [127,128], contributing toward reducing water competition and conflicts at local or national scales. The available knowledge and technology in the field (membranes, decreasing costs of operation, lower energy) [129–132] have allowed the expansion of desalination worldwide. However, there are still issues for the environmental footprint of this practice, particularly in developing countries [128,132]. Optimization of the technology, focusing on small-scale desalination plants, combined use of the sea and brackish water, and energy recovery, are of concern for the near future [106,132]. The other issue is the high cost of desalinated water, which has to be incorporated in water tariffs, leading to an increased water price compared to the regular water.

7.4. Water Conflicts and Climate Variability

Many world regions are likely to experience climate-induced impacts that may exacerbate the current water issues related to water resource degradation, water scarcity, and increased competition and/or conflicts among potential users and countries. Climate can influence weather-related hazards, extreme event occurrences, and rainfall and temperature patterns, affecting the water timing and flows on a small or large spatial scale, and further risking the quality and availability of water resources around the world [133–137].

Although there is still considerable uncertainty and relevant debates regarding the current and future impacts of climate variability across the different areas of the planet, arising mainly from the mistrust of applied methodologies [138], it is interesting to investigate the potential effects at least in more climate-vulnerable areas of the planet, such as the Mediterranean and Southern Africa [137,138]. Due to their geographical location, these areas are prone to climate fluctuations, which may further trigger the existing conflicts or tensions among water users on a local scale or even intensify existing conflicts and tensions on the transboundary scale. It is worth noting that some of these countries undergo the impact of other problems, such as poverty, unsuitable infrastructure, and lack of strong institutions, which further challenges the existing tensions, and make it hard to adapt to climate fluctuations [133].

Climate-induced impacts on water resources' status inevitably will cause perturbations in the environment and the social-economic status of the areas of concern, impacting human security and triggering conflicts at various scales [133,137,139]. In the food sector, climate variability can impair food security and production systems, such as cereal yield that contributes to two-thirds of global food consumption [140], risking food availability and the economy [141,142].

Extreme climatic and hydrological events are likely to increase the risk for human health and mortality caused by waterborne, airborne, foodborne, and vector borne diseases, a problem that is mainly expected in the developing countries [82,90,143–146]. Impacts are also expected on terrestrial and marine biodiversity, affecting ecosystems' sustainability and provided services [147,148]. Another important issue is the effect on water use efficiency (WUE) [149,150] and the response of the domestic sector [151]; technological innovations, updated policy frameworks, and market-based solutions can face these challenges [152].

Previous research has indicated that it is difficult to provide a robust relationship between climatic drivers and conflict, as political and economic factors influence the existing conflicts [139,153]. However, it is imperative to increase our understanding of how climate interacts with the socioeconomic system and potential implications in emerging conflicts.

The operation of functional and well-adapted institutions/organizations that could help this task by providing a better understanding of the climate–water–security-nexus via a systematic framework of monitoring, recordings, and/or elaboration upon climate variability, and the environmental and social-economy responses, is commonly accepted. This could facilitate cooperation and conflict resolution at a local, national, or international scale, and propose options to adapt to hazards originated from variations of climatic conditions, fundamental to sustaining human security [154–157].

Policies in the water sector, which promote holistic approaches, that integrate management, coordination, knowledge sharing, and planning across different sectors and water users, supporting sustainable adaptation and fair settlement of the issues raised between users [137].

In 2013, the UN carried on a project entitled "Climate Change, Hydro Conflicts and Human Security (CLICO)" to link economic, social, and political water conflicts and climate change. The results involve some guidelines in several directions for policymakers to improve adaptive capacities, enhancing human security to face climate change, and to decrease vulnerabilities.

7.5. New Approaches of Negotiation and Governance

Current and future advances in science and technology must play an essential role in determining and addressing water's critical issues worldwide. Access to new technologies, such as advanced remote sensing, modeling, water conflict negotiation, and technologies and management practices, which can substantially improve water use efficiency [55] and, hence, availability of water resources spatially and temporally. Widespread adoption of these is expected to strongly improve water resources management and governance.

Negotiation-based conflict resolution mechanisms (CRMs) are the most frequent (34%) strategies to solve water conflicts, followed by arbitration (30%), mediation (28%), and adjudication (8%) [158]. The advent of new variabilities, such as the growth of the globalized economy and climate change, will lead to more challenges in managing transboundary water conflicts [68,159]. Against these challenges, countries develop and establish, besides the in-state, a transboundary legal cooperation framework for water [160]. An important option is to invest in institutional capacities by establishing river basin organizations–institutions and signing agreements or treaties with their neighbors to achieve effective negotiations and cooperation. Institutions of each country delineate the national rights and obligations regarding shared water bodies, signed agreements, or implicit cooperative arrangements, and have in place conflict resolution mechanisms [161]. Moreover, institutions may keep a chronological archive of past and current records for river basin data and issues, analyze the causes of transboundary water conflict, and manage risks from future climate shifts, growth of populations, national policies–measures, and water management [161,162].

The policies (international and domestic) provide legislative framework and support the countries in managing water resources in a sustainable way, which in turn may act as the background knowledge against the problems and challenges in water resources management, on a domestic or even on a transboundary scale. Policy frameworks developed through the adoption of "bottom up" approaches, compared to the traditionally employed "up down" approaches in water resources management, will accelerate the progress to successfully negotiate and prevent tensions between and within states. However, there are challenges in joint management of shared water resources in areas of the planet, particularly where asymmetric power relations coexist with differences in political and legal frameworks between competing countries [160]. Politicization of water constitutes constrain in resolving transboundary conflicts that, in many cases, prevents countries from a common cooperative platform and excludes the involvement of international securitization actors [163–165].

Increasing public participation [166] poses an important tool for producing ideas and solutions in critical issues in water resources management and competitions/conflicts, at a local or national scale. However, it is still a great challenge for many countries and regions of the world. In developed countries, however, there is a remarkable interest in strengthening the public consultation supported by technological tools that allow civilians and organizations to be involved in critical local or national water issues. An example of this is the adoption by governments of public consultation (via an internet platform), involving the inter-discipline participation and investigation of emerging water issues. There are also many other electronic applications, forums, and data resources, which support public participation directly or indirectly [165]. An example of this is the new software called "*civic games*" belonging to a new class of socially-engaged games [165]. The purpose of this software is to involve citizens in public affairs and democratic processes. It presents several underlying principles that configure civic games. It also shows how the software links water scarcity and environmental policy with water wars.

Different approaches proposed, such as the human rights-based approach and Transboundary Water Interaction Nexus (TWINS) concept, still face challenges, mainly arising from socio-political and technical limitations [160,166,167]. The game theory has been introduced into water resources [168,169]. Tian et al. [167] developed a framework to deal with inter-regional water resource conflicts in China (Figure 7). They established an evolutionary game based on game theory between the two sides of water rights trading. They provided a new solution to solve water disputes in transboundary regions by establishing water markets and water rights trading.

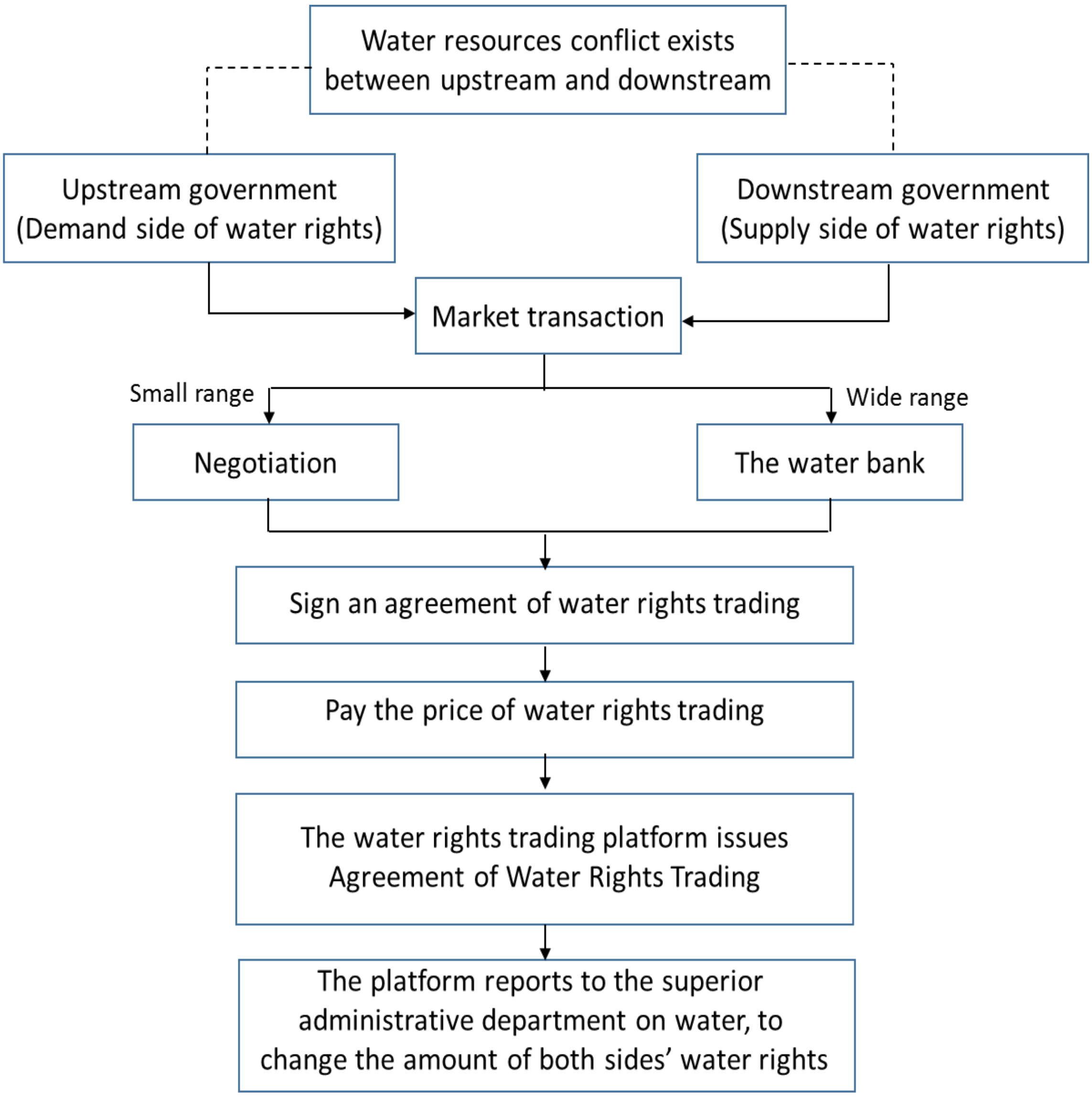


Figure 7. A mechanism for coordination of inter-regional water resources conflict [167].

8. Epilogue

The current global population growth, as well as urbanization, exacerbate the difficulties that cities face to provide water and sanitation services, particularly in developing countries. On the other hand, complicated socioeconomic problems, including inequality, incompetent legal frameworks, land use/cover changes, poverty, and poor water governance have important implications for the management of urban and rural water resources. Reforms in the shape of ownership and management of water and sanitation facilities via privatization and various forms of semi-private and public partnerships also have impacts on access to water resources. These reforms may lead to the augmentation of water conflicts over access to water resource services if not undertaken with serious consideration to socioeconomic situations. The collection of references presented in this paper focus on water conflicts, politics, wars, arguments, fights, tensions, and violence, in an effort to determine controversial aspects of water resources management.

As states rely on competing claims and rising war conflicts—which not only occur in modern history, but also in prior millenniums—it is no coincidence that, as the years pass, the inequity of water distribution will expand globally. This element is indicative of how likely the scenario will be of future wars causes (in regards to claiming aquifers) [170].

Since Bronze Age, massive droughts that wiped out cities, civilizations—as we have learned from history—depend on water. This precious resource has been a source of tension and a factor in conflicts among countries, states, and groups, and will continue to be a determining factor for development in the future.

The United Nations recognizes that water disputes result from opposing interests of water users, public or private [171]. Other terms of water conflict describe it as a conflict between countries, states, or human groups over access to water resources [99,171–173].

The same methods of conducting armed conflicts are strongly influenced by the water factor, which has therefore constituted a crucial aspect of military logistics since ancient times. Units of the Roman army during the military campaigns were specifically assigned to water transportation, as shown in Rome on the Trajan and Aurelian Columns, depicting soldiers loading water barrels on wagons supporting the troops. In recent times, technological evolution has strongly influenced the logistics systems supporting the troops, especially in areas with a shortage of water resources. The first mobile desalination units—"*distillers*"—were used during World War II in the Pacific area; subsequently, since the 1980s, there has been increasing use of reverse osmosis systems.

Various sub-disciplines have grappled with war's etiology, but each in turn, as with definitions of war, often reflects a tacit or explicit acceptance of broader philosophical issues on the nature of determinism and freedom. Heraclitus decried that war is the father of all things, and Hegel echoed his sentiments. Interestingly, even Voltaire, the embodiment of the Enlightenment, followed this line: "*famine, plague, and war are the three most famous ingredients of this wretched world...Air, earth and water are arenas of destruction*" (from Pocket Philosophical Dictionary).

The high number of shared rivers, combined with increasing water scarcity for growing populations, led many politicians to claim that the wars of the next century will be about water. The only problem with this scenario is a lack of evidence. While water supplies and infrastructure have often served as military tools or targets, no states have gone to war specifically over water resources, since the city–states of Lagash and Umma fought each other in the Tigris−Euphrates Basin in 2500 BC. Instead, according to the Food and Agriculture Organization of the United Nations (FAO), more than 3600 water treaties were signed from 805 to 1984 AD. Whereas most were related to navigation, over time, a growing number addressed water management, including flood control, hydropower projects, or allocations in international basins. Since 1820, more than 680 water treaties and other water-related agreements have been signed, with more than half of these concluded in the past 50 years.

The historical record proves that international water disputes do get resolved, even among enemies and even as conflicts erupt over other issues. Some of the world's most vociferous enemies have negotiated water agreements, or are in the process of doing so, and the institutions they have created often prove to be resilient, even when relations are strained.

The Mekong Committee, for example, established by the governments of Cambodia, Laos, Thailand, and Vietnam as an intergovernmental agency in 1957, exchanged data and information on water resources development throughout the Vietnam War (1955–1975). Israel and Jordan have held secret "*picnic table*" talks on managing the Jordan River, following the unsuccessful Johnston negotiations of 1953–1955, even though they were at war from the time of Israel's establishment in 1948 until the 1994 peace treaty. The Indus River Commission set up under the Indus Waters Treaty between India and Pakistan in 1960 survived two major Indo–Pakistani wars in 1965 and 1971. All 11 Nile Basin riparian countries are also currently involved in senior government-level negotiations to develop the basin cooperatively, despite continuing disagreement between upstream and downstream states. So, are we going to see a third world war over water, as some alarming predictions suggest? It is unlikely, say most analysts. More probable are regionalized conflicts between neighboring states that are heavily dependent on the same water source.

If China decides to continue damming upstream sections of the Mekong river, then the downstream impacts on Burma, Thailand, Laos, Cambodia and Vietnam could be profound. Similarly, Uzbek farmers are unlikely to take kindly to Tajikistan's desire to dam the Vakhsh river. Nor have moves by Ethiopia, to build a hydropower facility on the Nile, been well received in Cairo.

As for the use of water as a weapon of war, one can conclude that it is unfortunately still an element present in military conflict or in situations of "*asymmetric war*"—from the bombing of dams in Europe in the Second World War to the destruction of water infrastructure, and attempts to contaminate water by terrorist groups, especially in the Middle East. Despite the existence of shared international rules, the problem persists, and this is why we need to be prepared—from a technical point of view—to protect the populations. Reasonable and democratic agreements are necessary.

Future water conflicts will be somewhat different from the past with different types of challenges [174–176]. These new challenges include a water–energy nexus complicated further by the energy–water–land (EWL) nexus, which is then further complicated by the climate-EWL nexus, with many linkages and interactions, with the three resource sectors and climate fluctuations [176]. Water conflicts will also include water supply systems security [175], especially related to terrorism, where "*water resources or water systems are either targets or tools of violence or coercion by non-state actors*". The vulnerabilities in water supply systems include raw water sources (surface and/or groundwater); raw reservoirs; raw water channels and pipelines; connections to water distribution systems; pump stations and valves; and finished water tanks and reservoirs. Physical disruption would include destroying or disrupting key elements of the water system; however, contamination has generally been viewed as the most severe potential threat to water supply systems.

The concept of sustainability is also a major component of water conflicts. In particular, water resources sustainability, which is defined as follows [176]: "*Water resources sustainability is the ability to use water in sufficient quantities and quality from the local to the global scale to meet the needs of humans and ecosystems for the present and the future to sustain life and to protect humans from the damages brought about by natural and human-caused disasters that affect sustaining life*". In summary, the future will be challenging in regards to water conflicts, especially in areas that have potential for water crisis challenges, such as central Asia [177,178].

It must be noticed that water can be considered as a weapon to fight enemies/rivals who want to access/withdraw water for their benefit. Additionally, it can be considered as a resource to fight for when its availability is very low. Therefore, the access to water could be a weapon against or a reason for a fight.

Today and in the future, there is a greater focus on the peaceful sharing and management of water at both the international and the local level in the developed world. Moreover, there is a tendency to reduce water use and increase water production. However, in the developing world, internal, sub-state conflicts about water are endangering the livelihoods of millions of people and, therefore, deserve the international community's full diplomatic, scientific, and financial attention.

Author Contributions: Conceptualization, A.N.A.; methodology, A.N.A.; investigation, A.N.A.; writing—original draft preparation, A.N.A.; writing—review and editing, A.N.A., M.V., A.T.A., V.T., N.V.P., J.K., R.D., L.M., F.E.G., D.K., S.K. and L.J.D.G.; supervision, A.N.A. and M.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors greatly acknowledge Cynthia Lynn Hann for her considerable contribution of English grammatical and fluidity improvement in the development of this paper.

Conflicts of Interest: The authors declare no conflict of interest.

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