The vanishing of Iran's Lake Urmia

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CHAPTER 6

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Matthias Schmidt

Abstract

The Middle East is characterised by high water stress. Current climate change processes and increasing demand are leading to even higher water stress in the future. A drastic example not only of the mismatch between limited water availability and high water consumption, but also of intense human intervention in hydrology, is the desiccation of Lake Urmia, Iran's largest inland lake and one of the most substantial hypersaline lakes in the world. This massive environmental crisis which has long gone unnoticed by the world is by no means a natural phenomenon but a human-made environmental and social disaster which can also be seen as a disastrous feature of the Anthropocene. This article deals with the causes and consequences of the water crisis surrounding Lake Urmia.

1 Introduction

Aridity and desert-like landscapes are widespread images connected with the Middle East. In fact, large parts of the Middle East are characterised by irregular and low precipitation patterns and by sparse vegetation cover, steppes and deserts. In order to live in such environmental conditions, humans have had to develop specific adaptations. Over the centuries, societies in the Middle East have evolved sophisticated forms of water management to match the spatial and seasonal limited water availability. The famous qanats as well as distinctive systems of water procurement and distribution[1] are striking indicators of these

1 Hans E. Wulff, "The Qanats of Iran," *Scientific American* 218 (1968): 94–105; Peter Beaumont, "Qanat Systems in Iran," *Hydrological Science Journal* 16 (1971): 39–50; Peter Beaumont, and Michael E. Bonine, *Qanat, Kariz and Khattara: Traditional Water Systems in the Middle East and North Africa* (London: University of London, 1989); Mahmoud Jomehpour, "Qanat Irrigation Systems as Important and Ingenious Agricultural Heritage: Case Study of the Qanats of Kashan, Iran," *International Journal of Environmental Studies* 66 (2009): 297–315; Asghar Tahmasebi, "Indigenous Knowledge for Water Management in Iran's Dry Land—Siraf," *International Journal of Environmental Studies* 66.3 (2009): 317–325; Fatemeh Zafarnejad, "The Contribution of Dams to Iran's Desertification," *International Journal of*

efforts, established thousands of years ago (see also Eckart Ehlers, "Deserts—Wind—Water," Chapter Five in this volume). These physical structures and institutional arrangements were well adapted to the climatic conditions of the region and allowed the evolution of advanced civilisations. Human creativity and agency were the central factors in using limited natural resources, most importantly water, and creating the ability to live in such environments.

Over the past centuries, however, it has become more and more obvious that human beings not only have the ability to establish and evolve advanced civilisations including the creation of sophisticated technologies and institutions, but also that human agency is a destructive force leading to extensive changes and severe damage to the natural environment more often than we would wish. Human beings have not only transformed the land cover in almost all corners of the planet by removing forests, planting crops, digging canals or founding settlements, but their construction works and exploitation efforts have also led to widespread erosion, interference in the ecology through the extinction of species, and the burning of fossil fuels on a vast scale leading to pollution and, finally, global climate change.

The Middle East is particularly exposed to climate change since already low and decreasing precipitation rates can quickly lead to severe droughts. Prolonged droughts, desertification, and landscape degradation are already widespread in the Middle East;[2] in fact, the water supply is running short in many places through diminishing groundwater tables or the springs drying up. These obvious and highly problematic examples of environmental change and water shortage are often explained by climate change, though a closer look very quickly shows that these effects are in fact the result of a number of factors.

Today, the Middle East is experiencing severe water scarcity which is projected to get even worse in the near future.[3] As a consequence, there is high

Environmental Studies 66.3 (2009): 327–341; Yazdi Semsar, Ali Asghar, and Majid Labbaf Khaneiki, *Qanat Knowledge: Construction and Maintenance* (Dordrecht: Springer, 2016).

2 Madjid Abbaspour, and Alieh Sabetraftar, "Review of Cycles and Indices of Drought and their Effect on Water Resources, Ecological, Biological, Agricultural, Social and Economical Issues in Iran," *International Journal of Environmental Studies* 62.6 (2005); Zafarnejad, "The Contribution,"; Amiraslani, Farshad, and Deirdre Dragovich, "Combating Desertification in Iran over the Last 50 Years: An Overview of Changing Approaches," *Journal of Environmental Management* 92 (2011): 1–13; Iraj Emadodin, and Hans Rudolf Bork, "Degradation of Soils as a Result of Long-term Human-induced Transformation of the Environment in Iran: An Overview," *Journal of Land Use Science* 7.2 (2012): 203–219.

3 United Nations World Water Assessment Programme (WWAP)/UN-Water, *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water* (Paris: UNESCO, 2018), 12. Regions are considered severely water scarce when total annual withdrawals for human use exceed forty per cent of the total available renewable surface water resources.

water stress,[4] which means an unfavourable water withdrawal-to-availability ratio.[5] Thus, water scarcity is not only a function of precipitation and evaporation, but it must also be seen in connection with human water consumption. Population growth aligned with increasing food demand, economic development, and modernisation efforts in the Middle East have all led to growing water demand, resulting in increasing water stress and even water crises in the region.[6]

A particularly drastic example of one such water crisis is the desiccation of Lake Urmia, Iran's largest lake. Lake Urmia is located in a highly dynamic region in which population numbers and settlements have scaled up significantly over the last few decades and, following the paradigm of technocentric modernisation, where several dams have been built for power generation and to feed irrigation systems, leading to an enormous expansion of irrigated farmlands. As a result, the inflow from several rivers into Lake Urmia has decreased dramatically.

No other lake of this magnitude has dried out so quickly in such a short time. Parallels are evident when comparisons are made to the once much larger, now largely dried-out Aral Sea.[7] These processes became well-known in science and are discussed as the so-called Aral Sea syndrome.[8] Worldwide attention to the disastrous developments at Lake Urmia, however, came relatively late, mainly due to the political isolation of Iran and the restrictive information policies of its government. A major characteristic of the Aral Sea syndrome is the restructuring of landscapes by centrally planned large-scale projects including the construction of dams, canals, and irrigation systems to achieve strategic goals without considering ecological and social consequences

4 WWAP, *The United Nations World Water Development Report 2016: Water and Jobs* (Paris: UNESCO, 2016), 17.

5 Karen Frenken, *Irrigation in the Middle East Region in Figures. AQUASTAT Survey—2008* (Rome: Food and Agriculture Organization of the United Nations, 2009); Petra Hellegers, Walter Immerzeel, and Peter Droogers, "Economic Concepts to Address Future Water Supply-Demand Imbalances in Iran, Morocco and Saudi Arabia," *Journal of Hydrology* 502 (2013): 62–67.

6 Richard Foltz, "Iran's Water Crisis: Cultural, Political, and Ethical Dimensions." *Journal of Agricultural and Environmental Ethics* 15 (2002): 357–359.

7 Philip Micklin, "The Aral Sea Disaster," *Annual Review of Earth and Planetary Sciences* 35 (2007): 47–72; Philip Micklin, Nikolai V. Aladin, and Igor Plotnikov, *The Aral Sea: The Devastation and Partial Rehabilitation of a Great Lake* (Heidelberg: Springer, 2014); Amir AghaKouchak et al., "Aral Sea Syndrome."

8 Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, *Welt im Wandel: Herausforderungen für die deutsche Wissenschaft*. Jahresgutachten 1996 (Bremerhaven: WBGU, 1996), 125.

and ignoring local conditions. Its consequences include large-scale environmental degradation, biodiversity loss, local climate change, deficient fresh water supply, soil degradation, forced resettlement of local populations, and water conflicts between political entities.

This paper analyses and discusses the main reasons for and consequences of the desiccation of Lake Urmia as an example of human destructive effects on the water cycle in the Middle East.

2 Desiccation of Lake Urmia

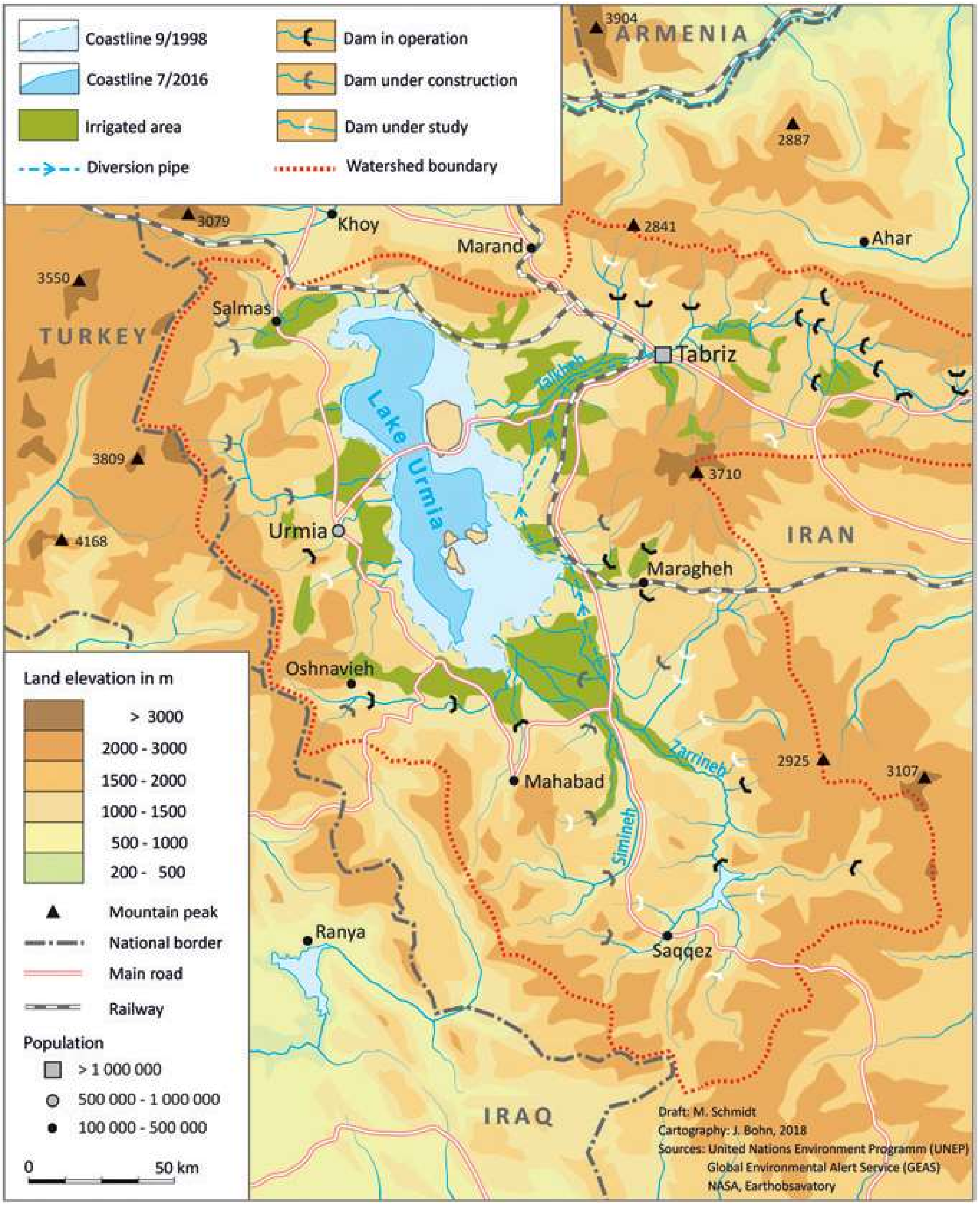
Lake Urmia is located at an altitude of 1276 metres at the edge of the Zagros Mountains in northwestern Iran and is the country's largest inland body of water (map 6.1). Due to its unique ecology as a wetland in a desert-like landscape, it was declared a protected wetland area by the Ramsar Convention in 1975 and a UNESCO Biosphere Reserve in 1976. At the time, despite its high salt content, it had a remarkably high level of biodiversity[9] and was the largest habitat of the endemic *Artemia urmiana*, a brine shrimp species that adapted very well to the hypersaline environment. *Artemia urmiana* was also an important element in the food chain for more than two hundred species of migratory birds such as ibis, storks, geese, and gulls that rested on or near the lake during their annual migration.[10] In addition, river mouths and brackish water swamps represented important biodiversity hotspots.

Twenty years ago, Lake Urmia covered an area of about 5,200 square kilometres. Since then, it has lost about eighty per cent of its water volume, causing the lake's surface to shrink to fewer than 2,000 square kilometres and the overall level to fall by more than six metres[11] (fig. 6.1 and 6.2). At the same time,

9 Alireza Asem et al., "Biodiversity of the Hypersaline Urmia Lake National Park (NW Iran)," *Diversity* 6 (2014): 126.
Alireza Asem, Amin Eimanifar, and Michale Wink, "Update of 'Biodiversity of the Hypersaline Urmia Lake National Park (NW Iran)'," *Diversity* 8.6 (2016): 7.

10 UNEP-GEAS, "The Drying of Iran's Lake Urmia and its Environmental Consequences," *Environmental Development* 2 (2012): 129; Amin Eimanifar, and Feridon Mohebbi, "Urmia Lake (Northwest Iran): A Brief Review," *Saline Systems* 3.5 (2007): 5–6.

11 Iran Environment and Wildlife Watch (IEW), accessed May 18, 2018. http://www.iew.ir/1396/10/19/57250; Somayeh Sima and Mohammad Tajrishy, "Using Satellite Data to Extract Volume—Area—Elevation Relationships for Urmia Lake, Iran," *Journal of Great Lakes Research* 39.1 (2013): 94; Amir AghaKouchak et al., "Aral Sea Syndrome Desiccates Lake Urmia: Call for Action," *Journal of Great Lakes Research* 41.1 (2015): 308; Mohammad J. Tourianet al., "A Spaceborne Multisensor Approach to Monitor the Desiccation of Lake Urmia in Iran," *Remote Sensing of Environment* 156 (2015): 349;



MAP 6.1 Lake Urmia watershed in Northwest Iran with irrigated areas and water dams.

Somayeh Shadkam et al., "Impacts of Climate Change and Water Resources Development on the Declining Inflow into Iran's Urmia Lake," *Journal of Great Lakes Research* 42 (2016): 943; Somayeh Shadkam et al., "Water-saving Interventions Assessment Framework: an Application for the Urmia Lake Restoration Program." *Geophysical Research Abstracts* 19 (2017): 1; Urmia Lake Restoration Program (ULRP), "Urmia Lake Restoration Program: Brief Report and Projects Outline," last modified October 2, 2015, accessed May 18, 2018. https://usu.instructure.com/files/61057414.

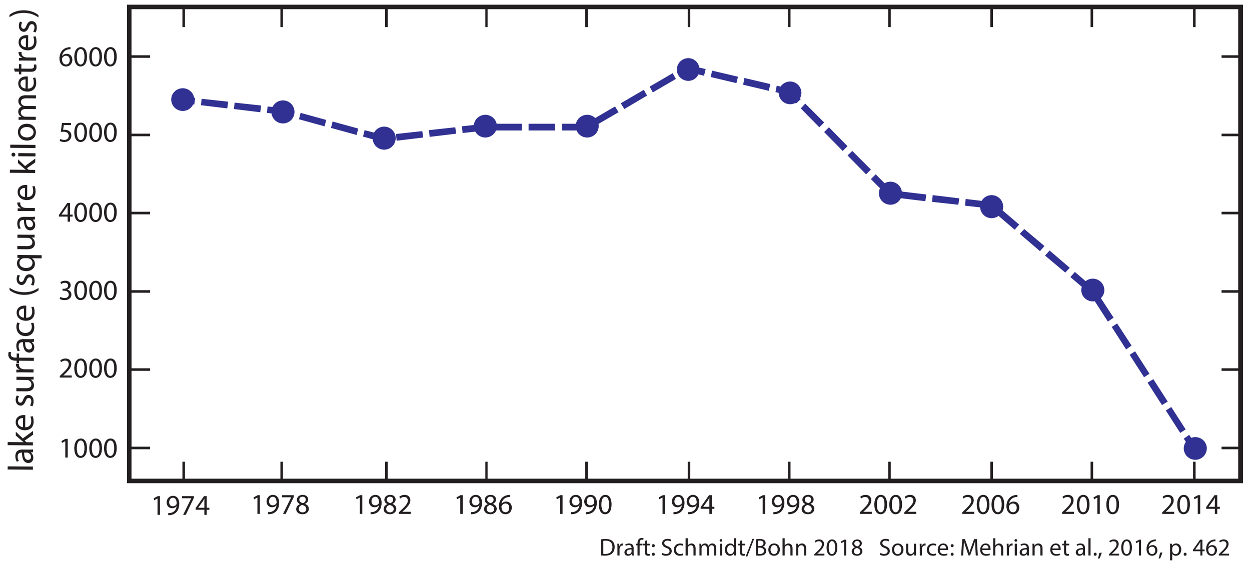


FIGURE 6.1 Lake Urmia's surface area changes between 1974 and 2014.

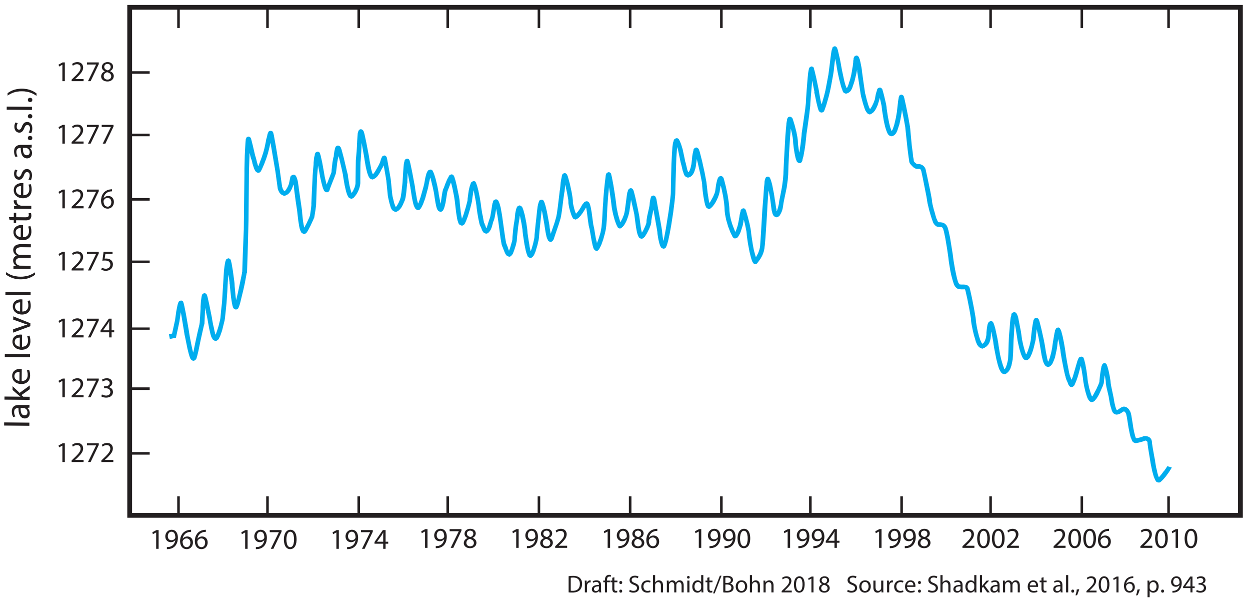


FIGURE 6.2 Lake Urmia's surface elevation changes between 1966 and 2010.

the salt content in the remaining lake water has risen to such an extent that most organisms cannot survive.

Significant fluctuations in water levels and shorelines are not unusual for endorheic lakes, as can be seen, for example, at Great Salt Lake in the USA or Lake Chad in Central Africa. Accordingly, water volume—and thus the surface area of Lake Urmia—has always varied considerably due to climate change processes and weather variability. However, the current water loss is unparalleled in terms of its sheer speed, causing a historical low the causes of which cannot be traced back to natural phenomena alone. The recent development of Lake Urmia is a rather extreme example of human intervention in a fragile ecosystem.

The reasons for this dramatic water loss are diverse and of intense interest to the scientific community.[12] Desiccation is blamed consistently on a combination of climate change and direct human interference in the water cycle,[13] but in either case, one may safely suggest that it has been influenced by humans since the present climate change is human-induced, and can thus be seen as a warning sign which could presage future events and hazards.

3 Climatic Conditions and Recent Changes

Water is an essential natural resource and is widely available in many areas of the world, but in short supply in others. Although the Middle East is commonly seen as an arid region with very limited water resources, there are areas with high precipitation rates and water abundance such as Eastern Anatolia, the Lebanon Mountains, or the Elburz Mountains. However, the prevalent image of the Middle East as a desert or steppe region is not wrong in principle since large areas are subject to arid to semi-arid climatic conditions.

This holds particularly true for Iran, where the climate in most parts of the country is characterised by low and irregular rainfall and high temperatures, and thus enormous evaporation potential. Significantly higher precipitation

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12 Alizadeh-Choobari, Omid, and Mohammad S. Najafi, "Extreme Weather Events in Iran under a Changing Climate," *Climate Dynamics* 50.1–2 (2018); Hassanzadeh, Elmira, Mahdi Zarghami, and Yousef Hassanzadeh, "Determining the Main Factors in Declining the Urmia Lake Level by Using System Dynamics Modeling." *Water Resource Management* 26.1 (2012): 129–145; Sheida Jalili, Sajad Ahmad Hamidi, and Reza Namdar Ghanbari, "Climate Variability and Anthropogenic Effects on Lake Urmia Water Level Fluctuations, Northwestern Iran," *Hydrological Sciences Journal* 61.10 (2016); Shadkam et al., "Impacts of Climate,"; Shadkam, Somayeh et al., "Preserving the World Second Largest Hypersaline Lake under Future Irrigation and Climate Change," *Science of the Total Environment* 559 (2016); Taravat Talebiet al., "The Late-Holocene Climate Change, Vegetation Dynamics, Lake-level Changes and Anthropogenic Impacts in the Lake Urmia Region, NW Iran." *Quaternary International* 408 (2016).

13 AghaKouchak et al., "Aral Sea Syndrome," 309–310; Farshad Fathian, Zohreh Dehghan, and Saeid Eslamian, "Analysis of Water Level Changes in Lake Urmia Based on Data Characteristics and Non-parametric Test," *International Journal of Hydrology Science and Technology* 4.1 (2014): 35–36; Fatemeh G. Hamzekhani, Bahram Saghafian, and Shahab Araghinejad, "Environmental Management in Urmia Lake: Thresholds Approach." *International Journal of Water Resources Development* 32.1 (2016): 84–86; Hassanzadeh, Zarghami, and Hassanzadeh, "Determining,"; Jalili, Hamidi, and Ghanbari, "Climate Variability," 139–143.

rates can only be found in the Zagros and the Elburz Mountains where water generation exceeds evaporation and water consumption so that these areas serve as the main water sources for other regions of Iran.

Various studies as well as the daily experience of the local population demonstrate that the Middle East is highly affected by present and future climate change which is already one of the main reasons for worsening extreme heat, drought, and aridity.[14] Climate projections for the Middle East predict a high increase in average temperatures and a strong decrease in precipitation.[15] Iran already warmed by nearly 1.3°C between 1951 and 2013 and is showing an increase in the frequency of heat extremes, while annual precipitation has decreased by eight millimetres per decade, causing an expansion of the country's dry zones.[16]

Moreover, these climatic and hydrological changes, paired with population growth and modernisation efforts, and thus increasing water consumption, will intensify the already severe levels of water stress in most regions.[17] The agricultural sector in particular is highly exposed to changing climatic conditions,[18] because in rain-fed areas, lower precipitation and more frequent droughts will lead to decreasing yields[19] and more crop failures while re-

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14 Katharina Waha et al., "Climate Change Impacts in the Middle East and Northern Africa (MENA) Region and their Implications for Vulnerable Population Groups," *Regional Environmental Change* 17 (2017).

15 Jason P. Evans, "21st Century Climate Change in the Middle East," *Climatic Change* 92 (2009): 431; Hossein Tabari and Parisa Hosseinzadeh Talaee, "Temporal Variability of Precipitation over Iran: 1966–2005," *Journal of Hydrology* 396 (2011): 313; Mohammad R. Kousari, Hossein Ahani, and Razieh Hendizadeh, "Temporal and Spatial Trend Detection of Maximum Air Temperature in Iran during 1960–2005," *Global and Planetary Change* 111 (2013): 97; Edoardo Bucchignani et al., "Climate Change Projections for the Middle East-North Africa Domain with COSMO-CLM at Different Spatial Resolutions," *Advances in Climate Change Research* 9 (2018): 66; Tugba Ozturk et al., "Future Projections of Temperature and Precipitation Climatology for CORDEX-MENA Domain Using RegCM4.4," *Atmospheric Research* 206 (2018): 102–104.

16 Alizadeh-Choobari, and Najafi, "Extreme Weather," 249.

17 Kaveh Madani, "Water Management in Iran: What is Causing the Looming Crisis?" *Journal of Environmental Studies and Sciences* 4 (2014): 315; Hossein Hashemi, "Climate Change and the Future of Water Management in Iran," *Middle East Critique* 24.3 (2015): 320–321.

18 Hamideh Maleksaeidi, and Ezatollah Karami, "Social-Ecological Resilience and Sustainable Agriculture under Water Scarcity," *Agroecology and Sustainable Food Systems* 37.3 (2013): 262–290.

19 Sarvenaz Farhangfar et al., "Vulnerability Assessment of Wheat and Maize Production Affected by Drought and Climate Change," *International Journal of Disaster Risk Reduction* 13 (2015): 37; Hassan M. Mosammam et al., "Analyzing the Potential Impacts of Climate

duced water discharge,[20] already critically low, will affect most irrigated lands with negative consequences for food production.[21] Additionally, higher average temperatures and more heat extremes are increasing the evaporation potential, resulting in higher water demand for crop fields. Furthermore, from a livestock point of view, prolonged dry seasons reduce the length of time that rangelands can be grazed.[22]

In semi-arid areas such as northwestern Iran, precipitation is irregular and long dry periods are not unusual, which has led to considerable fluctuations in the level of Lake Urmia in the past,[23] reaching its peak between 1994 and 1996. The climate development of the last decades, however, has engendered a significant trend towards higher air temperatures, decreasing precipitation, and increasing drought periods.[24] For instance, the average annual precipitation in the Urmia basin decreased by 14.8 millimetres per decade from 1968 to 2011 while the average temperature increased by 0.18°C per decade in the same period.[25]

This not only reduced direct inflow into the lake,[26] but also increased the evaporation rate and subsequently the water demand of the agricultural sector.[27] A climate change scenario indicates a further increase in temperature by +0.88°C and a precipitation loss equal to 0.37 millimetre per decade by the year 2100.[28] It is clear that these trends are consequences of human-induced

Change on Rainfed Wheat Production in Hamedan Province, Iran, via Generalized Additive Models," *Journal of Water and Climate Change* 7.1 (2016), 212.

20 Mahdi Zarghami, et al., "Impacts of Climate Change on Runoffs in East Azerbaijan, Iran," *Global and Planetary Change* 78 (2011): 137.

21 Alireza Gohari et al., "Climate Change Impacts on Crop Production in Iran's Zayandeh-Rud River Basin," *Science of the Total Environment* 442 (2013): 405; Waha et al., "Climate Change Impacts," 1623–1624.

22 Evans, "21st Century," 417; Asghar Tahmasebi, Eckart Ehlers, and Conrad Schetter, "Climate Change and Mountain Pastoralism—The Shahsevan of Northwest Iran," *Erdkunde* 67.4 (2013): 320.

23 Shadkam et al., "Impacts of Climate Change," 943; Jalili, Hamidi, and Ghanbari, "Climate Variability," 1766.

24 Tabari, and Talaee, "Temporal Variability," 313; Amir H. Delju et al., "Observed Climate Variability and Change in Urmia Lake Basin, Iran," *Theoretical and Applied Climatology* 111.1–2 (2013): 295; Jamileh Farajzadeh, Ahmad Fakheri Fard, and Saeed Lotfi, "Modeling of Monthly Rainfall and Runoff of Urmia Lake Basin Using 'Feed-Forward Neural Network' and 'Time Series Analysis' Model," *Water Resources and Industry* 7–8 (2014): 46–47; Alireza Taravat et al., "A Spaceborne Multisensory, Multitemporal Approach to Monitor Water Level and Storage Variations of Lakes," *Water* 8.11 (2016): 478.

25 Zarrineh, and Abad, "Integrated," 43.

26 Zarghami et al., "Impacts of Climate Change," 137.

27 ULRP, "Urmia Lake Restoration Program."

28 Zarrineh, and Abad, "Integrated," 43.

climate change, and so the increased air temperatures and aridity that appear to be natural processes must in fact be counted as anthropogenic causes.

It seems obvious that climate change has already influenced and will continue to transform hydrology in many areas of Iran, and the desiccation of Lake Urmia is an extreme example of this. Moreover, it has the potential to put additional ecological, economic, and societal pressure on the already existing high water stress as it poses serious challenges to populations whose livelihoods depend principally on water and natural resources.[29] Paired with a lack of resilience, this will cause high levels of vulnerability within the agricultural sector. However, a closer look at Lake Urmia shows that an explanation based purely on climatic arguments is insufficient since other factors are more relevant to this severe ecological disaster.

4 Human Hydrological Interference

In addition to climatic factors, various direct effects of human agency are even more relevant to the desiccation of Lake Urmia. The socioeconomic development in Northwest Iran in the form of high population growth, increasing urbanisation, and extensive infrastructure expansion has been accompanied by massive intervention in the water cycle.[30]

Notably, 48 dams have been built in the Lake Urmia catchment area over the last few decades. These are used for power generation, flood protection, and the expansion of irrigation areas. Another 24 dams have been under construction or were planned until recently[31] (see map 6.1). In principle, hydro-

29 Marzieh Keshavarz, Ezatollah Karami, and Mansoor Zibaei, "Adaptation of Iranian Farmers to Climate Variability and Change," *Regional Environmental Change* 14 (2014): 1163.

30 Shahram Khalighi Sigaroodi and Shiva Ebrahimi, "Effects of Land Use Change on Surface Water Regime (Case Study Orumieh Lake of Iran)," *Procedia Environmental Sciences* 2 (2010); Delju et al., "Observed Climate"; Farajzadeh, Fakheri F., and Lotfi, "Modeling of Monthly"; Hassanzadeh, Zarghami, and Hassanzadeh, "Determining"; Henareh Khalyani, Mayer, and Norman, "Water Flows"; Somayeh Shadkam et al., "Preserving the World Second Largest Hypersaline Lake under Future Irrigation and Climate Change," *Science of the Total Environment* 559 (2016); Talebi et al., "The Late-Holocene"; Mostafa Zeinoddini, Arash Bakhtiari, and Majid Ehteshami, "Long-term Impacts from Damming and Water Level Manipulation on Flow and Salinity Regimes in Lake Urmia, Iran," *Water and Environment Journal* 29 (2015); Alizadeh-Choobari and, Njafi, "Extreme Weather,"; Jalili, Hamidi, and Ghanbari, "Climate Variability."

31 Azad Henareh Khalyani, Audrey L. Mayer, and Emma S. Norman, "Water Flows toward Power: Socioecological Degradation of Lake Urmia, Iran," *Society & Natural Resources* 27.7 (2014): 762.

logical electricity generation does not lead to a reduction in available water volume because only the kinetic energy of the water is used and not the water itself. Nevertheless, with the extension of open water bodies under arid climatic conditions, large amounts of water are lost as flow velocities are lowered and the water surface massively enlarged, which results in significantly higher evaporation.

An even more significant intervention in the water cycle is the function of the reservoirs for irrigation purposes. Agriculture is the largest water consumer in Iran, accounting for 92 per cent of the total demand.[32] In the Lake Urmia catchment area, irrigated farmland has increased in size by 67.5 per cent, from 3,035 square kilometres in 1984 to 5,086 square kilometres in 2014.[33] Overall, the total size of cultivated land has tripled in recent times,[34] while a great deal of previously solely rain-fed agricultural land has become irrigated farmland. This major increase in farmland is the result of demographic and political developments: on the one hand, the high population growth in Iran—the number of inhabitants rose from 61 to 82 million between 1996 and 2018—and the changed consumption patterns that go along with ongoing modernisation processes, and on the other hand, the international trade embargo imposed on Iran that forced the nation's government to increase food production to secure the food supply of its own population.

In addition to the discharge of surface water from tributaries, groundwater is increasingly used intensively in the Lake Urmia catchment area. Almost 90,000 deep wells,[35] most of which were drilled without permission, provide groundwater for agricultural irrigation and drinking water use. The strong increase in the number of deep-water wells is linked to population growth as well as to inheritance laws. Islamic law provides for a division in the case of land inheritance according to which the land is divided equally among the heirs on the principle that male descendants receive twice the share as females. This form of inheritance law leads to the division of farms and thus to the reduction of landed property, and since most farms look to their own water supply, more and more deep wells are being drilled. Due to the high extraction rate of groundwater, levels in some places have fallen by up to 16 metres, which in the

32 Madani, "Water Management," 320.

33 Majid Ramezani Mehrian et al., "Investigating the Causality of Changes in the Landscape Pattern of Lake Urmia Basin, Iran, Using Remote Sensing and Time Series Analysis," *Environmental Monitoring and Assessment* 188 (2016): 462.

34 Simon Dalby and Zahra Moussavi, "Environmental Security, Geopolitics and the Case of Lake Urmia's Disappearance," *Global Change, Peace & Security* 29.1 (2017): 48.

35 "Urmia Lake Restoration Program."

vicinity of Lake Urmia has also increased the risk of salt water intrusion into the groundwater body.[36]

In addition to the expansion of irrigated farmland, there has also been a major shift in cultivation patterns over recent years towards economically more valuable, but thirstier crops such as sugar beets and apples.[37] About seven per cent of the irrigated arable land in the Urmia area has been converted into fruit gardens,[38] and many vineyards are replaced by water-intensive apple plantations.

Two construction projects, affecting the lake ecology directly and indirectly are also highly controversial. First, since 2000, the road between the cities of Tabriz and Urmia has been shortened greatly by means of a 15 kilometre-long causeway across Lake Urmia. Due to this massive structural intervention, the lake is now divided into two parts connected to each other by a 1.25 kilometre-wide passage which severely hampers circulation and water exchange between the northern and southern parts of the lake.[39] As a result, sedimentation behaviour has changed significantly and the lake water now heats up faster, which in turn leads to higher evaporation rates.

The second construction project is a water pipeline that has channelled about three billion cubic metres of water annually from the Zarrineh River into the metropolitan region of Tabriz since 1999.[40] This in turn has significantly reduced the runoff of one of the most important inlets into the lake. In this context, the disproportionately high demand for water in the rapidly growing urban agglomerations of Tabriz (about 2.2 million inhabitants) and Urmia (about 0.7 million inhabitants) is a major cause of increased water consumption. Undoubtedly, the cities in the catchment area of Lake Urmia show a marked increase in water utilisation. As a matter of fact, however, the water is used but not necessarily consumed in the cities because it diffuses back into the water cycle via the sewage system or other diffusers—undoubtedly in a much reduced quality—and is therefore only partly lost to the water cycle at Lake Urmia.

36 Mahdi Zarghami, "Effective Watershed Management. Case Study of Urmia Lake, Iran," *Lake and Reservoir Management* 27.1 (2011): 90.

37 Dalby, and Moussavi, "Environmental," 47; Ercan Ayboğa and Akgün Ilhan, "Iran's Dam Policy and the Case of the Lake Urmia," last modified July 31, 2012, accessed May 18, 2018. http://www.academia.edu/9613644.

38 Sigarodi, and Ebrahimi, "Effects of Land Use," 256.

39 Aliasghar Marjani and Mirmosadegh Jamali, "Role of Exchange Flow in Salt Water Balance of Urmia Lake," *Dynamics of Atmospheres and Oceans* 65 (2014): 1; Zeinoddini, Bakhtiari, and Ehteshami, "Long-Term Impacts," 85–86.

40 Henareh Khalyani, Mayer, and Norman, "Water Flows," 763.

The construction boom in luxury holiday homes on the outskirts of urban agglomerations and in rural areas has been largely neglected in scientific debates, but it, too, is associated with high water consumption.[41] In many places, arable, pasture, and fallow lands have been transformed into building land where wealthy city dwellers construct weekend cottages, often with large ornamental gardens. Finally, aquaculture farms, which have been set up in recent years, must also be regarded as unfavourable to the water supply since they require a lot of water and are associated with high evaporation.[42]

Currently, approximately seventy per cent of renewable water resources in the Lake Urmia basin are consumed, mainly by the agricultural sector, instead of being discharged into the lake. According to ULRP, the runoff amount feeding the lake has decreased by fifty per cent during the past two decades, amounting to a total of thirty billion cubic metres of 'lost water.'[43] Therefore, human intervention in the expanding agricultural sector is considered the major contributor to Lake Urmia's water crisis as feeding insufficient water into the terminal lake is the main cause of its drying out. Consequently, scientists refer to this phenomenon as a "socioeconomic drought"[44] or an "Anthropocene disaster."[45]

5 Ecological and Socio-economic Consequences of the Urmia Disaster

The drying out of large parts of Lake Urmia and the increase in the salinity of the remaining water have had a destructive effect on the aquatic ecosystem, leading to the interruption of food chains and threatening biodiversity. Due to high evaporation and the accompanying accumulation of salt in the lake's residual water, the saline content of Lake Urmia has almost doubled from 166

41 Sigaroodi and Ebrahimi, "Effects of Land-use," 256.

42 Nina Zarrineh and Mohammad Azari Najaf Abad, "Integrated Water Resources Management in Iran: Environmental, Socio-economic and Political Review of Drought in Lake Urmia," *International Journal of Water Resources and Environmental Engineering* 6.1 (2014).

43 As of January 2018, the lakes total water volume stood at 1.1 billion cubic metres, around 15.17 billion cubic metres below its long-term average volume. "Urmia Lake Restoration Program."

44 Kaveh Madani, Amir AghaKouchak, and Ali Mirchi, "Iran's Socio-economic Drought: Challenges of a Water-Bankrupt Nation," *Iranian Studies* 49.6 (2016).

45 Matthias Schmidt, "Wasserkrise am Urmiasee im Iran: Eine Umwelt- und Sozialkatastrophe des Anthropozäns," *Geographische Rundschau* 70.1–2 (2018).

to over 300 g/l since 1995.[46] This has led to the subsequent extinction of many species, and even the saltwater brine shrimp *Artemia urmia*, adapted to the hypersaline environment, looks to be becoming extinct soon, thus eliminating the most important food source for migratory birds.

Apart from the destructive consequences for the ecosystem, the desiccation of Lake Urmia has also had massive negative impacts on the lives and economies of the two provinces of West and East Azerbaijan. About 6.5 million people live in the catchment area of Lake Urmia.[47] Accompanying the drying out of the lake bottom (fig. 6.3), there has been an increase in wind erosion and the occurrence of dust storms in recent years which threatens surrounding farmlands, livestock and livelihoods through salt deposits.[48] The aeolian dust load may transport high concentrations of fine-grain saline or alkaline materials and other potentially toxic components, and it is thus a health hazard that could lead to an increase in respiratory and immune diseases.[49] A further depletion of the lake will most certainly amplify the health problems of the local population.

In the past, Lake Urmia was known all over Iran as a popular area for relaxation that allowed various bathing opportunities and water sports. Spa tourism in the form of mud applications was widespread and led to large investments in tourist infrastructure, and numerous holiday facilities, tourist resorts, and marinas for water sports were built up to the turn of the millennium, when a tipping point was reached and the number of visitors who benefitted from medicinal mud applications steadily decreased.[50] With the desiccation of Lake Urmia, tourism-dependent businesses such as the production of clay for healing purposes, tourist shops, and boat rentals, were no longer viable,[51] and hotels, holiday homes, and boat jetties were now far away from the water's edge (fig. 6.4). As a result, many households that relied directly on tourism needed to look for other income opportunities.

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46 Marjani, and Jamali, "Role of," 2.

47 SEDAC—Socioeconomic Data and Applications Centre, "Gridded Population of the World: Future Estimates," accessed May 18, 2018. http://sedac.ciesin.columbia.edu/mapping/popest/gpw-v4/.

48 Vahid Garousi et al. "Environmental Crisis in Lake Urmia, Iran: A Systematic Review of Causes, Negative Consequences and Possible Solutions," in *Proceedings of the 6th International Perspective on Water Resources & the Environment* (*IPWE*), (Izmir,2013).

49 Henareh Khalyani, Mayer, and Norman, "Water flows," 762; Zarrineh, and Abad, "Integrated," 45.

50 Zarrineh, and Abad, "Integrated," 45.

51 Farhudy, and Hajilou, "Strategic Evaluation of Tourism Industry Development Pattern with Emphasis of Ecotourism (Sample is Urmia Lake)" (paper presented at the "International Conference on Lake Urmia," Urmia, December 8–12, 2012).

FIGURE 6.3 Desiccated lake bottom of Lake Urmia.
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FIGURE 6.4 Former shore of Lake Urmia.
© SCHMIDT 2014.

The reduction of Lake Urmia's inflows, caused by upstream water extraction and the draining of groundwater levels due to the overexploitation of groundwater resources, has resulted in major challenges for the region's agriculture.[52] Deep-water wells have to be drilled deeper and water shortages have become an everyday problem. Furthermore, water quality is decreasing throughout the basin due to fertiliser and pesticide deposits as well as the overuse of local groundwater which has led to salt-water intrusions into aquifers.[53] Currently, farmers do not have to pay for water, but investment costs are rising and with a further depression of groundwater levels, many farming households could lose their economic basis which would result in unemployment, emigration from rural regions, and the disintegration of rural settlements and infrastructure.

It is obvious that the ecological disaster at Lake Urmia is creating increasingly difficult socio-economic conditions for millions of households living in the basin's villages and cities. Local reports have indicated that many people around the lake have already abandoned the area, and it is believed that a further escalation in environmental degradation will result in many more people choosing to migrate either temporarily or permanently as their livelihoods and their economic and social well-being are undermined.[54]

6 Perception of the Urmia Disaster and Prospects

The obvious ecological crisis at Lake Urmia, resulting in negative socio-economic impacts, is increasing the sense of resentment and resistance in the affected population of the region; for instance, demonstrations and riots took place in Tabriz in 2011 and 2012, addressing the deterioration of the environmental situation in the Urmia area and calling on the government to act.[55] In addition, the 2009 film *Keshtzar haye sepid* (The White Meadows) which impressively presents the Urmia disaster as an apocalypse can be understood

52 Arezoo Anvari, and Mohammad Valaie, "Evaluation of the Effects of Water Level Decline of Urmia Lake in Sustainable Rural Development: Case Study: Central Marhamat Abad Rural District, Miandoab County," *Bulletin of Environment, Pharmacology and Life Sciences* 4.7 (2015): 70.

53 Dalby, and Moussavi, "Environmental," 46.

54 Elham Torabian, "Exploring Social Vulnerability and Environmental Migration in Urmia Lake of Iran: Comparative Insights from the Aral Sea," in *The State of Environmental Migration 2014*, ed. François Gemenne, Pauline Brücker, and Dina Ionesco (Geneva: IOM, 2014).

55 Henareh Khalyani, Mayer, and Norman, "Water Flows," 764.

as an attack on the current ignorance of most politicians in relation to the unfolding catastrophe.

Although the Iranian government has now recognised the high socio-economic costs of the environmental crisis and promised to secure the water supply of the population living in the Urmia catchment area and to save Lake Urmia in 2012, the situation has not changed greatly. According to the affected population, bewilderment and frustration still dominate in this regard.

In the context of a study project at the University of Hannover in 2015, assessments and perceptions of the Urmia crisis were surveyed by interviewing residents in the area as well as various functionaries. According to the respondents, the drying out of the lake is perceived as depressing and catastrophic. Their statements reflect lost pride of this once-largest lake in Iran as well as frustration and profound grief over the socio-ecological disaster:

> "The lake is everything to us."
>
> "We are children of the lake. The loss is great and painful; the lake was our pride."
>
> "When I look at the lake, I feel very bad, my thoughts are confused, I am sad."

In 2014, Iran's President Rouhani declared the saving of Lake Urmia a national priority. Since then, an energetic campaign has been put into action in politics and science, for instance by holding conferences with the aim of developing solutions. Various ways out of the crisis have been discussed, most of which technological in nature. One of the most questionable proposals was the transfer of water from the Caspian Sea to Lake Urmia. To this end vast amounts of water would have to be pumped over an altitude difference more than 1,300 metres, which would mean enormous energy requirements over a long period of time. Proposals to discharge water from Lake Van in Turkey or from Armenia must also be filed in the category of unrealistic utopia. Up to the present day, technological measures such as discharging water from remote rivers into the Urmia Basin[56] or chemical desalination plants[57] have been discussed. However, these 'solutions' would lead to undetermined environmental impacts as well as unpredictable economic and social consequences, and this certainly would

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56 Eimanifar, and Mohebbi, "Urmia Lake," 3; Zarghami, "Effective Watershed Management," 91.

57 Abdolreza Karbassi, Gholamreza Nabi Bidhendi, Amirhossein Pejman, Mehdi Esmaeili Bidhendi, "Environmental Impacts of Desalination on the Ecology of Lake Urmia," *Journal of Great Lakes Research* 36 (2010): 423. https://doi.org/10.1016/j.jglr.2010.06.004.

not be the way out of the current situation.[58] In fact, the Urmia disaster is less a purely ecological problem that can be solved technologically but rather a complex mixture of political and socioeconomic causes, all of which require political and institutional resolutions.[59]

Agriculture is the largest water consumer in the Urmia catchment area. At the same time, it offers the greatest potential for a turnaround in fortunes because water use efficiency is poor. Water loss in reservoirs and canals through evaporation and infiltration is very high, and a lot of irrigation water is wasted through the common practice of flood irrigation. There is a great saving potential here, for example through the use of water-saving technologies such as drop irrigation, grey water recycling, or the cultivation of less water-intensive crops.

Water shortages, in quantitative and qualitative terms, along with ecological degradation, high unemployment, and the massive demographic shifts caused by rapid urban growth on the one hand, and migration from rural areas and the resulting ageing of the rural population on the other, pose great potential for conflict.

Climate models suggest that temperatures will continue to rise and droughts will become more likely,[60] resulting in an expected increase in evaporation rates which will further reduce the lake level.[61] Local climatic conditions will also change with further water surface decrease since the balancing effect of the water body will be reduced and thus hotter and drier weather conditions can be expected in the summer. State water use plans until recently envisaged the construction of additional dams and an extension of irrigated agricultural land in the Urmia catchment area by 25 per cent. In the course of the recently adopted Urmia Lake Restoration Program, these projects were halted and a forty per cent reduction target in water consumption set up. However, according to model calculations, the lake level will continue to drop even with the successful implementation and realisation of this goal, due to worsening climate change.[62]

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58 UNEP-GEAS, „The Drying," 136; AghaKouchak et al., "Aral Sea Syndrome,"310–311.

59 Habib Alipour and Hossein Ghasemi Tangal Olya, "Sustainable Planning Model toward Reviving Lake Urmia," *International Journal of Water Resources Development* 31.4 (2015): 535–536.

60 Farajzadeh, Fakheri Fard, and Lotfi, "Modeling of Monthly," 38.

61 Sima, and Tajrishy, "Using Satellite Data," 97–98.

62 Shadkam et al., "Preserving," 324.

7 Conclusion

The environmental and societal disaster witnessed at Lake Urmia is the result of various processes. These include anthropogenic climate change along with reduced precipitation and higher air temperatures (and thus increased evaporation), the construction of small and large dams to discharge water for agricultural purposes, the expansion of irrigated farmland, the excessive abstraction of groundwater, and increasing water requirements in urban agglomerations and for holiday home gardens. The result is an ecological disaster with political and socioeconomic consequences which must currently be considered just the tip of the iceberg. In political and scientific discussions on the Urmia disaster, technological solutions are still being discussed while institutional and socioeconomic aspects are mostly neglected. Instead, agro-economic practices, water governance, clientelism and patronage, as well as the increasing vulnerability of certain population groups need to be put to the test.

The Urmia tragedy represents a general water crisis in the Middle East where water is widely treated as an unlimited resource that can be exploited without much hesitation. Interference with the water cycle is implemented on a breathtaking scale, including the construction of numerous reservoirs, massive water redirection projects, and the expansion of irrigated areas. In contrast to traditional water management systems such as qanats, which are well adapted to the environmental conditions, the application of technology with high energy inputs has led to the exploitation of water resources far beyond their recovery rate. Water utilisation in the Middle East is far from being sustainable; groundwater levels are falling all over the region, and water has to be pumped from ever-deeper levels.

The major reason for the paucity of water is the government's policy of supporting and subsidising the agricultural sector to match growing food demand. The unstable political situation in the entire region has also meant that every country is trying to secure its food requirements through its own agricultural sector since they cannot depend on food imports. As a result, water is treated as an open access, free of charge resource, leading to very wasteful water use. Additionally, all governments in the Middle East follow a modernisation paradigm at any cost, and the erection of massive and impressive dams as a matter of national pride showing the technological and economic potency of the national economy. Dams continue to serve as symbols of development, progress, and modernity.

In view of the major ongoing desiccation processes in many parts of the Middle East, Lake Urmia is a vivid example of how ecological and societal systems are intertwined and how human interference influences hydrology and the ecosystem of a whole region, resulting in unpredictable consequences for the population. In this sense, Lake Urmia is a striking, disastrous testimony to the so-called Aral Sea syndrome. Understanding the complex set of causes and the development of a sustainable resource management programme requires a multidisciplinary approach and must include social science perspectives.