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Sustainable restoration of the Urmia Lake: History, threats, opportunities and challenges

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Abstract: The natural and human-induced processes are currently major threats to aquatic ecosystems and water bodies, all over the world. Urmia Lake, the world's second largest saline lake, is located in the Northwest of Iran, is being drying up mainly due to the mismanagement of water use in the basin and the reduction of inflow to the lake. The lake water level has rapidly declined since the mid-1990s. Construction of more than fifty dams and diversion structures, along with the effects of climate change, are the main causes. Construction of a 15 km long causeway in the middle of the lake is an additional cause, which eliminates the natural circulation in the lake. The situation has turned to critical over the past two decades, and the need for restoration is an urgent priority for the region. The contribution of the ten principal rivers for flowing water into Urmia Lake is considered an ultimate solution to this crisis. However, the most challenges for any restoration plan are to be public awareness and general knowledge on the environmental values of the lake to local communities. This paper addresses the major causes to the desiccation of Urmia Lake, and presents an overview on the restoration plan and strategies that have been setup for the next years. Major threats and challenges are also highlighted in terms of the public awareness and community benefits in order to secure the feasibility of the plan for preservation of this internationally recognized wetland at a sustainable environmental status.

Key words: Causeway Urmia Lake, Restoration plan, Water management, Drought, Lake Causeway

1. INTRODUCTION

The Urmia Lake Basin is one of the most valuable ecosystems that is located in the northwest of Iran, between the provinces of West and East Azerbaijan. As an endorheic or terminal lake, water leaves the lake only by evaporation. So it is a closed-basin and the only outlet is evaporation (UNEP, 2012), but the inlets consist of precipitation, rivers, runoff flow and groundwater inflow (Ghaheri, 1999).

Because of its unique natural and ecological features, such as existence of exclusively a kind of Artemia (Urmiana Artemiana) as an exclusively parthenogenetic population (Barigozzi et al., 1987), this hypersaline lake was declared as a Wetland of International Importance by the Ramsar Convention in 1971 (Ramsar Site) and in 1976 as designated a UNESCO (UNESCO Site) Biosphere Reserve (ULRC, 2015a).

Since 1979 a dike type causeway gradually has been constructed in the middle of the lake and divided the lake into north and south parts, where connects the city of Urmia (West Azerbaijan Province) to city of Tabriz (East Azerbaijan Province) and limits the exchange of water within just 1.25 Km long opening that covered by a bridge (Teimouri, 1998). Results of hydrodynamic numerical modeling of Urmia Lake reveal that flow regime have been effected by wind input as a climate and hydrologic factor, but river discharge, evaporation and rainfall were main parameters affecting salinity distribution in the lake models. Therefore, the causeway has no significant effect on the lake flow and salinity regime (Zeinoddini et al., 2009). However, the influence of the causeway on salinity difference between north and south parts as well as on exchanging of flow between these two parts is unassailable, and needs much more hydrodynamic studies to have a better knowledge about it. The location of Urmia Lake and the causeway as well as mouth of its major input rivers are shown in Figure 1.

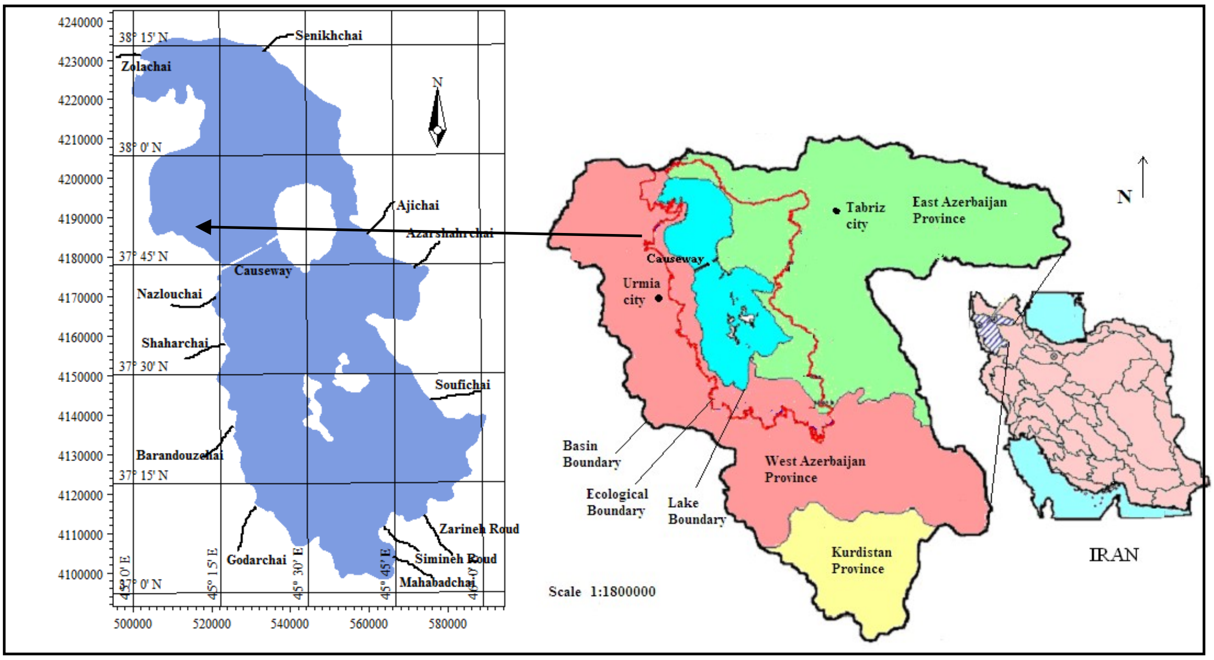


Figure 1. Study site: (a) general shape of Urmia Lake with input rivers and location of Causeway, (b) the location of Urmia Lake Basin in Iran

2. CAUSES AND CONSEQUENCE OF DRYING

During the last two decades (since 1995) some parameters severely have been declined the water level of Urmia Lake. Based on precipitation measurement stations in the lake basin, the average of the basin precipitation from 1995 to 2013 has been decreased about 18 percent, about 68 millimeters (ULRC, 2015a). Investigations result by Hassanzadeh et al. (2011) revealed that four dams (Alaviyan, ZarinehRoud, Mahabad and Nahand) have been responsible for 25% of the lake level reduction, while climate change and overuse of surface water is the cause of 65% of the lake level reduction in the recent years. The remained 10% is caused by lower precipitation on the lake.

Nonetheless, reduction of the water level of the lake through the two recent decades, whether in monthly or yearly scales was more harsh and different than changes of precipitation and temperature anthropogenic factors impacts rather than natural variability. (Jalili et al., 2016a,b; Zoljoodi and Didevarasl, 2014).

Furthermore, last assessment of water demand in the Urmia Lake Basin revealed that 70 percent consumption of renewable water resources of the basin. Whereas according to stable development index of United Nations Commission, the amount of secure and acceptable consumption of renewable water resources have been determined between 20 and 40 percent. Therefore, 30 percent overuse from the Urmia Lake Basin (because of development of agriculture) has effected stability of the water resources of the basin (ULRC, 2015a).

In the Urmia Lake Basin, population growth leads to increasing in the need for food as well as demand for water (Khatami and Berndtsson, 2013). Agriculture activities in the basin consume about 90 percent of water of the whole basin and more than 60 percent of the renewable water. Based on recently published data by Ministry of Energy (MOE), in 2011 annual water volume consumption for agriculture purpose was 4.3 MCM. In spite of that, agriculture consist of 30 percent of whole basin incomes (ULRC, 2015a). It seems that developing industrial activities in Urmia Lake basin can decrease, depending on the economy of the region to agriculture and may decrease water demand.

Drop in the lake water level increase the salinity of the lake. Artemia Urmiana tolerate a salinity range of 40 to 250 g/l (Csavas, 1996) so continuation of this trend in recent years treat the life of Artemia, and confront it with extinction danger. Since Artemia is the main food resources of birds, especially flamingos, which spawn in the basin, a severe decrease in number of birds have been occurred (Abbaspour et al., 2012).

Furthermore, drying of Urmia Lake leaves the majority of the lake converted by salt, especially in southern part. Based on experience from Aral Sea, this change leads to numerous problems in the ecosystem and the climate of the area such as salt storm and subsequently refractory diseases for child and other health hazards (Zetterstrom, 1999). Unfortunately converting the lake to an active region of saline dusts can be threatening significantly the population of the lake basin.

In Figure 2, some examples of consequences of drop in the Urmia Lake water level are shown. Other impacts are rising of the lake bed level and change it to flatter bed because of settling salts. Basis on satellite images and Remote Sensing observations bed level of the Lake 4 up to 108 centimeter has increased since 2013 to 2015 (WRI, 2015).

(a) (b) (c)

Figure 2. Examples of consequence of drying the Urmia Lake; a) desertification in Jabalkandi region (south -western part of UL, in January 2014); b) salt storm; c) disappearing of birds.

3. ADMINISTRATIVE ACTION PLANS OF URMIA LAKE RESTORATION NATIONAL COMMITTEE

Management and structural policies have been proposed for the restoration of the lake by Urmia Lake Restoration National Committee (ULRC). While these programs have had benefits and defects, so professional investigation of cost to benefit of projects is essential. Mentioned action plans consist of below actions (ULRC, 2015b).

I. Reduction of inflow volume in watercourses ending to the Urmia Lake.
   - Connecting two major rivers, ZarinehRoud and SiminehRoud, for facilitating water delivery into the lake.
   - Dredging of SiminehRoud, Godarchai, Mahabadchai and Ajichai Rivers

II. Increase in input water volume to the lake by extrication of stored water of the constructed dams

III. Inspection of illegal overusing of surface and ground waters.

IV. Protection actions for decreasing to salt storm disasters

V. Inter basin water transfers plans
   - from Zaab River subbasin
   - from Silve Dam in Southern part of the lake

VI. Increasing the efficiency of irrigation water by using new irrigation methods.

Some of the mentioned action plans have high cost such as dredging of major rivers and inter basin water transfers plans. So those restoration plans so far have had multi millions dollars expenses for government but implementation process is slow and the efficiency of them in restoration of the lake water level is a matter of question (Khatami and Berndtsson, 2013).

Transferring of water from other basins to Urmia Lake, because of long distance between two basins have had much more expenses, and also cause problems for the water balance and ecosystem of the other basins. Thus, inter basin water transfer plans are expensive and time consuming, and at least cannot be considered as a short term solution.

4. MAIN FINDINGS AND IMPLICATIONS

Results of the sensitivity analysis of different parameters declared that the lake is highly sensitive to river input, so that the water development projects implementation in the Urmia Lake Basin will disturb the lake ecosystem (Abbaspour et al., 2012).

Japan International Cooperation Agency (JICA et al., 2016), in collaboration with Water Resources Management Company (WRMC) and MOE have been modeled the projects effect and the hydrological cycle of Lake Urmia Basin by MIKE-SHE and GETFLOWS numerical models respectively.

Based on the result of the MIKE-SHE model, the water level of Urmia Lake was simulated for the condition that the selected hydrological situation will continuously occur every year from the beginning to the end of the sequential simulation. The results of sequential simulation are summarized in Figure 3. As a result, it can be seen that only the Project 3 (P3) can achieve the target water level (1,274.1 m), even though all projects except No. 1 have the possibility to recover the lake water level to some extent (JICA et al., 2016). It seems that there is essential to design an appropriate dams operation schedule.

From the result of the simulation, it became clear that the river inflow volumes of approximately 2,050 MCM is necessary for around 10 years to adjust the in target water level. However, in case of the project prepare of over 2,100 MCM/year, the water level will also rise to more than the target water level of 1,274.1 m in the future. Other studies estimate inflow volumes as 3085 MCM of inflow per year for restoration of the lake (Abbaspour and Nazaridoust, 2007). Thus, to adjust the water level to the target, after the achievement of the target water level, the total river inflow volume should be controlled to approximately 2,100 MCM/year (JICA et al., 2016).

If all projects are implemented, the river inflow volume will increase to approximately 3,177 MCM/year and the lake water level is likely to rise to around 1,276.78 m (higher than the target water level). In this case, it takes around 6 years to reach the target water level (1,274.1 m) (JICA et al., 2016).

If all projects are implemented, the river inflow volume will increase to approximately 3,177 MCM/year compared with Project No. 1 (maintenance status quo) and the lake water level is likely to rise to around 1276.78 m (higher than the target water level). In this case, it takes around 6 years to reach the target water level 1274.1 m (JICA et al., 2016).

One of the solutions proposed for reducing the salt content of Urmia Lake is using desalination techniques, but desalination in hypersaline waters is a hight cost projects. A better strategy would be better to allow more fresh water through several rivers reaching the lake to reduce salinity and improve aquatic life rather than creating fresh water through reverse osmosis and distillations processes (Karbasi et al., 2010). Fortunately, authorities of the Ministry of Energy have agreed with this policy.

Among varies restoration plans, its seem be better to allow the rivers flow to reach the lake for reducing salinity and increasing aquatic life rather than creating fresh water through reverse osmosis and distillations processes (Karbasi et al., 2010). During dry seasons, Southern part of the Urmia Lake was dry in the last two years (Figure 4). An emergency action was to release 136 MCM water from three reservoir dams (Bukan, Sarough, and Hassanlou) to the lake during February and March 2015. In 2016, extra precipitation over the Urmia Lake Basin resulted in the overflow of flood flows from the most of the basin dams to the lake. So, the lake water level approached to 1270.55 m in February 15, 2016. Figure 5 shows the effectiveness of natural water inflows on the lake surface area. At the same time, other actions such as dredging of the rivers mouths, connecting ZarinehRoud and SiminehRoud Rivers, and controlling the illegal overuse of surface waters facilitated the recovery of the lake.

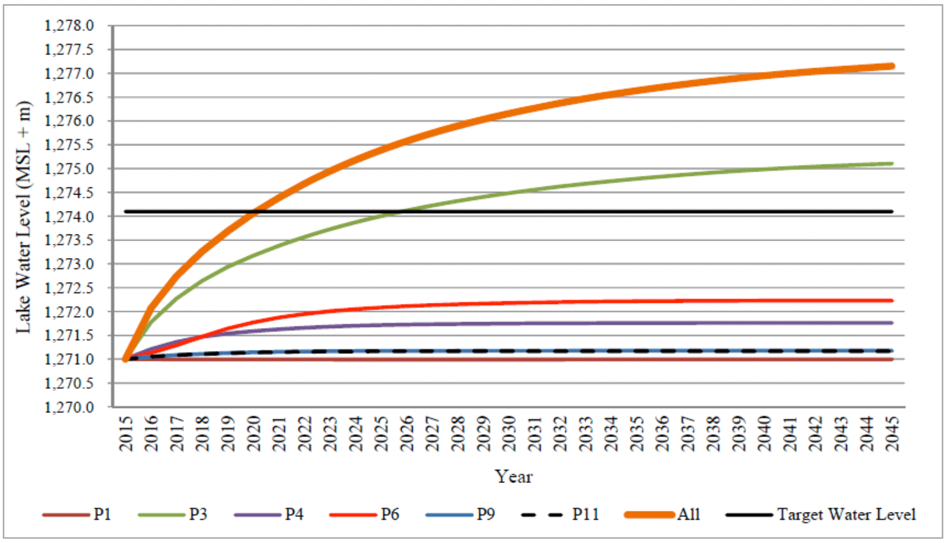


Figure 3. Project effects (change of yearly average water level).
P1: Prohibition against any increase of water use (maintenance of status quo). P3: Stop of whole water supply. P4: Water Transmission from Zab River to Urmia Lake Basin. P6: Controlling and reducing water consumption in agriculture section. P9: transferring Rivers' water into the body of the Lake. P11: Transferring from Aras River in West Azerbaijan merely into Urmia Lake. Including No.3, 4, 9, 11 (in this case No.6 contain in No.3)
(JICA et al., 2016).

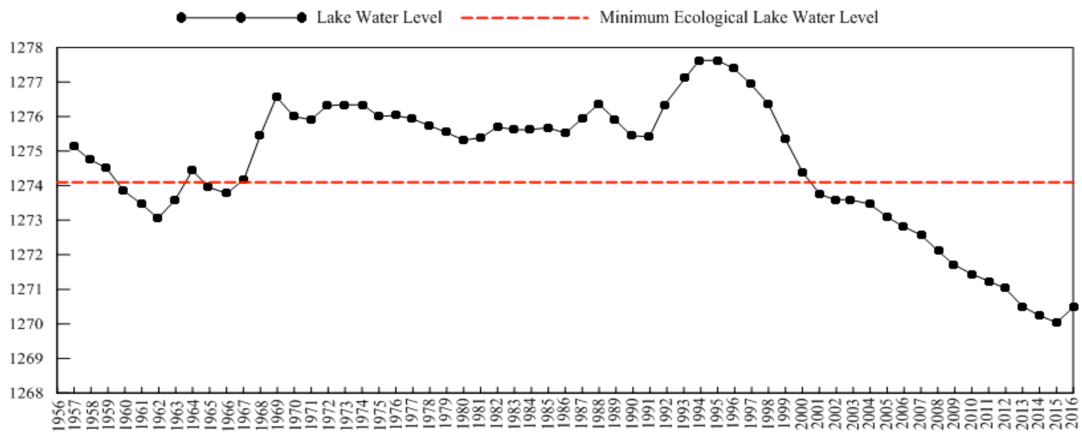
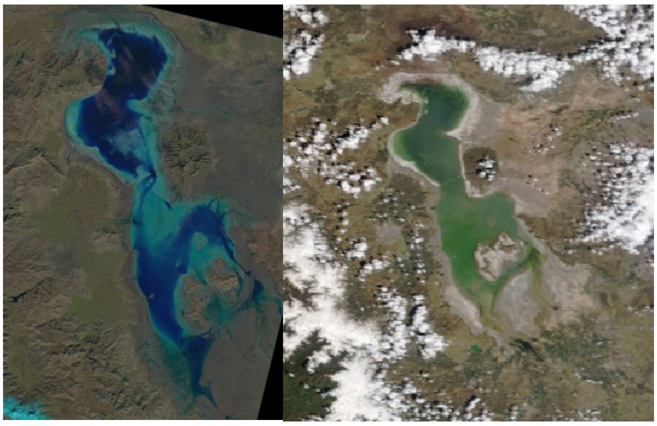


Figure 4. Urmia Lake surface trend for last 60 years



(a) Before (b) After
Figure 5. A satellite image of the storage water extrication action effects in the Urmia Lake, captured on (a) November 28, 2015 (showing the extent of dried regions (white) in the Southern part; and (b) February 15, 2016.
Image source: https://earthexplorer.usgs.gov/

5. CONCLUSIONS

Traditional water management will soon result in the drying crisis of Urmia Lake, an internationally registered hyper-saline wetland, in Iran. The most priority is an action plan to deliver in-basin surface waters into the lake. The restoration of the lake demands the action plan for supplying and delivering water from the ten major rivers around the lake, in the order of 20% to 40% of potential annual flows from these rivers. The revision of the current water allocation for agricultural uses, emergency plan to reduce 40% of irrigation water, to lease farmers' water-rights, to prevent illegal water intakes from the rivers, to release 30 to 40% of reserved water from 13 large dams around the lake, and to perform river improvement works to facilitate water delivery are necessary for saving the Urmia Lake. Long life and sustainable solution is to increase the rivers environmental flow allocations from existing 10% to 20% to 40% of their potential annual flows. The change in the volume of water regulation in the 13 operating dams, and the reduction of possible storage of water in the 11 under-construction dams are to be considered for the future restoration of the Urmia Lake.

In recent years the southern part of the lake was completely dried out. This part of the lake is wide and shallow, and as a consequence of the drying, crystallized salt has been deposited on the lake bed. The lake bed has risen, and thereby strategies such as more discharge from dams may not be effective. Because by discharge of stored fresh water in the dams in the southern part of the lake a large quantities of fresh water will be released on a crystalized salt bed and this will waste a lots of water by evaporation.

Therefore it is important to develop models to study the effects of dams' release in different parts of the lake. A multi-purpose multi-disciplinary project is underway by authors to develop numerical framework to study the hydrodynamic behavior of the lake under the natural drivers as well as different restoration strategies to analyze the effectiveness of these efforts and predict the future of this precious natural body of water. The output of this research will be useful to improve our understanding about the future plans and also effective operation of dams and management of water resources.

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