

Review

Integrated water resources management in Iran: Environmental, socio-economic and political review of drought in Lake Urmia

N. Zarrineh and M. Azari Najaf Abad*

Department of Hydrology and Hydrological Engineering, Vrije Universiteit Brussel (VUB), Brussels Belgium.

Accepted 18 December, 2013

In recent years Lake Urmia, the largest saline lake in the Middle East located in northwestern Iran has undergone severe environmental changes. As a result of drought and anthropogenic impacts, the area of the Lake has been shrunk and the water level has been dropped. In this article the environmental, political and socio-economic impacts of drought in Lake Urmia basin has been reviewed and the obstacles regarding institutional water frameworks in national and regional levels has been studied and assessed. Furthermore, lack of sufficient mitigation and adaptation policies and inadequate attention to the environmental impact assessment during megaprojects has been discussed. The most crucial impacts have been realized as ecological and environmental consequences of lake drying up on all over the Lake Urmia catchment. In associated with these consequences, several scarce species of flora and fauna are exposed to the danger of extinction, and polluted air ensued by the salt storms affect the daily life of people in the region. In addition, this event has a direct influence on the economy of the region. Therefore, the implementation of a holistic institutional-based remediation program to accomplish lake restoration seems to be inevitable.

Key words: Lake Urmia management, Lake drought, human activities, climate change, environmental impact assessment.

INTRODUCTION

Lake Urmia (formerly called Rezaiyeh) is a shallow landlocked hypersaline lake located in northwestern corner of Iran close to the border with Turkey. It is known as one of the largest continental salt lake in the world and the largest one in the Middle East (Figure 1) (Hassanzadeh et al., 2012). Recently, area and volume of the lake have been shrinking seriously. The lake was declared a Wetland of International Importance by Ramsar Conversation in 1971 and designated a UNESCO Biosphere Reserve in 1976 (Chander, 2012).

Lake Urmia is one of the hyper saline lakes throughout the world. In addition, this basin is an endorheic basin

that retains water and does not allow any outflow to other external bodies of water. According to the information issued by The Ramsar Convention on Wetlands, the primary outflow of Lake Urmia is evaporation and the primary inflows are precipitation, freshwater discharge from the rivers and getting fed by springs. Increase in evaporation and decrease in rainfall, freshwater inflow and springs inflow has led to salinization and water level decline.

The surface area of Lake Urmia has been estimated about 5200 km² and the area of the basin is estimated 51,876 km². Lake Urmia possesses more than 102 rocky

*Corresponding author. E-mail: Mohammad.Azari@student.kuleuven.be, m.e.azari@gmail.com.



Figure 1. Location of the Lake Urmia.

saline islands and its ecosystem is the habitat for more than 212 species of birds, 41 reptiles, 7 amphibians, and 27 species of mammals which most of them are endemic species (Rezvantalab et al., 2011).

According to the U.S. Geological Survey anticipation, the Lake Urmia is sharply drying, and it may completely vanish in just two years (USGS, 2012). If this scenario happens just a vast salt desert will remain from this lake which is an undeniable treat to the local ecosystem. Therefore two main problems have been recognized and defined lately based on water quantity and water quality.

In terms of water quantity, according to the official statistics, more than 60% of Lake Urmia is disappeared since 1960s (Karmi, 2011). The water level decline is another drought indicator. Based on current investigations, in a recent drought of the Urmia basin, started in 1999, the water level of Lake Urmia dropped from 1277.80 masl to 1273.35 masl (Tabari et al., 2012). During August 1998 to August 2001, water level of Lake Urmia declined up to three meters and caused serious decrease in the area of the lake, approximately from 6000 to 5200 km².

In terms of water quality, the lake has been decayed and sudden change in salinity regime has been occurred. Currently the amount of the salt, dissolved in the lake water, increased from 160 to 170 gL⁻¹ up to 400 gL⁻¹ (Zarghami, 2011). The mentioned disaster has affected the biota of the lake. In these conditions, water with so high salinity is no longer a suitable and sustainable environment for fauna and flora and has caused to destroy the ecology of the lake.

Figure 2 represents shrinking in the area of the Lake and severe drought has been observed (left picture) and the trend to this drought is likely to be continued (right picture). As a plausible consequence, the eastern and southern areas of the lake would be completely dried up until 2019 and this can be associated with irreparable environmental impacts in the ecosystem of the Lake Urmia catchment.

Objective

This article aims to develop a holistic review on ecological and environmental impacts and political and socio-economic implications of Lake Urmia basin drought in response to anthropogenic drivers such as increased water demand due to population growth (Statistical Center of Iran, 2012) and environmental pressures (e.g. climate variability and climate change) within the context of current institutional set-up. Political and institutional obstacles will be presented and comprehensively discussed in this review. Thus the final conclusion of this review reflects the previous and the current river basin's characteristics and the impacts of human activity and climate change on the status of water bodies in the basin and the possible measures. For this aim, this study will also address how the water quantity and quality and ecological states of Lake Urmia Basin has been changed over the past decades. The ultimate objective of this review paper is to create and develop a recommended list of measures that might improve the management of the Lake Urmia Basin.

LITERATURE REVIEW

Main drivers and pressures

Two major aspects of drivers which are responsible for this environmental crisis are anthropogenic driving forces and natural driving forces. In this occurrence, anthropogenic drivers are more effective than environmental drivers. Sharp population growth during 1980 to 2011 and intensive immigration towards big cities raised the food and water demand. Regarding to the amount of water which is consumed instead of being discharged in the Lake Urmia, these participations can be obtained that agriculture sector is responsible for 91% of the water consumption, whereas industry and domestic consumption are responsible for 6 and 3% of the water consumption respectively (Faramarzi, 2012). Raise of demand for water forced the government and farmers to provide numerous damming and water diversion projects and groundwater pumping stations to supply water demand.

The main freshwater resource is Zarrineh River, located in the south of the lake, supplying more than 50% of the annual inflow. Simineh River and Ghadar River are providing 35% of the inflow (Mohaggeg, 2002). Some of the freshwater from these sources flows unimpeded to Lake Urmia, but much of it is impounded within reservoirs or water diversion dams for the sake of irrigation, drinking water, power generation (hydro-power plant) and industrial usage of water. For instance, Bukan dam was constructed on Zarrineh River in order to launch hydropower plant and supply water demand. The location of the Bukan Dam is specified in Figure 3. In addition, several damming and water projects are currently under

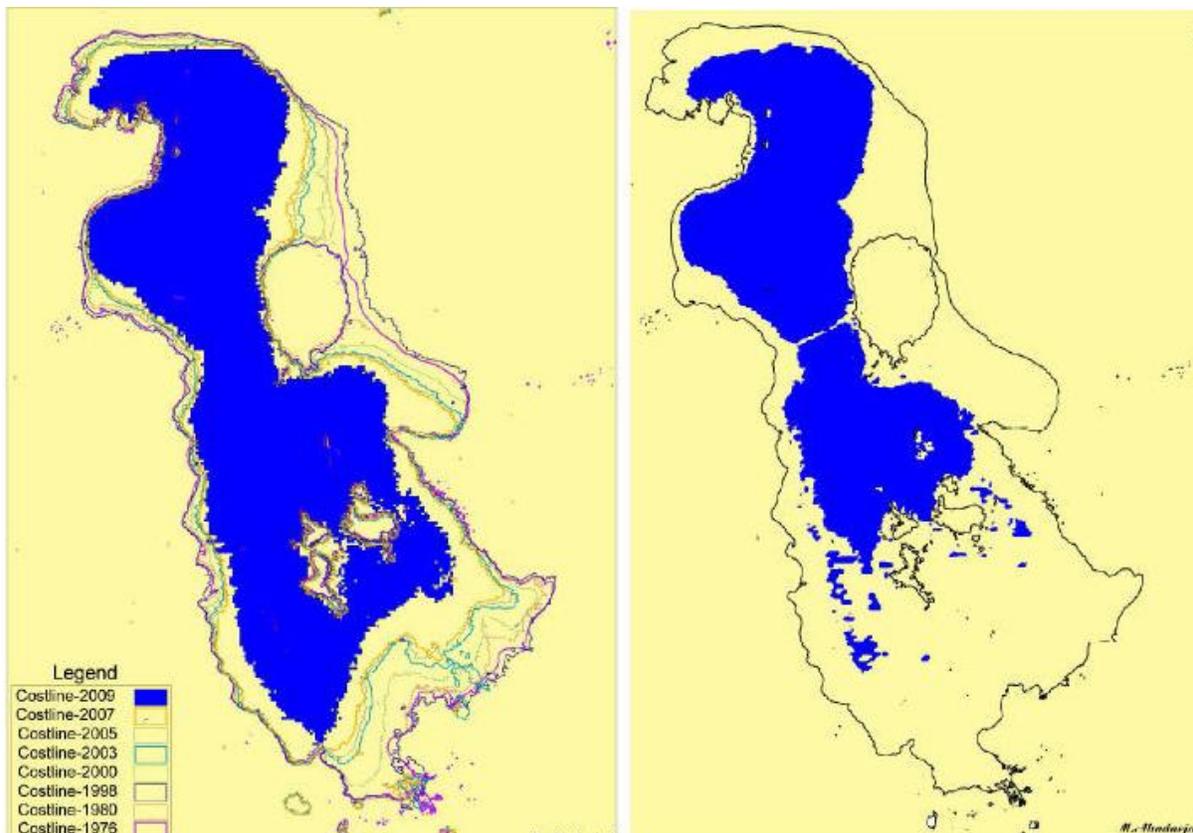


Figure 2. Lake Urmia water level changes in period 1976-2009 (left) and predicted change map by 2019 (Ahadnejad Reveshty, 2010).

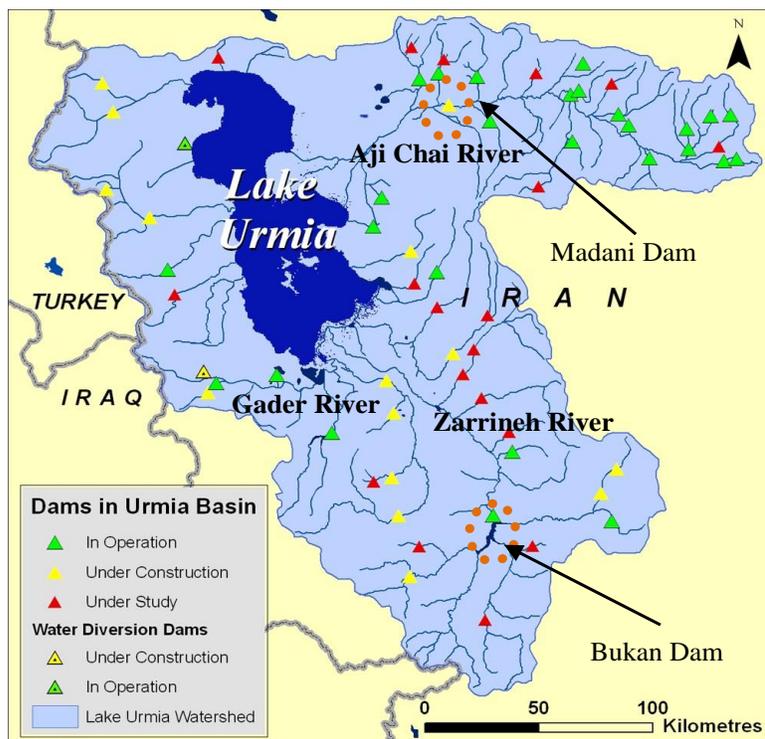


Figure 3. Dams location in Urmia Basin.

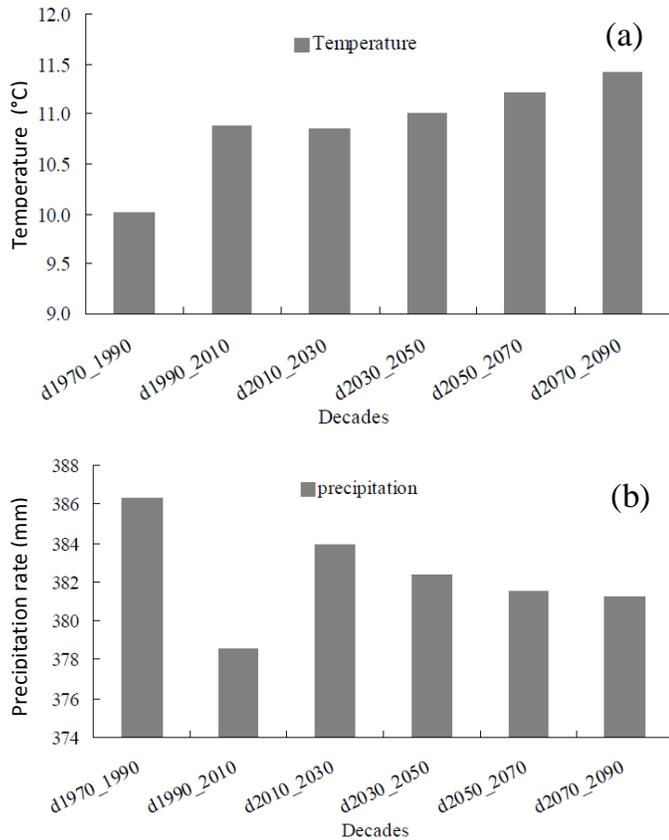


Figure 4. (a) Ten-year average (1970-2100) of trend of changes in temperature components of the Lake; (b) the ten-year average (1970-2100) of trend of changes in precipitation components of the Lake.

study and under construction. Since large number of dams and water diversion projects are already in operation on the rivers feeding the lake, Lake Urmia is shrinking, getting shallower and extremely drying, and a salt desert has been remained which can lead to several environmental consequences. Furthermore, groundwater excessive unsupervised overuse caused groundwater depletion which decreased the amount of water that is fed into the lake by the springs. This event may lead to the salt intrusion in the catchment of Lake Urmia.

Moreover, the construction of a causeway, from 1999 until 2007, in order to decrease the distance between Tabriz city, capital of East Azerbaijan province, and Urmia city, capital of West Azerbaijan Province, was believed to pressurize the flow and salinity regime of the lake. Various studies has shown the influence of the causeway construction on the lake's hydrodynamics and water quality by using two-dimensional and three-dimensional numerical models (Zeinoddini et al., 2009). The necessity to build a new road is the direct effect of population and trade growth as the main drivers and consequently increasing transportation demand is the main pressure (Khosravifard, 2010). This bridge divides the lake into two parts. The severe drying of the lake was

simultaneously coincided with the project construction duration and has been intensified after running the project. The flow and salinity regimes are affected by the presence of this new causeway (Zeinoddini et al., 2009).

Furthermore, due to climatic variability and climate change the quantity of water flowing into the lake varies annually. Higher temperature and less precipitation have led to higher evaporation from the lake and less water yield into it. As evaporation is the primary output and precipitation is the input, salinization will increase dramatically due to less dilution.

Figure 4 shows the trend of the average temperature and precipitation changes which two time scales of the past and future are considered. To characterize the changes in climate components for time scale of the past and future the longitudinal data set between 1968 and 2011 and between 2012 and 2100 considering the climate change effect have been used respectively. The changes of annual average of precipitation display a decreasing trend every decade from 1968 to 2011 which is equal to -14.8 mm/decade. The trend of changes in average temperature between 1968 and 2011 displays a significant rise which is equal to $0.59^{\circ}\text{C}/\text{decade}$. Also the increasing trend of annual temperature considering climate change scenario, indicates an increase in temperature of $+0.88^{\circ}\text{C}$ by the year 2100 in the Lake Urmia region. Furthermore, it is expected that the average of precipitation is projected equal to -0.37 mm/decade. Totally it will decrease as 3.3 mm by the year 2100 (Tisseuil et al., 2013).

These results of latter study are fully compatible with the map given in Figure 5. It shows that areas around Lake Urmia are being threatened by drought.

The decreasing factor in precipitation rate is estimated between 50% (severe drought) to 80% (weak drought). The map is based on the percentage of rainfall from September 2010 to January 2011 in comparison with the long-term average.

Therefore it is concluded that the precipitation (primary inflow of Lake Urmia) will decrease and the evapotranspiration will increase (primary outflow the Lake) by increase in the temperature.

States

All of these drivers and pressures have led to the current lake situation. As the Lake Urmia basin is an internal drainage system, the climatic factors have driven the lake to the more evaporation and less precipitation and the anthropogenic factors have led to less freshwater input. Less freshwater inflow and higher evaporation have led to higher salinity and water level decline.

Figure 6 represents the gradual change in surface area of the lake. After fluctuations between 1963 and 1998, sharp drop of surface area has been observed.

As shown in Figure 7, in terms of water quantity, although there are fluctuations in water level over the past

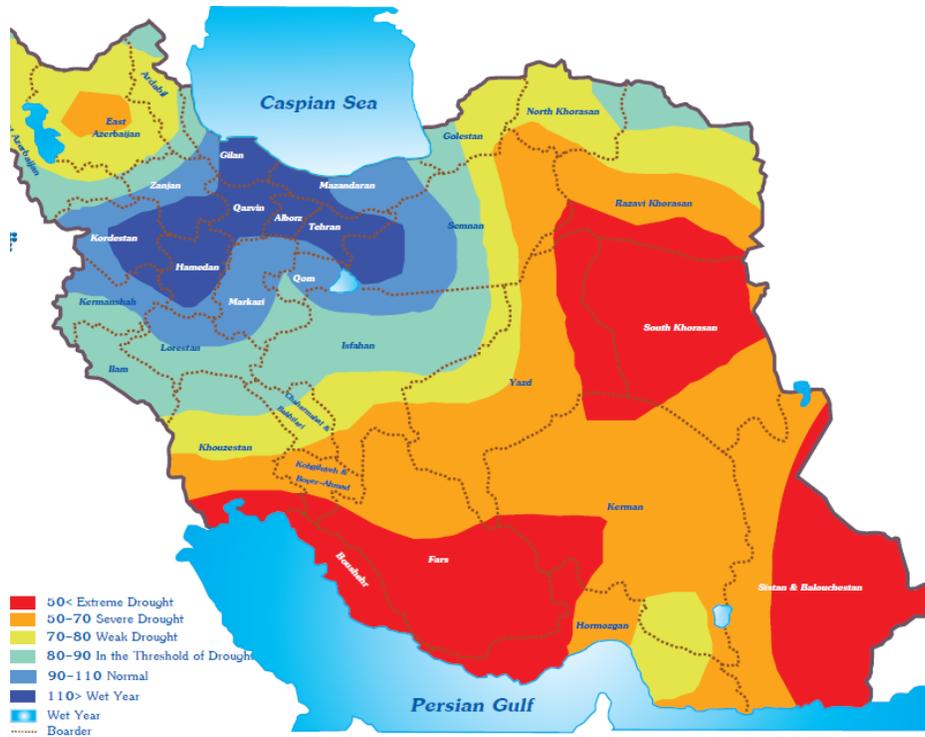


Figure 5. Drought map of Iran.

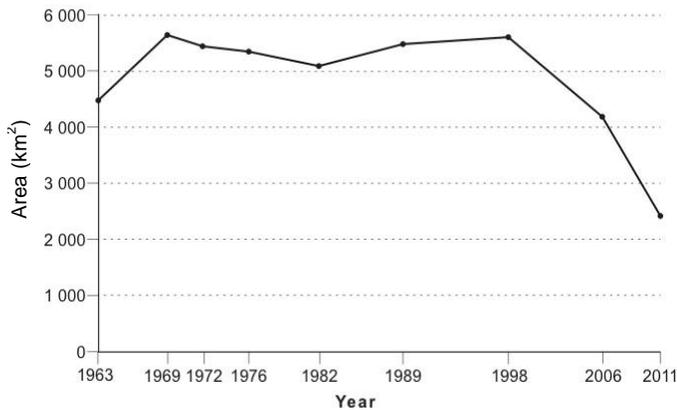


Figure 6. Lake Urmia surface area, 1963-2011 (Chander, 2012).

100 years, the trend line slope is negative which implies that the lake situation is getting worse.

In terms of water quality, recent investigations denotes that in early 2003 salinity of the lake has been raised up to 250 g/L in the southern part, whereas salinity was as high as 280 g/L in the northern part. More recent studies illustrate the amount of salt in the lake water increased from 160 to 170 g/L up to 400 g/L (Zarghami, 2011).

Environmental and ecological Impacts

Environmental campaigners claim that the construction of

dams on rivers and the recently built causeway across the narrowest part of the lake have reduced the water level, affected the water circulation, increased the water salinity and jeopardised animals as well as aquatic organism. The most important flora and fauna which are presently endangered and may extinct in the future are aquatic organisms, regional vegetation, flamingos and Iranian yellow deer. Lake Urmia possesses more than 102 rocky islands. The islands and the wetlands around the lake are major staging areas for migrating flamingos, however their numbers have recently declined (Zafarnejad, 2010) (Figure 8).

Significant alterations in the biota of the lake endangered aquatic organisms such as *Artemia*, a kind of brine shrimp which is a unique cosmopolitan anostracan living in hypersaline and saline lakes. *Artemia* serve as food source for the migratory birds such as flamingos and is also used in aquaculture sector. Because of high salinity, *Artemia* was not able to fully recover in the lake's water (Abbaspour and Nazaridouost, 2007). The other consequence on the biota of the lake is fish mortality. Due to the high level of salinity, the Lake Urmia is no longer able to sustain any fish species.

The hydrological pressures on the lake have profound impacts not only on the lake itself, but also on the land cover and the water quality and the ecosystem of surrounding wetlands especially those located in estuary parts. Water quality conditions differed among the wetlands and ranged from mostly freshwater, nutrient-rich (eutrophic) conditions to more saline, nutrient-poor

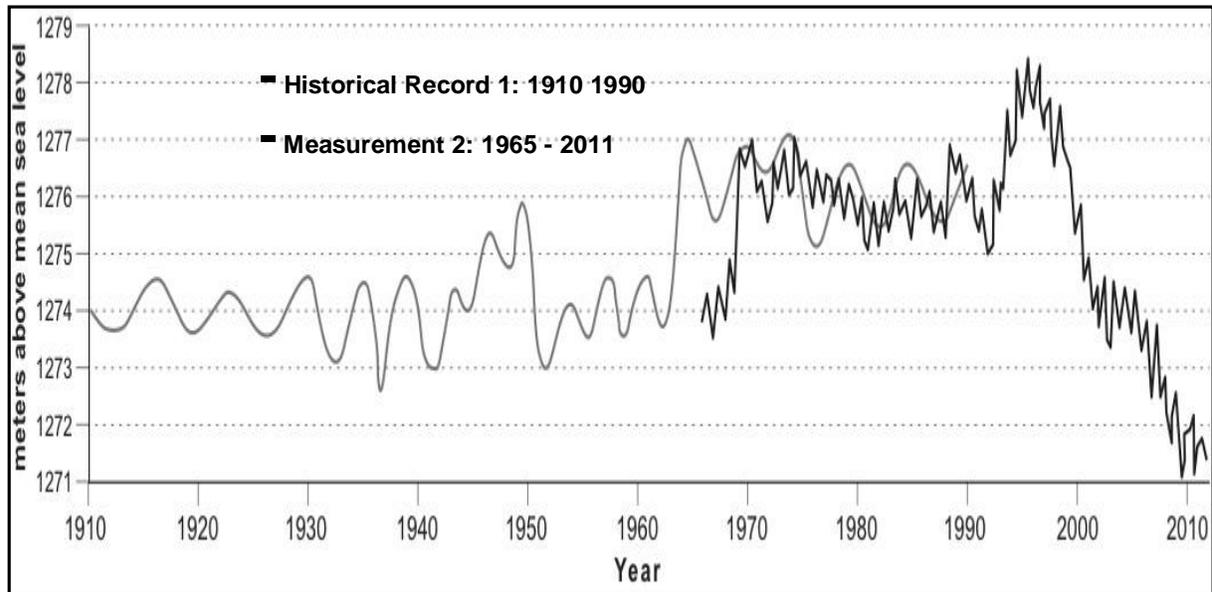


Figure 7. Lake Urmia water level change and its fluctuations, 1910-2011 (Chander, 2012).



Figure 8. Environmental Impact of Lake Urmia Drying on biota of the lake basin: (Left: flamingos, right, and a dead flamingo).

(oligotrophic) conditions. One principal example is the aquatic macroinvertebrates living in Zarrineh River which are currently endangered upon poor nutrient conditions and highly saline water (Ahmadi et al., 2011).

Socio-economic impacts

The use of *Artemia* in fish and shrimp aquaculture is commercially important and recently has been restricted. Due to fish kill in Lake Urmia no fishing benefits can be expected which has led to reduce economic benefits.

Increase in the number of salt storm events is noticed over the last few years. Destructive effects of chemical pollutants of salt storms on bridge constructions and

other infrastructures such as harbor and port facilities, cargo warehouses and passenger boats have been observed lately. In addition, when the toxins and minerals from the salt flats are blown into the air by these storms and inhaled, the toxins and minerals may cause throat and lung cancer, infant mortality, decreasing the life expectancy and increase in birth defects. Vice president of the Iranian Department of Environmental Protection believes that the consequences may lead to exacerbate air pollution in adjacent regions (Fazel, 2012; Interview).

The environmental specialists call these events "Salt Tsunami" (Khabbaz, 2012). The other impact on the social life is related to the mud bathing properties of Lake Urmia salt marshes. This is a medicinal bath in heated mud to treat some diseases such as Rheumatism.

Recently due to severe drought and unsatisfactory environmental conditions, this region may not be as a target for patients.

Political and Institutional implications

Integrated Management Plan for Lake Urmia Basin was signed by Ministry of Agriculture, Ministry of Energy, Chief of Iran's Department of Environment Protection and the governors of provinces responsible for the Lake Urmia basin. This IWRM plan consists of two main programs which are currently under implementations by Ministry of Energy, the main client for projects related to supplying water demand, and Ministry of Agriculture, the main responsible for irrigation sector.

The first and main suggested plan is to reduce agricultural water use to provide 3100 MCM Lake Urmia's water demand by expanding pressurized irrigation and changing cropping pattern (Morid, 2012). The proposed duration is 3 years and Ministry of Agriculture is the main supervisor of this plan.

As the second plan, constructing dams in the Lake Urmia basin will be suspended, and the possibility of transfer water from out of the basin for instance from Aras River and Caspian Sea will be explored. Water transfer from Aras River has started from February 2012, through this way annually 600 MCM water can be transferred into the basin, but the ecological consequences have seriously concerned ecologists (Chit Chian, 2013; Interview).

Prospective barriers of current Lake regenerative programs are insufficient collaboration between corresponding responsible ministries and organizations, mismanagement in responsible regional institutions and inconsistency in other administrative sectors which are leading to a notable delay in ongoing projects.

Furthermore, most studies on Lake Urmia are based on a few limited samples, so investment on research by universities and research institutes are crucial. Lack of government supervision and inadequate attention to environmental issues and human activities impacts is undeniable.

In terms of obstacles caused by publics due to overconsumption and lack of sufficient information, an educational program for public awareness about how the potential volunteers can cooperate to lake restoration programs is inevitable. Volunteers can be involved directly in Non-Governmental Organizations (NGO), charity foundations and public companies to maintain a public-private partnership structure (PPP) in order to save Lake Urmia.

RECOMMENDATIONS

The authors recommend the current restoration plans for saving Lake Urmia could include some other measures.

We have integrated our new proposals and categorized the program of measures into three main procedures.

Procedure A is adjusting water allocation in the basin to allow an adequate flow for sustainable management of the Lake Urmia basin. Full descriptions on the proposed measures for water allocation adjustment (Procedure A) are given in Table 1. It has been presumed that the combination of all measures given in this procedure would be the best ecological option to save the Lake Urmia.

Procedure B could be carried out by importing water from outside the basin to supply water demand and let more water flow to the lake (Kordavani, 2012, Reisi, 2011). Although procedure B as transferring the water has been proposed by many specialists as a time-efficient way to rescue the lake, the head of Iran's Environmental Protection Organization, noted that the corresponding Organization does not consent with the idea of transferring water from Caspian Sea or Aras River to Lake Urmia. Due to this prospective view, the following plans are detrimental to the ecosystem of the basin and may bring severe environmental degradation. Regarding to the remarkable economic costs for the government and the unbeneficial impact on the agronomy of the neighboring catchments, the procedure B cannot be justified. Therefore, Instead of procedure B, Iran's Environmental Protection Organization is intended in strategies more compatible with region's ecology (Ebtekar, 2013; interview).

Procedure C is proposing investment on research, designing and implementing novel techniques e.g. cloud seeding. That would be possible by providing the artificial rains on the Urmia Lake basin. Although the limited cloud seeding projects are under study, but the operation of these projects are still controversial.

CONCLUSION

Lake Urmia located in northwestern of Iran has experienced the severe drought over the past years, where over 70% of the lake water has dried up. Studies show the water level has declined since 1960s. Climate change and climatic variability in climatic patterns, increase in sowing areas, construction of dams and occurrence of excessive water wells around the lake are the main natural and anthropocentric reasons which caused the lake to diminish. These driving forces result in major changes in the area's ecosystem and significant changes in economy of the region.

On August 2013, the Iranian president established a working group to tackle the issue of saving the Lake Urmia. The work group was commissioned to use the background of the already conducted studies and technical research works to resolve this environmental problem and to present their proposals for saving the Lake Urmia to the government. However, in a long-term vision, more studies have to be accomplished on establishing an innovative and holistic IWRM framework

Table 1. Full description on the proposed measures for water allocation adjustment (Procedure A).

S/N	Proposition	Remarks
1	Stopping under construction dams and all ongoing surveys	Pros: Providing sustainable ecosystem for future More budget will be saved Cons: Unemployment at consultancy sector Farmers dissatisfaction
2	Opening remaining dams permanently or temporarily during wet periods	Pros: Providing water for restoring the Lake periodically Cons: Farmers dissatisfaction
3	Reducing agricultural water demand: 3.1) Deficit irrigation, 3.2) Reducing cropped area 3.3) Elimination of some of the annual crops 3.4) Changing the cropping patterns 3.5) Expanding pressurized irrigation 3.6) wastewater reuse 3.7) Enhancing agricultural drainage system	Pros: Accomplish more than 3000 MCM/year to the lake Cons: Social tension Unemployment Endangering food security Consuming huge budget Stakeholder management and engagement is needed Subsidies for supporting frames are required
4	Reducing municipal and industrial water demand: 4.1) Studying modern approaches regarding to drinking water supply and distribution systems, urban drainage and sewage collection and disposal systems 4.2) Public participation programs 4.3) Water and wastewater reuse	Pros: Can accomplish more than 600 MCM annually Cons: Lack of education High budget is required No studies are implemented so far
5	Reducing available Lake Urmia basin water quota for different sectors in each province only in drought spells	Pros: Sustainable allocation during drought spell Cons: Stakeholder participation More collaboration between regional sectors
6	Enhancing the water quality of the lake towards a proper ecological status: 6.1) Enhancing water and wastewater treatment techniques to lower salt loads into the water bodies (e.g. membrane filtration) 6.2) Salt and minerals extraction from accumulated salts around the lake	Pros: Sustainable management of ecosystem of basin Minerals extraction from the lake is profitable Cons: High budget Insufficient studies

to study the casual relations between the different drivers and responses of this crisis within the catchment. Once these frameworks are established, a work plan of remediation consisting of structural and non-structural measures can be conceptualized and implemented for sustainable management of Lake Urmia basin.

REFERENCES

- Abbaspour M, Nazaridoust A (2007). Determination of environmental water requirements of Lake Urmia, Iran: an ecological approach. *Int. J. Environ. Stud.* 64(2):161-169.
- Ahmadi R, Mohebbi F, Hagigi P, Esmailly L, Salmanzadeh R (2011). Macro-invertebrates in the Wetlands of the Zarrineh estuary at the south of Urmia Lake (Iran). *Int. J. Environ. Res.* 5(4):1047-1052.
- Chit Chian A (2013). Official Interview. Accessed: 12/10/2013. Available form: <http://www.azernews.az/region/60438.html>
- Ebtekar M (2013). Official Interview. Accessed: 12/10/2013. Available form: <http://isna.ir/fa/news/92071308466>
- Faramarzi N (2012). Agricultural Water Use in Lake Urmia Basin, Iran: An Approach to Adaptive Policies and Transition to Sustainable Irrigation Water Use. Master Thesis, Upsala University, Department of Earth Science, p. 44.
- Fazel A (2012). Official Interview. Accessed by: 12/10/2013. Available from: <http://aftabnews.ir/fa/news/171331>
- Hassanzadeh E, Zarghami M, Hassanzadeh Y (2012). Determining the Main Factors in Declining the Urmia Lake Level by Using System Dynamics Modeling. *Water Resour. Manage.* 26:129-145.
- Karmi N (2011). Iran's largest lake turning to salt. Accessed: 16/12/2012. Available from: http://news.yahoo.com/s/ap/20110525/ap_on_re_mi_ea/ml_iran_environmental_disaster/print
- Khabbaz M (2012). Salt Tsunami. *Jame Jam News Paper*. Accessed: 16/12/2012. Available from: <http://jamejonline.ir/newstext.aspx?newsnum=100818506546>
- Khosravifard S (2010). Campaigners Fear Lake Urmia Drying Up. Institute for War & Peace Reporting (IWPR). Accessed: 19/12/2012. Available from: <http://iwpr.net/report-news/campaigners-fear-lake-urmia-drying>

- Kordavani P (2012). Little Zab is the way to rescue the Lake Urmia. Young Journalists Agency. Accessed: 16/12/2012 Available from: <http://www.yjc.ir/fa/news/40802114>
- Mohagheg MH (2002). Reducing on the water level of Urmia lake, future view and recomondations. Urmia lake and its potentials to development. Urmia University pp. 1:69
- Morid S (2012). Introducing Lake Urmia Basin (Iran) Drought Risk Management Plan. High Level Meeting on National Drought Policy, Geneva, Switzerland.
- Chander A (2012). The drying of Iran's Lake Urmia and its environmental consequences. Environ. Dev. 2(2):128-137. <http://dx.doi.org/10.1016/j.envdev.2012.03.011>.
- Reisi B (2011). Official speech, Mehr News Agency. Accessed by: 16/12/2012. Available from: <http://www.mehrnews.com/fa/news/detail.aspx?NewsID=1322>.
- Rezvantalab S, Amrollahi, MH (2011). Investigation of Recent Changes in Urmia Salt Lake. Int. J. Chem. Environ. Eng. 2(3):168–171.
- Statistical Center of Iran (2012). Result of Census. Accessed by 12/16/2012, Available from: http://www.amar.org.ir/Portals/0/Files/abstract/1390/sarshomari90_nahaii.pdf.
- Tabari J, Nikbakht J, Talaei PH (2012). Hydrological Drought Assessment in Northwestern Iran Based on Streamflow Drought Index (SDI). Water Resources Management
- Tisseuil C, Roshan G, Nasrabadi T, Asadpour GA (2013). Statistical modeling of future lake level under climatic conditions: Case study of Urmia Lake (Iran). Int. J. Environ. Res. 7(1):69-80.
- U.S. Geological Survey (2012). Changes Over Time: Lake Oroumeih (Urmia), Iran. Accessed by: 16/12/2012. Available from: <http://remotesensing.usgs.gov/feature/description.php?id=223>
- Zafarnejad F (2010). The contribution of dams to Iran's desertification. Int. J. Environ. Stud. 66(3):327-341.
- Zarghami M (2011). Effective watershed management: Case study of Urmia Lake, Iran. Lake Reservoir Manage. 27:87-94.
- Zeinoddini M, Tofighi MA, Vafaei F (2009). Evaluation of dike-type causeway impacts on the flow and salinity regimes in Lake Urmia, Iran. J. Great Lakes Res. 35(1):13-2.