Preserving the World Second Largest Hypersaline Lake Under Future Irrigation and Climate Change

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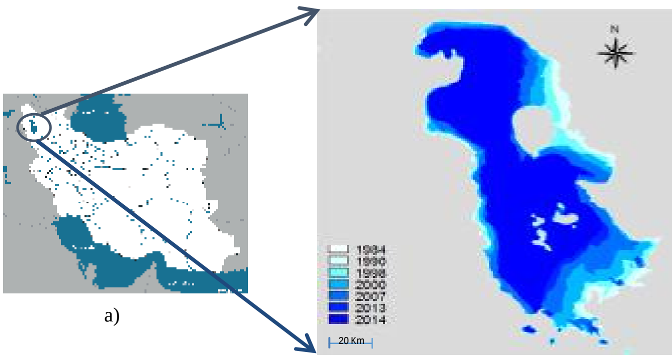
ABSTRACT: Iran Urmia Lake, the world second largest hypersaline lake, has been largely desiccated over the last two decades resulting in socio-environmental consequences similar or even larger than the Aral Sea disaster. To rescue the lake a new water management plan has been proposed, a rapid 40% decline in irrigation water use replacing a former plan which intended to develop reservoirs and irrigation. However, none of these water management plans, which have large socio-economic impacts, have been assessed under future changes in climate and water availability. The Variable Infiltration Capacity (VIC) hydrological model was forced with bias-corrected climate model outputs for both the lowest (RCP2.6) and highest (RCP8.5) greenhouse-gas concentration scenarios to estimate future water availability and impacts of water management strategies. Results showed a 10% decline in future water availability in the basin under RCP2.6 and 27% under RCP8.5. Our results showed that if future climate change is highly limited (RCP2.6) inflow can be just enough to meet the lake requirements by implementing the reduction irrigation plan. However, under more rapid climate change scenario (RCP8.5) reducing irrigation water use will not be enough to save the lake and more drastic measures are needed. Our results showed that future water management plans are not robust under climate change in this region. Therefore, an integrated approach of future land-water use planning and climate change adaptation is therefore needed to improve future water security and to reduce the desiccating of this hypersaline lake.

Keywords: Urmia Lake, Hypersaline Lake, Climate Change, Irrigation, Reservoirs, Hydrological Model

1. INTRODUCTION

Urmia Lake, in north-western Iran, is an important internationally recognized natural area designated as a RAMSAR site and UNESCO Biosphere Reserve (Eimanifar and Mohebbi, 2007). It is a home to many species of reptiles, amphibians and mammals along with a unique brine shrimp species (Asem et al., 2012). Urmia Basin supports a variety of agricultural production systems and activities as well as livestock. Over the last 20 years, the water level and surface area of Urmia lake have declined (Rokni et al., 2015) (Figure 1). As a result, the salinity of the lake has sharply increased which is disturbing the ecosystems, local agriculture and livelihoods, regional health, as well as tourism. (UNEP, 2012). Several studies have warned that the future of Lake Urmia could become similar to the Aral Sea, which has dried up over the past several decades and severely affected the surrounding people with windblown salt storms (Torabian, 2015). It has been estimated people living within 500 km^2 of the Lake location, are at risk (Torabian 2015), which could amplify economic, political and ethnic tensions in this already volatile region (Henareh et al., 2014).



a)

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Fig. 1: Urmia basin location (right) and the surface area changes from 1984 to 2014, derived from LandSat imagery (left)

The main objective of this study was to assess the impacts of future water resources management plans under climate change on the water inflow into Urmia Lake during the 21st century. To address this objective we first quantified how much water is needed to preserve Urmia Hypersaline Lake. Then, we developed future projections of total inflow into the lake, using the Variable Infiltration Capacity (VIC) hydrological model (Liang et al., 1994), including an irrigation and reservoir module (Haddeland et al., 2006). The model was forced with statistically bias-corrected General Circulation Models (GCMs) outputs from a low and high representative concentration pathways (RCPs) (Moss et al., 2010). In addition, to study the impact of the water resources plans on the future inflow, the two proposed plans plus the current, and the naturalized (without any irrigation and reservoirs) situations were applied in the model. The simulated inflow was compared with the annual and monthly estimated EFRs to assess the possibilities of Urmia lake restoration and preservation under different climate change and anthropogenic scenarios.

2. METHODS

The methodological framework for this study is shown in Figure 2. Future scenarios for daily flow into the lake were calculated using the VIC hydrological model forced by bias-corrected outputs from five GCMs, using the representative concentration pathway (RCP) 2.6, lowest; (Van Vuuren et al., 2011) and 8.5, highest; (Riahi et al., 2011), for 2010-2099 and for 1971-2000 (control) in combination with four different anthropogenic scenarios (40 simulations). Historical naturalized inflow from the control period was used to estimate annual and monthly environmental flow requirements (EFRs). To assess the significant impact of water resources plans and the climate change impact, the paired two-tailed Student’s t-test was used, P values of < 0.05 were considered significant.

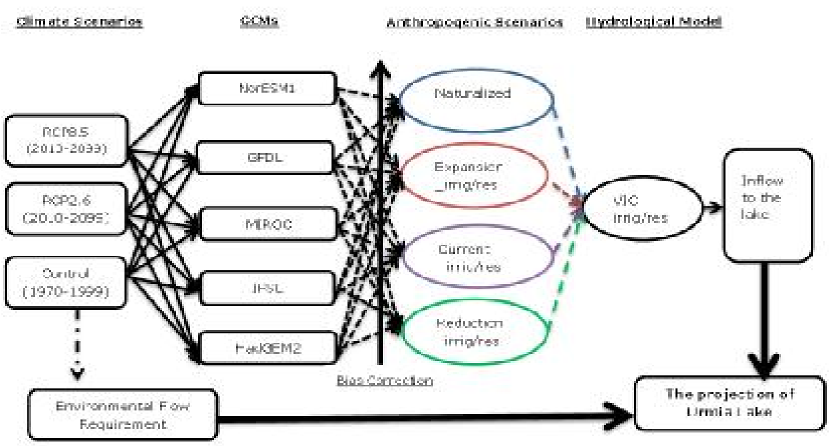


Fig. 2: Schematic representation of the modelling framework

3. RESULTS AND DISCUSSION

Our results showed that under both RCPs, climate change will reduce the water availability in the basin especially in the wet season (Figure 3). This is an important result as the basin already has a serious challenge to secure water availability. IPCC also reported a projected decline in future precipitation for the same period (March till August) for this region (Kirtman, 2013).

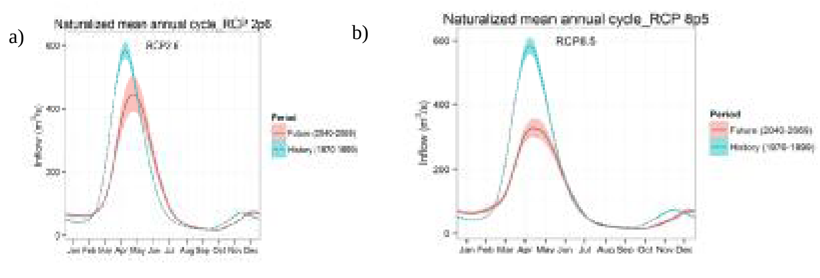
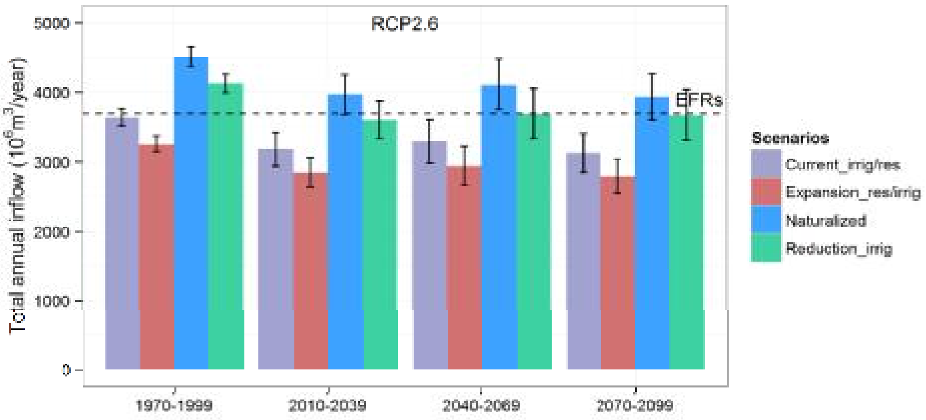


Fig. 3: mean annual cycle of projected 30-day moving average of naturalized inflow (without human impact) for five GCMs for control period (1971-2000) and future (2040-2069) under RCP2.6 (a) and RCP8.5 (b). The shadows represent the standard error of the mean for all five GCMs.

Our results from the control period (1971-2000) indicated that without climate change, the inflow would have been sufficient to meet the lake EFRs for all water resources scenarios (Figure 4). The finding of the current study supports other studies that have indicated the role of climate variabilities and change on the lake degradation. The results clearly showed the significant impact of climate change on annual inflow to the lake under RCP8.5. This impact is not significant under RCP2.6. These results are consistent with the IPCC report which showed a decline in runoff for this region for both near-term (Kirtman, 2013) and long-term future (Collins, 2013) under the rapid greenhouse-gas concentration scenarios. These findings also are consistent with the results obtained by Asokan et al. (2016) in Aral Sea basin, which has quite same condition as Urmia basin. They investigated freshwater fluxes and their changes under RCP2.6 and 8.5 by applying the Coupled Model Intercomparison Project, Phase 5 (CMIP5) outputs. They showed that the runoff is mostly projected to decrease in the Aral Sea basin, with overall negative values of runoff and relatively small standard deviation among models. However, they reported very high range of uncertainties which is not consisting with this study. It can be related to a larger number of GCMs outputs which applied in their study.



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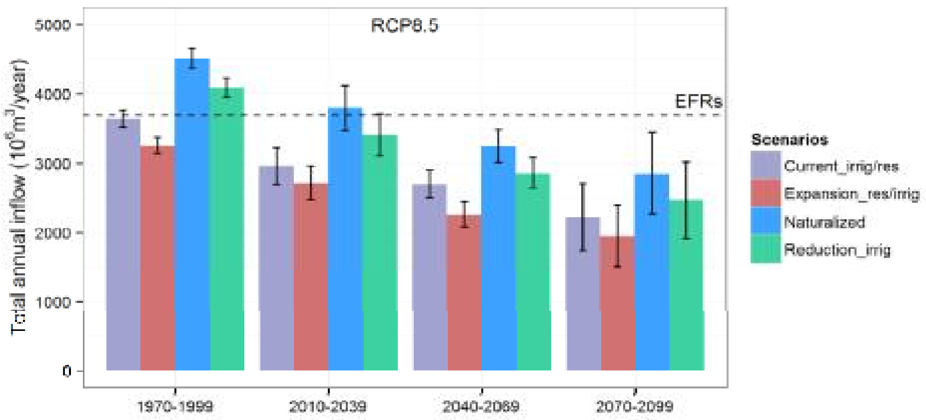

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Fig. 4: Total average inflow to that lake for the control (1971-2000) and future time slices (2010-2039, 2040-2069 and 2070-2099), for the two different water resources plans under RCP 2.6 (a) and RCP 8.5 (b), compared with EFRs, the error bars represent the standard error of the mean.

4. CONCLUSION

In this study we assessed how water resources plans can fulfil Urmia lake inflow requirements under different climate change scenarios. The results showed that the water resources plans are not robust to strong changes in climate. In other words, if future climate change is limited due to rapid mitigation measures (RCP2.6) the new strategy, reduction of irrigation water use, can help to preserve the lake. However, it is not the case for higher climate scenario. Therefore, regarding a drier future and increasing water demand in the region, an urgent action in both regional (to limit anthropogenic impact) and global scale (to limit greenhouse-gas concentration) is needed to save the lake. As RCP2.6 is a relatively optimistic scenario, we recommend investing in other adaptation options to increase the inflow to lake. The results of this study highlight the need for most attention for desiccating saline and hypersaline waterbodies, as one the most earth's vulnerable ecosystem, under future development and climate change.

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