Journal: Hydrology and Earth System Sciences (HESS)
Title: Quantifying the impacts of human water use and climate variations on recent drying of Lake Urmia basin: the value of different sets of spaceborne and in-situ data for calibrating a hydrological model

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1 Overall assessment

First and foremost, I would like to sincerely apologize for my late reviews – due to family reasons. I have now reviewed the new manuscripts and authors' responses to previous reviews. By and large, the authors have addressed most of the comments, updated the modelling, condensed the manuscript and improved the use of language, and improved the discussion of results (particularly adding a new section on the limitations of the study). So, I would like to thank authors for their efforts in this round of the review.

I would like to also thank authors for dedicating a section on **limitations (section 4.3)**. Not only it is good practice for scientific studies, but also it directs readers to design future studies to address past limitations. That said, a few major points are missing in the discussion of limitations:

- The study period is limited and do not include some of the most important years of the lake (and the basin) old/recent history and evolution, e.g. recent changes in the lake since 2013 (beyond the study period of this manuscript). Compared to most hydro-climatology studies of the lake, this study is based on a very short period (2003-2013), and hence generalizing its results beyond this domain is difficult, particularly due to the non-stationarity of the lake system. I expanded on this in section 3 of this review.
- Role of dam constructions, groundwater withdrawals and its hydrological connectivity to the lake, and seasonal variations of the flow overlooked in the model calibration.

Moreover, **section 4.2 "*Comparison to human vs. climatic contribution as determined in previous studies*"** comes short of providing an adequate and accurate characterization of the ongoing debate within the literature:

- I acknowledge that the Lake Urmia desiccation has been an ongoing contested debate, i.e. whether the main driver of drying is management-related and human activities or climatic. This very question is indeed the crux of the matter, and hence it is in the best interest of both authors and readers to be more rigorous on this discussion. As opposed to several previous studies, this study puts more weight on the climatic drivers of the lake drying. However, the authors (in section 4.2) misrepresented or overlooked some of those studies which argued for human activities over climatic drivers. Regardless of my personal position in this debate, authors are unduly framing the results and merits of the previous studies to justify their own side of the argument. Further, they have failed to discuss a few important studies on the lake. I demonstrate this in section 2 of this review. To help the authors, I discussed several points in details. I have also suggested few additional references and edits throughout. Therefore, in my opinion section 4.2 of the manuscript is inadequate and must be improved.

In my evaluation, the manuscript would be **accepted upon the suggested minor to moderate revisions**.

Below you could read my new reviews and replies to a few *responses of authors (in purple)* to my earlier reviews. The “*quotations”* are from the final version of the manuscript.

2 Section 4.2 “human vs. climatic contribution”

The discussion is not elaborative, lacks a clear discussion line, and previous studies are not appropriately represented/discussed. Here I discuss a few points in this section as an example, to help authors better discuss this important point.

Page 18 line 17-21: “*Chaudhari et al. (2018) concluded that human-induced changes accounted for 86% of the lake volume decline during 1995-2010, while we determined values of 39-43% for 2003-2013. According to our study, human water use was the reason for 39-45% inflow reduction into the lake during 2003-2013 which is very similar to the values of Shadkam et al. (2016) for the years 2003-2009 (comp. their Fig. 8). Discrepancies are likely due to different analysis methods but different analysis periods and conceptualizations make a direct comparison of the estimated contributions difficult*.” Re the underlined part: it is a general statement and not good enough to simply overlook the details leading to these difference. It is essential to discuss in more details what are the main differences between these studies e.g. in terms of data type, analysis approaches, fundamental assumptions, etc. For instance, Chaudhari et al. (2018) studied a considerably longer period. They also studied the land use changes in detail: over 1987-2016 showed ~98% and ~180% increase in agricultural lands and urban areas, respectively. They accounted for human impact during 1995-2010 (based on simulation of streamflow into the lake). Various studies identified two distinct periods of pre- and post-change in the lake dynamics, e.g. Khazaei et al. (2019) identified year 2000 as the change point and Fazel et al. (2017) identified year 2001. Given that, studies such as Chaudhari et al. (2018) take into account a wider range of the non-stationarity of the lake than the present study where only a part of the post-change period is investigated. It is plausible to expect that if your model was successfully calibrated over a longer period including years prior to 2000, it would have lead to different results.

"*While Ghale et al. (2018) seem to support the results of Chaudhari et al. (2018) as they state that 80% of drying of Lake Urmia is due to anthropogenic impacts during 1998-2010, their statistical analysis assumes that lake inflow from rivers can be considered to reflect "anthropogenic impacts" while precipitation and evaporation reflect climatic variation. However, inflow is in reality also affected by climatic variations.*" Your argument here is incomplete, as the impact of climate vs. human activities on river networks is different for headwaters and lower river reaches. Fazel et al. (2017) investigated this in detail, analyzing the flow regime changes across the lake basin (57 flow gauging stations) over the period 1949-2013 (perhaps the longest record of the basin flow studied so far). Their study showed that while "*flow regime in river headwaters appeared to be dominated by natural forces*", "*the reduction in river flow magnitude increased from headwaters to downstream reaches for all rivers*" due to dam river regulations and dam constructions. They further argued that "*Changes in river flow in the period 1965–2013 cannot be explained by climate change, the effects of which occur much more slowly than those of land use change in the region*". They concluded that "*The results showed that irrigation was by far the main driving force for river flow regime changes in the lake basin. All stations close to the lake and on adjacent plains showed significantly higher impacts of land use change than headwaters. As headwaters are relatively unaffected by agriculture, the non-significant changes observed in headwater flow regimes indicate a minor effect of climate change on river flows in the region*".

"*Using a statistical change point analysis and without modelling, Khazaei et al. (2019) stated that given the stable conditions of precipitation and temperature, climatic changes could not explain the dramatic decline of the lake level; however, they did not use in-situ data (except lake water level data) for their analysis*" Study by Khazaei et al. (2019) is more than a simple statistical change point analysis, they estimated the land use change (particularly vegetation dynamics and its associated hydrological loss in terms of evapotranspiration) and trends of various hydro-climatic variables across various time scales. While their study surely has its own limitations, lack of modeling and use of in-situ data are not the major limitations – let alone this is too generic for a scientific criticism. One of the major limitations of their work, for instance, is that they did not account for the role of groundwater dynamics in their analysis.

"*For quantifying human and climatic contributions to observed hydrological changes, a comprehensive modeling approach that takes into account, for example, the impacts of changing temperatures on runoff and thus river inflow and on evapotranspiration of the lake itself is preferable*." Preferable to what exactly? I tend to disagree that modeling is preferable to comprehensive analysis of historical data. Modeling introduce various sources of new uncertainty to a problem (such as model structural uncertainty, parameter uncertainty, over-parameterization, parameter transferability across time and space, etc.), which are not preferable to the simplifying assumptions underlying statistical analyses (such as trend, correlation, or linear regressions). In general, I believe, both approaches of modeling and data analysis can inform us in some ways, while each has its own shortcomings in other ways.

“*Chaudhari et al. (2018) but their uncalibrated global hydrological model that represented the basin by 5-6 cells only was not able to simulate well the flows and storages in the basin.*” This is a mischaracterization of Chaudhari et al. (2018), undermining their extensive modeling setup and evaluation. Although Chaudhari did not explicitly discuss the model setup and calibration, they demonstrated the adequacy of their model by evaluating various model outputs against available knowledge and data of the LU basin. For instance, they compared their simulation inflow to the lake with the observed inflow record (previously gathered by Hassanzadeh et al., 2012). As the figure shows it is in good agreement. I agree with the authors’ intent to critically review previous studies to elaborate their shortcomings, however this must be done rigorously and accurately.

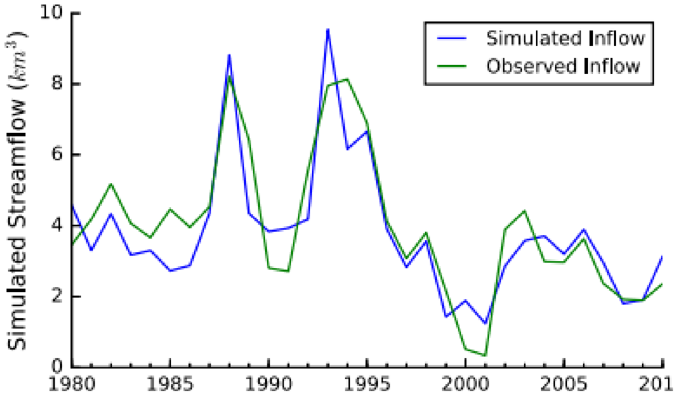


Fig. 7. Comparison of simulated river inflow to Urmia Lake from HiGW-MAT model and the inflow data from Hassanzadeh et al., (2012).

Page 19 lines 2-5: “*Hosseini-Moghari et al. (2018) showed that an increasing frequency of days with less than 5 mm precipitation in combination with decreasing monthly precipitation has led to the observed reduced inflow into two dams in the Lake Urmia basin that are located 5 downstream of areas with insignificant human water use.*” This study is not available online and it is not possible to confirm whether it is peer-reviewed or not.

“*We conclude that analyses should be done on a daily time scale or smaller.*” What type of analyses exactly? Such a generic statement. Needless to mention that the very present study of the authors is not done on a daily time scale either. The time scale of a study depends on its objective.

“*we examined the ratio of annual inflow into the lake (based on the ensemble mean) over annual precipitation during the study period. This ratio reached maximum values in 2003 (0.29 and 0.41 for the anthropogenic and naturalized conditions, respectivly) and minimum values in 2009 (0.07 and 0.15). Averaged over the period 2009-2013, these ratios are, with 0.11 (ANT) and 0.22 (NAT), much smaller than the values for 2003-2007, 0.20 and 0.32. Thus, the drought year 2008 as well as the relatively small ratio of inflow into the lake over precipitation in the last five years of the study period play a significant role in the decline of inflow and lake water storage*” There are various issues with this argument. First, the period 2009-2013 is a very short period to build a hydro-climatic analysis on, particularly for LU with remarkable non-stationarity. So, the naturalized scenario based on this period is not reliable. Second, the considerable extraction of groundwater resources has been an additional source of water for irrigation and consequently hydrological loss in this basin. The impact of groundwater withdrawal (and its consequent hydrological loss) would have had a direct impact on the lake and possibly on streamflow generation in the basin as well (e.g. as the land coverage of the basin has changed). Urbanization in this basin (discussed by Chaudhari et al. (2018)) together with the expansion of agricultural and irrigated areas would have an impact on streamflow generation (both magnitude and generation mechanisms).

"*For quantifying human and climatic contributions to observed hydrological changes, a comprehensive modeling approach that takes into account, for example, the impacts of changing temperatures on runoff and thus river inflow and on evapotranspiration of the lake itself is preferable.*" Also, estimating the impact of land use change (e.g. urbanization and cropland expansion) on runoff generation in the basin.

2.1. On the role of atmospheric drought

Figure 2 and the last paragraph of page 2: This figure and its associated text provide an **incomplete** overview of the lake dynamics. The decline of the lake water level started around the year 2000, which is way more abrupt than 2003 onwards.

Page 1 line 30: "*The study shows that even without human water use Lake Urmia would not have recovered from the significant loss of lake water volume caused by the drought year 2008*." First, you have not provided any evidence that the drought year 2008 caused a significant loss in lake volume, this causal link is non-existent in your study. The authors are trying to over-emphasize the role of atmospheric droughts, specially the 2008 one. There has been stronger atmospheric droughts in previous years than year 2008. Here is a figure from Alborzi et al. (2018). The historic droughts during 80s and early 90s are more severe than the 2008 drought, yet the lake has survived (AghaKouchak et al., 2015).

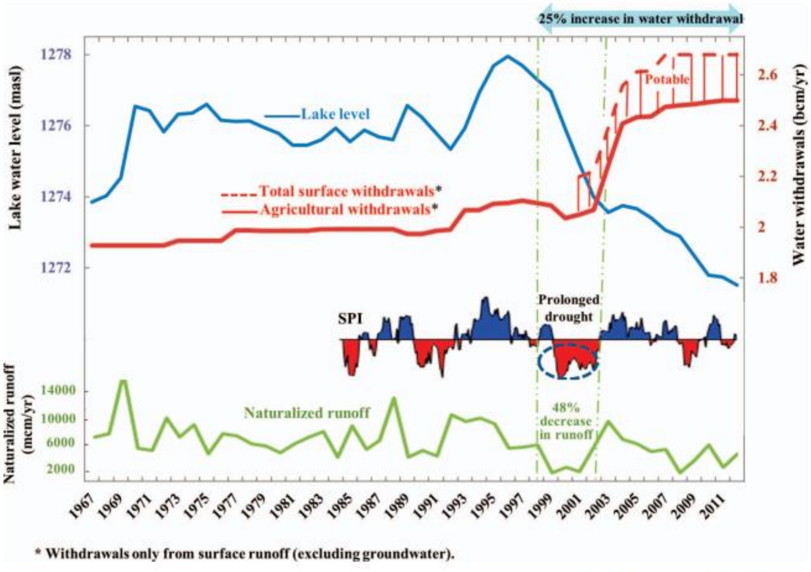
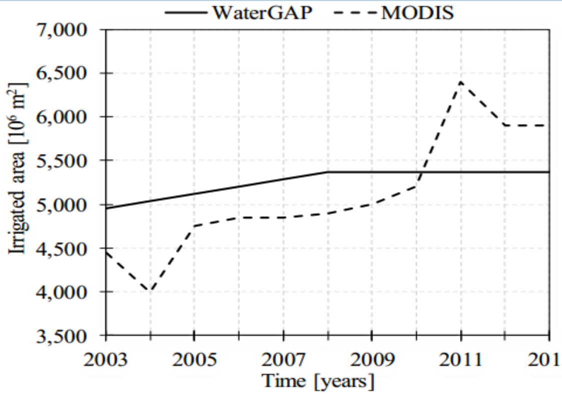


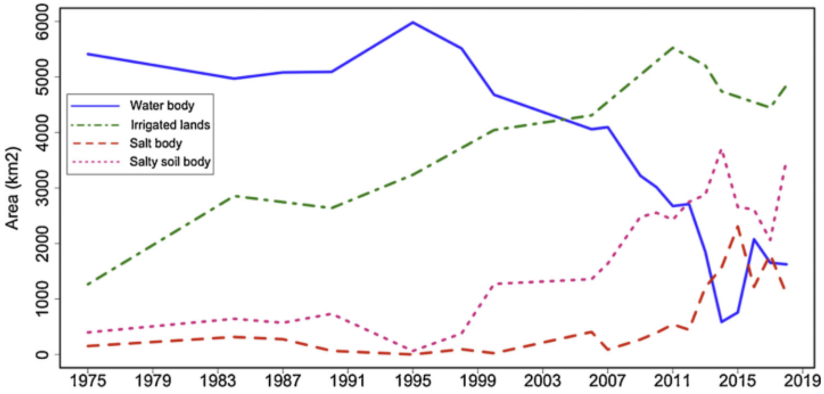
Figure 2. Key attributes of the lake-basin system prior to restoration program in 2013, including observed lake level, standardized precipitation index (SPI), basin-scale naturalized runoff, and surface water withdrawal. The basin's recent wet (blue) and dry (red) periods are illustrated in SPI and naturalized runoff curves. Post-1998 drop in lake level corresponds to a substantial increase (~25%) in surface water withdrawals during the prolonged drought of 1998–2002.

2.2. Irrigated area

One aspect that has not been discussed in section 4.2 is the irrigated area: how it is differently estimated by different studies and its implications. Below I have extracted figures corresponding to the estimated irrigated areas by 3 different studies.



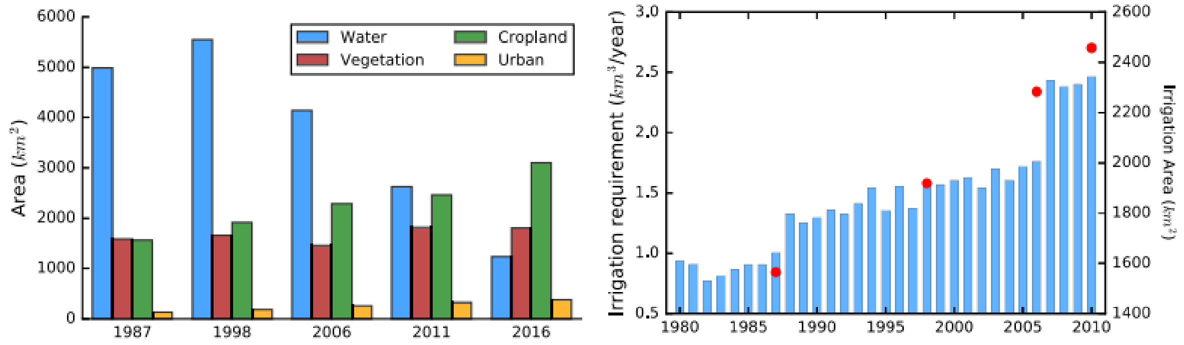
From the present study



From (Alizade Govarchin Ghale et al., 2019)

Supplement page 3 line 5: "*Considering that water management in the basin aims at preventing any increase of irrigated areas, it is assumed that the irrigated area in 2013 remained at the 2012 value (Fig. S3)*". This assumption is questionable. For instance, Alizade Govarchin Ghale et al. (2019) estimated the irrigated lands to decrease by ~12% from 2012, but again increase in 2018-2019. Further, their estimated irrigated area is very different from the present study: year 2003 is different by ~500 km^2 (~12%). The trend is also different, e.g. the increase during 2007-2011, or during 2003-2005.

While both this study and Alizade Govarchin Ghale et al. (2019) estimated the irrigated area based on the overall vegetation coverage, Chaudhari et al. (2018) made a distinction between natural vegetation and cropland. They showed (see the figures below) that the while the natural vegetation has oscillated throughout the years (1998 to 2006 → decreased, 2006 to 2011 → increased, and 2011 to 2016 → decreased), the cropland has continuously increased. Moreover, they estimated the



From Chaudhari et al. (2018)

annual net irrigation requirement (NIWR) during 1980-2010 based on the crop evapotranspiration (FAO Penman Monteith approach), independent of the global hydrological model they used, and compared it with estimations based on Landsat classification (see Figure 9 in their study). So, their estimated irrigation is independent of how well or poorly their model was calibrated, and arguably more comprehensive than your study. While the present study demerited Chaudhari et al. (2018) (page 19 of the manuscript) and entirely overlooked Alizade Govarchin Ghale et al. (2019) and Fazel et al. (2017), the authors failed to acknowledge that these studies delved deep into land use changes, irrigation water requirement, and flow regime changes.

3 Comments on “Section 4.3 Limitations”

3.1. Study period

Here I would like to allude to a previous comment of the review process.

Reviewer comment: the time period 2003-2013 is inadequate for modeling the lake dynamics. Before 2000 the lake was not as heavily impacted by over-regulation of the river flows, and also between 2000-2003 there is significant variation in the lake level and annual inflows to the lake. Therefore it is essential to include these years, for as many variable as possible. Otherwise, the model is biased and not representative of the lake dynamics.

Authors’ response: *We have considered this period due to the fact that the observed data was available for this period. We completely agree with you; it was better to consider a longer period for calibration. However, we don't prefer to reconstruct data, that is error-prone. The GRACE data and irrigated areas are not available for the period 2000-2003. Further, we don't want to use the model for out of calibration period, therefore we believe that for using the model in the calibration period there is no concern about the bias.*

Reviewer’s response: the point I argued is not simply about the length of data and model calibration. There are major aspects of the lake dynamics (and the basin evolution) that falls outside the 2003-2013 period. While you evaluated your model within the calibration period using an independent variable, you tend to generalize your findings about the lake beyond the limited period of 2003-2013. To study the drivers of the lake drying, it is not adequate to build up your entire argument based on a limited time period that does not include the non-stationarities of the lake system: various studies identified two periods of pre- and post-change for the lake, e.g. Khazaei et al. (2019) identified year 2000 and Fazel et al. (2017) identified year 2001 as the change point. Given that, your study does not cover the pre-change period, and both anthropogenic and natural scenarios are defined based on only a sub-period (2003-2013) of the post-change period (2000 to date), which biases the scenario analysis. Further, most recent changes in the lake system is also not discussed. The lake has experienced considerable changes since 2013, e.g. see the extensive study by (Alizade Govarchin Ghale et al., 2019) on the land use changes within the lake basin. The figure below (extracted from Alizade Govarchin Ghale et al. (2019) shows the historic surface area as well as its increase since 2013 – evidence of remarkable non-stationarity. To what extent your modelling assumptions and results are compatible with this non-stationarity, particularly the most recent changes of the lake?

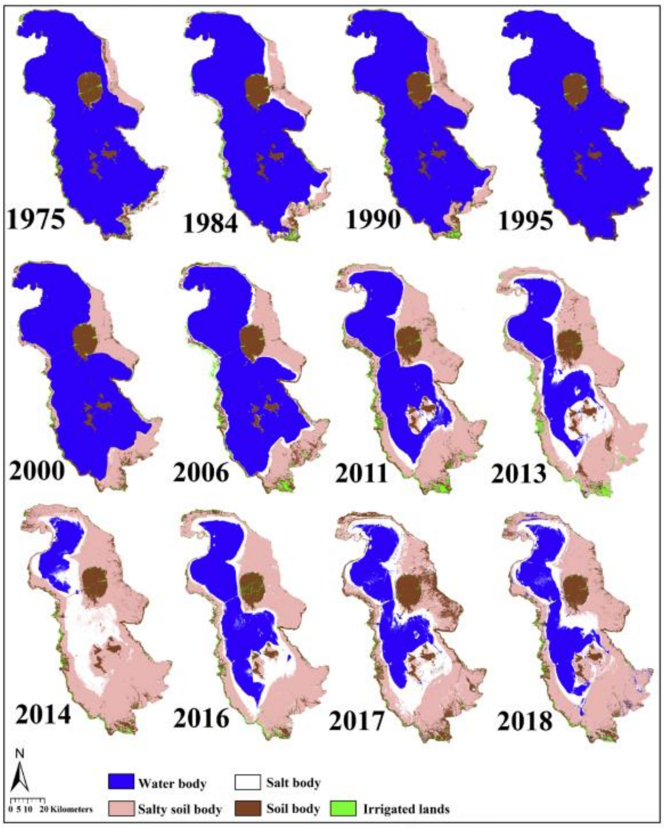


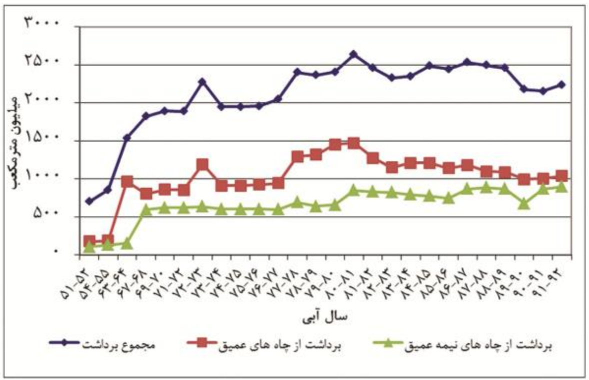
Fig. 4. Salinization and desertification progress in Urmia Lake from 1975 to 2018.

3.2. Other limitations and suggestions

Role of dams: Another aspect of the lake system that you did not accounted for explicitly is the dam construction within the lake basin over the past decades (24 dams were constructed during 1970-2000, and 32 during 2000-2014), which studies such as Fazel et al. (2017) and Alizade Govarchin Ghale et al. (2018) accounted for explicitly.

Seasonal flow and model calibration: While all variables are calibrated/evaluated on a monthly basis, the streamflow is calibrated on annual scale. I suspect that it is due to the fact that the model could not adequately represent the seasonal variations in streamflow, which are significant for this basin (Alizade Govarchin Ghale et al., 2019; Fazel et al., 2017). The seasonal variations of the flow have direct implications on irrigation estimations and the lake dynamics.

Groundwater withdrawal and its hydrological connectivity to the lake: The groundwater withdrawal is under-estimated in the model setup (a point that has been raised by reviewers before). While authors stated that "*Observed decline of groundwater storage was* $1.8 \cdot 10^9$



From LURP report (in Persian, attached to this review). Red is withdrawal from deep wells, and green is withdrawal from partial deep wells, and blue is the total extraction.

m^3, i.e. 18% of the observed total water storage loss in the basin" (page 17 line 20), the groundwater withdrawal (including both shallow and deep wells, see the figure) shows at least 2.1 MCM withdrawal in the past 2 decades.

Also, as discussed by Danesh-Yazdi and Ataie-Ashtiani (2019) the hydrologic connectivity between the lake and groundwater remains an under-studied aspect of the lake dynamics – which is a general limitation of most studies including the present one.

Page 20 lines 1-3: re lake bathymetry please also cite the below studies:

- Sima, S., & Tajrishy, M. (2013). Using satellite data to extract volume–area–elevation relationships for Urmia Lake, Iran. *Journal of Great Lakes Research*, *39*(1), 90-99.
- Karimi, N., Bagheri, M. H., Hooshyaripor, F., Farokhnia, A., & Sheshangosht, S. (2016). Deriving and evaluating bathymetry maps and stage curves for shallow lakes using remote sensing data. *Water Resources Management*, *30*(14), 5003-5020.

4 Minor comments

Page 3 line 10: "*Studies on various aspects of the Lake Urmia disaster abound. With decreasing lake water volume, salt concentration has increased*". Please cite the recent study on salt concentration as a dust source:

- Boroughani, M., Hashemi, H., Hosseini, S. H., Pourhashemi, S., & Berndtsson, R. (2019). Desiccating Lake Urmia: A New Dust Source of Regional Importance. *IEEE Geoscience and Remote Sensing Letters*.

Page 3 line 11: "*Precipitation reduction, temperature increase, agricultural development including construction of man-made dams and building a causeway across the lake have been identified as the reasons for the degradation of Lake Urmia (Abbaspour and Nazaridoust, 2007; Zeinoddini et al., 2009; Delju et al., 2012; Jalili et al., 2012; Sima and Tajrishy, 2013; Fathian et al., 2014; Farajzadeh et al., 2014; Banihabib et al., 2015; AghaKouchak et al., 2015; Azarnivand and Banihabib 2017; Alizadeh-Choobari et al., 2016; Ghale et al., 2018; Khazaei et al., 2019)*". Please separate out the references and cite relevant references for each factor (underlined phrases) individually. It helps the readers to track back.

Page 4 line 25: "*a good fit of simulated and observed streamflow may not necessarily lead to an appropriate simulation of other flows and storages (Beven and Freer, 2001). Therefore, additional types of observations have to be added to avoid equifinality (Beven and Freer, 2001; Döll et al.,* *2016).”* The second sentence does not follow the first sentence, and using “therefore” does not make sense here. Also, by adding further data types, one will not “avoid” equifinality, because equifinality is a general property of open complex systems (e.g. hydrological models) and cannot be avoided. The goal is to “reduce” equifinality when possible. Please also cite the following recent studies on equifinality which are directly relevant to the discussion:

- Kelleher, C., McGlynn, B., & Wagener, T. (2017). Characterizing and reducing equifinality by constraining a distributed catchment model with regional signatures, local observations, and process understanding. *Hydrology and Earth System Sciences*, *21*(7), 3325.
- Khatami, S., Peel, M. C., Peterson, T. J., & Western, A. W. (2019). Equifinality and flux mapping: A new approach to model evaluation and process representation under uncertainty. *Water Resources Research*, 55, 8922– 8941.

Page 12 line 17 “*We determined that the results of the naturalized run differ by less than 2% from a run with reservoirs but without human water use*”. First, it is not clear 2% of what is discussed here exactly. Second, such a small difference between the two scenarios is clearly a red flag, indicating that the model setup and/or scenarios are problematic. Most of the recent studies concluded that the lake condition is heavily impacted by human water use.

Page 14 line 20 “*In this way, efficient simulation of regional water flows and storages can be achieved, possibly as an alternative to a costlier setup of a regional model*”. I’m not sure if I understood this part. What is costly about a regional model that is discouraging? What do you exactly mean by “setup a regional model”, do you mean to develop a model from scratch?

Page 18, reword the title of the subsection 4.2 “*Comparison to human vs. climatic contribution as determined in previous studies*”, it does not read well.

Page 19 line 8: “*respectivly*” → respectively

References

AghaKouchak, A., Norouzi, H., Madani, K., Mirchi, A., Azarderakhsh, M., Nazemi, A., et al. (2015). Aral Sea syndrome desiccates Lake Urmia: Call for action. *Journal of Great Lakes Research, 41*(1), 307-311. doi:http://dx.doi.org/10.1016/j.jglr.2014.12.007

Alborzi, A., Mirchi, A., Moftakhari, H., Mallakpour, I., Alian, S., Nazemi, A., et al. (2018). Climate-informed environmental inflows to revive a drying lake facing meteorological and anthropogenic droughts. *Environmental Research Letters, 13*(8), 084010.

Alizade Govarchin Ghale, Y., Altunkaynak, A., & Unal, A. (2018). Investigation Anthropogenic Impacts and Climate Factors on Drying up of Urmia Lake using Water Budget and Drought Analysis. *Water Resources Management, 32*(1), 325-337. doi:10.1007/s11269-017-1812-5

Alizade Govarchin Ghale, Y., Baykara, M., & Unal, A. (2019). Investigating the interaction between agricultural lands and Urmia Lake ecosystem using remote sensing techniques and hydro-climatic data analysis. *Agricultural Water Management, 221*, 566-579. doi:https://doi.org/10.1016/j.agwat.2019.05.028

Chaudhari, S., Felfelani, F., Shin, S., & Pokhrel, Y. (2018). Climate and anthropogenic contributions to the desiccation of the second largest saline lake in the twentieth century. *Journal of Hydrology, 560*, 342-353. doi:https://doi.org/10.1016/j.jhydrol.2018.03.034

Danesh-Yazdi, M., & Ataie-Ashtiani, B. (2019). Lake Urmia crisis and restoration plan: Planning without appropriate data and model is gambling. *Journal of Hydrology, 576*, 639-651. doi:https://doi.org/10.1016/j.jhydrol.2019.06.068

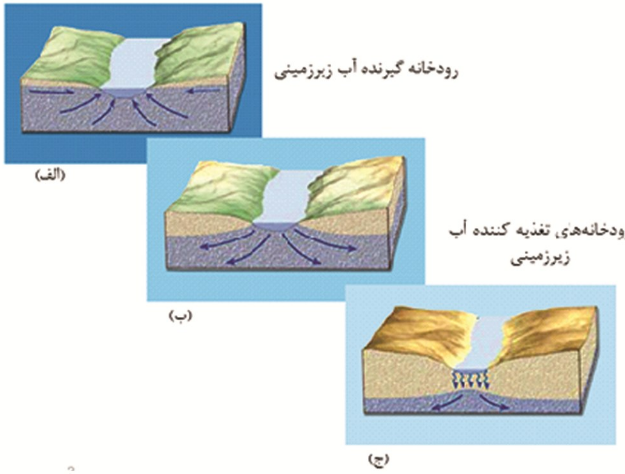
Fazel, N., Torabi Haghighi, A., & Kløve, B. (2017). Analysis of land use and climate change impacts by comparing river flow records for headwaters and lowland reaches. *Global and Planetary Change, 158*, 47-56. doi:https://doi.org/10.1016/j.gloplacha.2017.09.014

Khazaei, B., Khatami, S., Alemohammad, S. H., Rashidi, L., Wu, C., Madani, K., et al. (2019). Climatic or regionally induced by humans? Tracing hydro-climatic and land-use changes to better understand the Lake Urmia tragedy. *Journal of Hydrology, 569*, 203-217. doi:https://doi.org/10.1016/j.jhydrol.2018.12.004

۳.علیرغم افزایش تعداد چاه‌های حفرشده در سطح حوضه، میزان تخلیه و برداشت از آن‌ها در سالیان اخیر با روند نزولی همراه بوده است. این امر به‌خوبی نشان‌دهنده کاهش توان آبدهی آبخوان‌های حوضه می‌باشد.

۴. کیفیت بسیاری از آبخوان‌ها با روند نزولی همراه بوده است و این مسئله ناشی از برداشت بی‌رویه از منابع آب زیرزمینی حوضه می‌باشد.

۵.در شکل ۴، نحوه تأثیرگذاری برداشت بی‌رویه از چاه‌ها بر رواناب‌های رودخانه‌ها نشان داده شده است. درواقع این شکل به‌خوبی نشان‌دهنده تغییرات نحوه اندرکنش آب زیرزمینی با آبراهه‌ها و رودخانه‌ها می‌باشد. به بیان بهتر، به دلیل افزایش برداشت از منابع آب زیرزمینی یک رودخانه تغذیه‌شونده از منابع آب زیرزمینی تبدیل به رودخانه تغذیه‌کننده گردیده و حتی دبی پایه خود را نیز ممکن است از دست دهد. افت میزان آبدهی بسیاری از رودخانه‌های حوضه، به‌خوبی مؤید این مطلب است.



شکل ۴- **اندرکنش رودخانه با آب زیرزمینی**

راهکارهای مصوب در خصوص مدیریت آب زیرزمینی

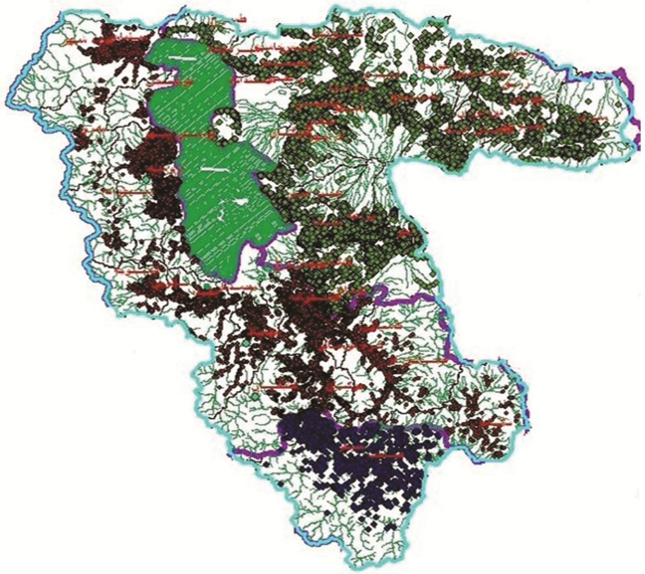
به‌منظور ایجاد پایداری در وضعیت منابع آب زیرزمینی حوضه و همچنین کاهش پیامدهای منفی ناشی از برداشت بی‌رویه از منابع مذکور در تداوم افت تراز دریاچه ارومیه، راهکارهای مختلفی توسط دفتر برنامه‌ریزی و تلفیق ستاد احیای دریاچه ارومیه بررسی شد و درنهایت راهکارهای ذیل در این خصوص مورد تصویب قرار گرفته است:

- ساماندهی چاه‌های حوضه آبریز دریاچه ارومیه و نصب کنتورهای هوشمند و حجمی جهت کنترل برداشت در راستای افزایش میزان جریان ورودی از رودخانه‌ها به دریاچه ارومیه
- انجام هماهنگی‌های لازم با قوه قضائیه در راستای تسهیل و تسریع در اجرای قانون تعیین تکلیف چاه‌های فاقد پروانه به‌ویژه چاه های اثرگذار بر آب‌های سطحی
- شناسایی محدوده‌های اثرگذار بر آبدهی رودخانه‌های اصلی منتهی به دریاچه ارومیه و تقویت آن‌ها از طریق عملیات آبخیزداری و آبخوان‌داری به‌منظور افزایش حجم آب ورودی به دریاچه.

در مجموع شواهد نشان می‌دهد که، یکی از عوامل مهم موثر بر کاهش آبدهی رودخانه‌های منتهی به دریاچه ارومیه، برداشت بی‌رویه از منابع آب زیرزمینی حوضه از طریق حفر تعداد قابل ملاحظه‌ای چاه مجاز و غیر مجاز می‌باشد. لذا بر اساس مصوبات کارگروه ملی نجات دریاچه ارومیه ساماندهی وضعیت منابع آب زیرزمینی حوضه به ویژه بیش از ۴۰۰۰۰ حلقه چاه غیرمجاز و نظارت بر وضعیت برداشت از منابع راهبردی حوضه با همکاری همه نهادهای مسئول، امری بسیار ضروری می‌باشد.

دبیر خانه مرکزی: خیابان آزادی، جنب دانشگاه صنعتی شریف، پلاک ۵۱۷، طبقهٔ همکف، واحد۳.
دبیرخانه استانی:
- آذربایجان غربی، ارومیه خیابان عدالت، پلاک ۱۶، دفتر استانی ستاد احیای دریاچهٔ ارومیه.
- آذربایجان شرقی، تبریز، بلوار۲۲ بهمن، ابتدای شهرک زعفرانیه، ساختمان شماره دو استانداری، مدیریت بحران، دفتر استانی ستاد احیای دریاچهٔ ارومیه.

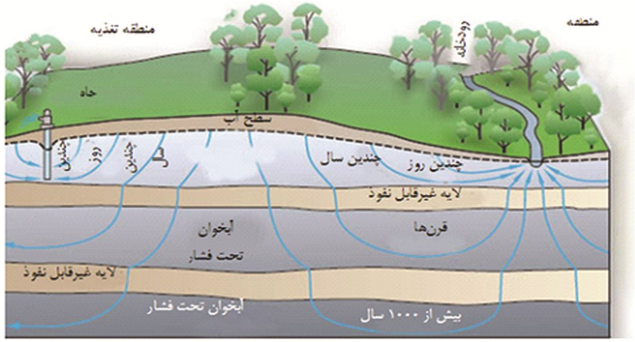
آب زیرزمینی و احیای دریاچه ارومیه



وضعیت پراکندگی چاه های حوضه آبریز دریاچه ارومیه

اهمیت آب زیرزمینی

آب زیرزمینی از مهم‌ترین مؤلفه‌های منابع آب تجدیدپذیر هر حوضه آبریز محسوب گردیده و به‌عنوان ذخایر راهبردی آب شیرین از اهمیت منحصربه‌فردی در سطح دنیا برخوردار می‌باشد. همچنین این منابع نقش بسیاری در آبدهی چشمه‌ها، قنوات و تغذیه و تأمین آبدهی پایه رودخانه‌ها بر عهده دارد. گرچه منابع آب زیرزمینی درصد قابل‌ملاحظه‌ای از منابع آب شیرین دنیا را به خود اختصاص داده‌اند، اما این منابع در مقابل برداشت‌های بی‌رویه و ناپایدار بسیار حساس و آسیب‌پذیر بوده و قدرت تجدیدپذیری خود را به‌سرعت از دست می‌دهند. برخی از لایه‌های آب‌های زیرزمینی به‌خصوص لایه‌هایی که با حفر چاه‌های عمیق از آن‌ها برداشت می‌شود، قرن‌ها و حتی هزاران سال طول می‌کشد که تجدید شوند و تنها لایه‌های سطحی منابع آب زیرزمینی از قابلیت تجدید سالانه برخوردارند.

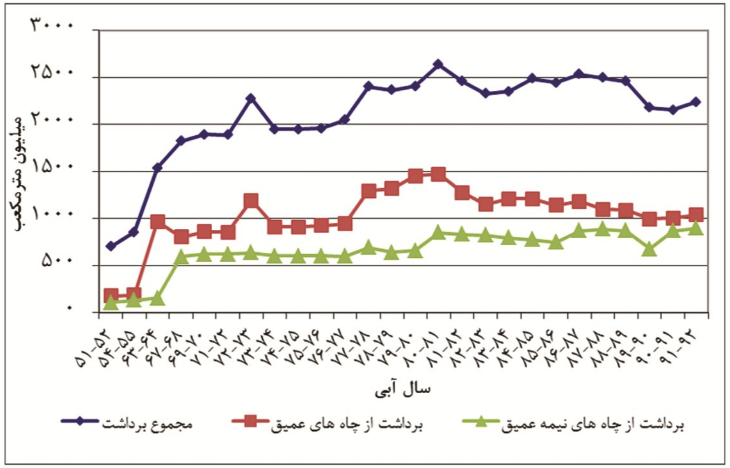


شکل ۱ - مدت زمان مورد نیاز جهت تشکیل لایه های مختلف آب زیرزمینی

از لحاظ برداشت از منابع آب زیرزمینی در سطح دنیا، ایران با جمعیت به‌مراتب کمتر پس از کشورهای هند، چین، آمریکا و پاکستان در مقام پنجم دنیا قرارگرفته است. افزایش تعداد چاه‌های غیرمجاز کشور به بیش از ۲۵۰ هزار حلقه در سال‌های اخیر و برداشت بیش از ۱۱۰ میلیارد مترمکعبی (حدود ۳۶ درصد) از ذخایر استاتیک آب زیرزمینی شیرین کشور، شاخص‌های بسیار نگران‌کننده‌ای هستند. اعلام ممنوعیت در ۳۱۷ دشت از ۶۰۹ دشت کشور، فرونشست و ایجاد فروچاله در بسیاری از دشت‌ها تبعات بسیار ناگوار وضعیت نابسامان و ناپایدار منابع آب زیرزمینی در کشور است. در حوضه آبریز دریاچه ارومیه نیز، تعدد چاه‌های غیرمجاز حفرشده، افت کیفیت آبخوان‌ها و کاهش رواناب رودخانه‌ها و آبراهه‌های حوضه ازجمله مهم‌ترین پیامدهای برداشت بی‌رویه از منابع آب زیرزمینی این حوضه می‌باشد.

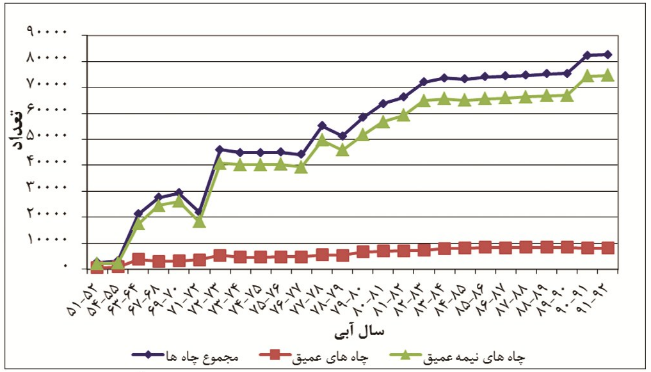
نقش آب زیرزمینی در وضعیت کنونی دریاچه ارومیه

اگرچه بررسی‌های صورت گرفته توسط دفتر برنامه‌ریزی و تلفیق ستاد احیای دریاچه ارومیه نشان‌دهنده عدم ارتباط مؤثر و فعال بین دریاچه ارومیه و آبخوان‌های ساحلی آن می‌باشد، اما حفر حدود ۸۸۰۰۰ حلقه چاه در سطح حوضه تأثیر قابل ملاحظه‌ای بر آبدهی رودخانه‌های حوضه داشته و این امر منجر به کاهش قابل‌ملاحظه رواناب ورودی به دریاچه گردیده است. با فرض مساحت ۱۲۵۰۰ کیلومتر مربعی برای دشت‌ها و کوهپایه‌های حوضه، یک محاسبه ساده نشان می‌دهد که متأسفانه به‌طور متوسط در هر کیلومتر مربع از سطح دشت‌های حوضه تعداد ۷ حلقه چاه حفر گردیده است. البته با توجه عدم توزیع یکنواخت چاه‌ها در سطح حوضه، تراکم چاه‌ها در برخی از دشت‌ها به‌مانند ارومیه، میاندوآب و تبریز بیش از این تعداد می‌باشد. پراکنش چاه‌های حفرشده در سطح حوضه به‌خوبی مؤید مطلب فوق است.



شکل ۲ - روند تغییرات مقدار برداشت از منابع آب زیرزمینی حوضه آبریز دریاچه در چهار دهه اخیر

نکته تأسف‌برانگیز در خصوص چاه‌های حفرشده در سطح حوضه این است که بسیاری از آن‌ها غیرمجاز بوده و بر طبق آمار موجود تعداد آن‌ها به بیش از ۴۰۰۰۰ حلقه می‌رسد. در نمودار ارائه‌شده در شکل ۲ روند تغییرات میزان برداشت از منابع آب زیرزمینی حوضه و در شکل ۳ روند افزایشی میزان حفر چاه ها در سطح حوضه به تفکیک عمیق و نیمه عمیق در چهار دهه اخیر نشان داده شده است.



شکل ۳ - روند تغییرات تعداد چاههای عمیق و نیمه عمیق حوضه آبریز دریاچه

با توجه به ارقام ارائه‌شده در نمودارها ذکر چند نکته زیر، نشان دهنده وضعیت منابع آب زیرزمینی در سطح حوضه می‌تواند باشد:

۱.تعداد کل چاه‌های عمیق و نیمه‌عمیق حفاری شده در سطح حوضه در طی چهار دهه منتهی به سال آبی ۹۲-۹۱، ۳۱ برابر و نسبت به سال آبی ۶۴-۶۳، ۴ برابر شده است.

۲.تعداد قابل ملاحظه‌ای از چاه‌های حفرشده در سطح حوضه به‌صورت چاه‌های نیمه‌عمیق می‌باشد که اکثراً در حریم رودخانه‌ها و آبراهه‌های حوضه واقع‌شده‌اند. بر طبق آمار اعلام شده تعداد چاه‌های نیمه‌عمیق در سطح حوضه در سال آبی ۹۲-۹۱ نسبت به سال آبی ۶۴-۶۳، بیش از ۴ برابر و میزان تخلیه از آن‌ها در حدود ۶ برابر افزایش داشته است. لازم به ذکر است که بخش عمده‌ای از این چاه‌ها به‌صورت غیرمجاز و توسط صاحبان باغات، مزارع و ویلاها حفر شده و مورد بهره‌برداری قرار گرفته است.