Drought Risk Management Plan For

Lake Urmia Basin

Summary Report

Department of Environment

UNDP

Conservation of Iranian Wetlands Project

Water Engineering Research Institute (TMU)

Permanent Secretariat of Regional Council of Lake Urmia Basin

Working Group on Sustainable
Management of Water Resources and Agriculture,
Regional Council of Lake Urmia Basin Management
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1. Preface

1.1. Introduction

Lake Urmia (LU) basin is located in northwest of Iran with a total area of 51800 km^2 (Figure 1). It is the largest lake in the country and is also one of the world's saltiest bodies of water. The political boundaries of three provinces (West Azerbaijan, East Azerbaijan and Kurdistan) cross the basin, which is a determinant constraint for any basin-wide planning.

The lake has been shrinking since 1995 and its area has dramatically decreased. Continuation of the present condition will damage the region's industrial and agricultural sectors and allow salt beds exposed by the shrinkage to be picked up by winds, creating a serious threat to the health of the inhabitants of the region.

An integrated plan to save the lake was drawn by stakeholders, which was facilitated by the UNDP/GEF/DOE Conservation of Iranian Wetlands Project (CIWP). With the cooperation of the LU provinces, the Integrated Management Plan for Lake Urmia Basin (IMPLUB) was developed. The plan helps provincial and national agencies address the current critical ecological state of the lake, which is also required by the 4th National Development Plan. The most important agreement in this plan is to allocate 3100 MCM of water per year to the lake.

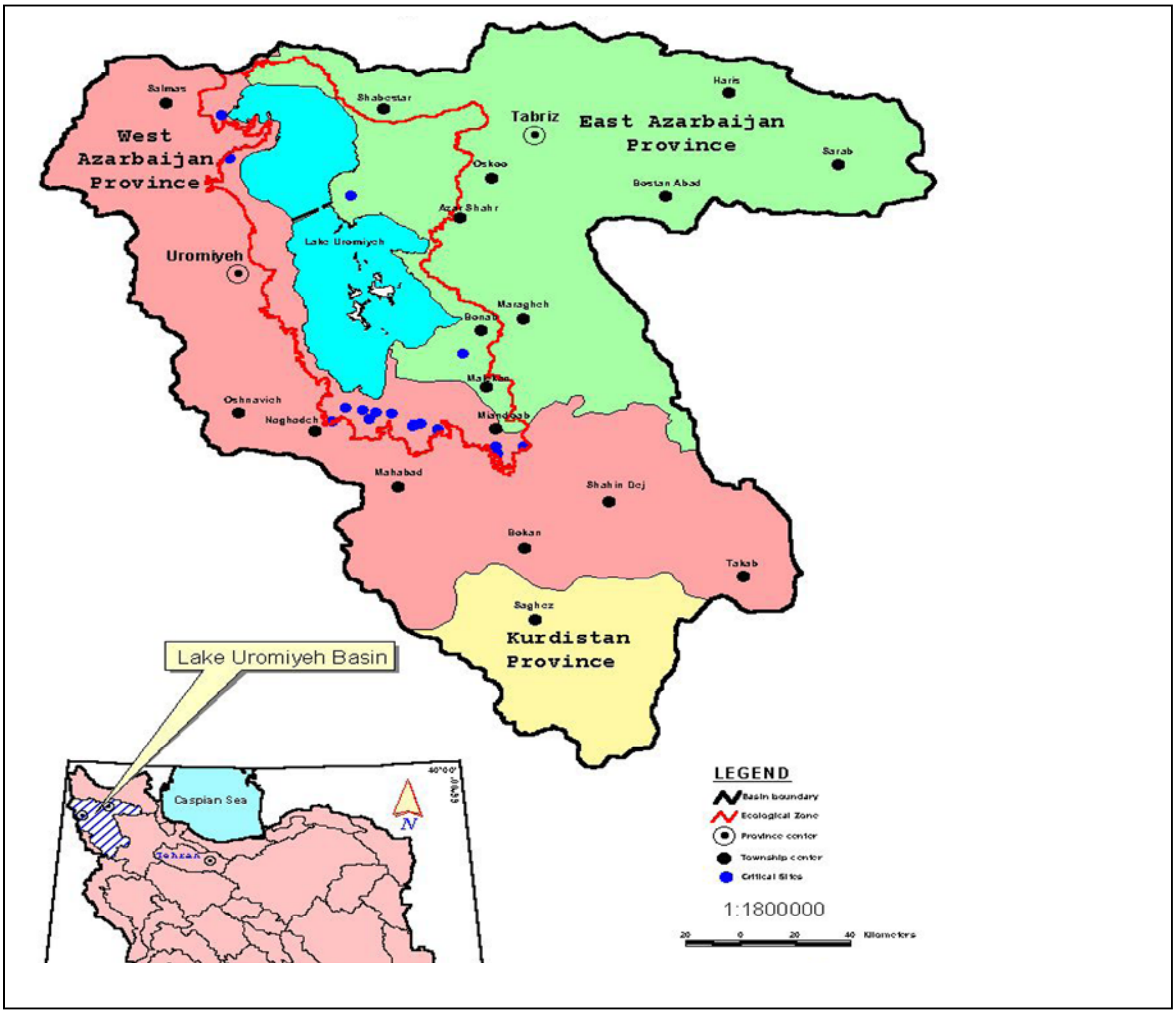


Figure 1. Map of study area and provinces (Yekom, 2002).

1.2. Drought risk management for Lake Urmia basin

To promote the ability of IMPLUB to address drought and consequent water shortages, a subproject was defined by CIWP as Drought Risk Management (DRM) for Lake Urmia basin. The DRM was admitted to the Water Engineering Research Institute (WERI) of Tarbiat Modares University in 2010. The project objectives are:

- Evaluate temporal and spatial patterns of drought in the LU basin
- Evaluate methodologies to monitor drought
- Identify types of drought and measures to alleviate loss and meet LU water requirements
- Institutionalize measures for drought management

The DRM has developed a comprehensive scientific program and liaises regularly with basin stakeholders. The project framework incorporated critical aspects of the:

- National Strategy and Action Plan on Drought Preparedness, Management and Mitigation in the Agricultural Sector, Islamic Republic of Iran (FAO, 2006)
- Basics of Drought Planning: A 10-Step Process (Wilhite et al., 1999)
- Drought Management Guidelines (MEDROPLAN) (Iglesias et al., 2006).

The project output comprises:

- Report 1: Study Area and Data
- Report 2: February 2010 Workshop on LU Drought Risk Management
- Report 3: Trends of Hydro-Climatic Variables in LU basin
- Report 4:Drought Behavior in LU basin
- Report 5:Drought Management Organization for LU basin
- Report 6:Drought Monitoring System for LU basin
- Report 7:Agricultural Water Allocation Model for Drought
- Report 8:Agriculture and Agricultural Water Allocation During Drought
- Report 9:Water Allocation Model of LU Basin and Status of Provinces and Lake During Drought
- Report 10: Operational Component of the Plan

Two software programs were developed for the project:

- The LU drought monitoring system (UDMP)
- The LU water allocation model (UWAP).

2. Report 1: Study Area and Data

The LU basin comprises 14 main sub-basins that surround the lake with areas from 431 to 11,759 km^2. The most important rivers are Zarrineh Rood, Simineh Rood and Aji Chai. Numerous hydro-meteorological stations exist in the basin, but some are not applicable because of their brief span of record keeping. The stations selected for this study are shown in Figure 2. They comprise 35 rain gauge stations, 35 stream gauge stations and 11 temperature gauge stations. The selected stations were as evenly distributed throughout the basin as possible. The missing data gaps were patched using regression equations for the nearest suitable station. Data quality was tested using four strong non-parametric tests; the Spearman trend and independence tests, the run-test, and the Man-Whitney homogeneity test (Pilon et al., 1985).

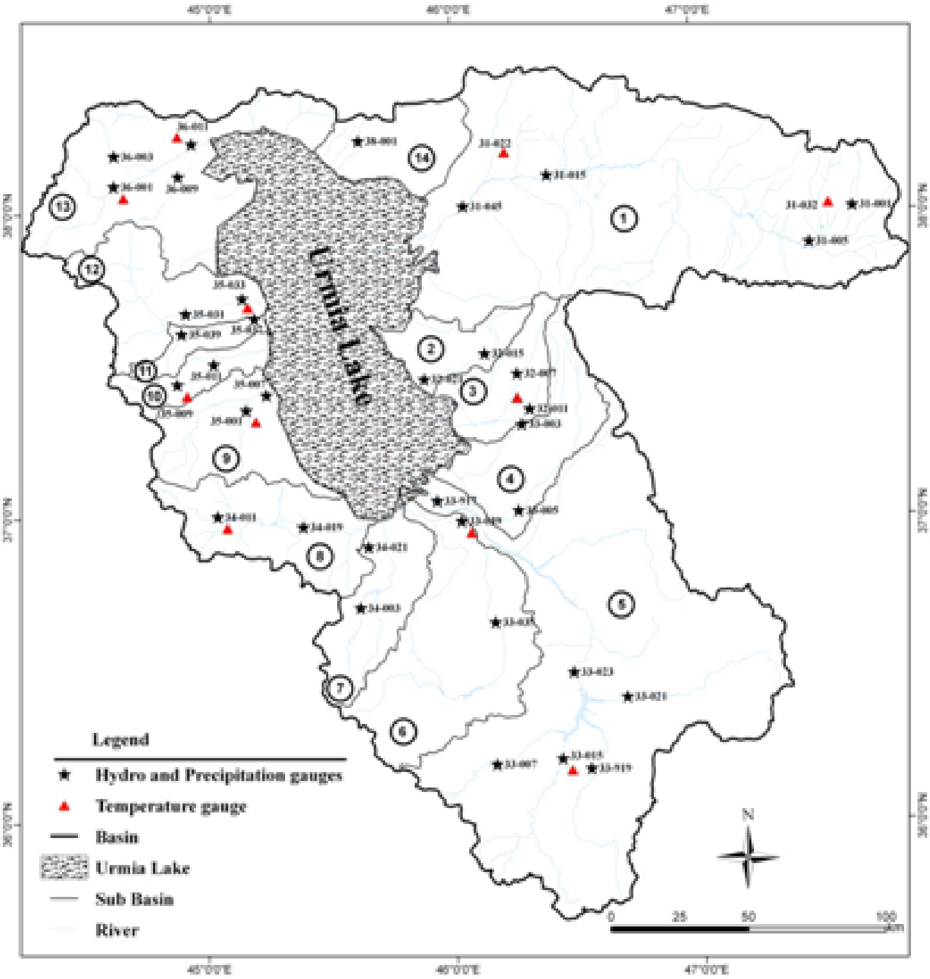


Figure 2. Location of hydro-climatic stations and main rivers.

2.1. River systems in Urmia Basin

Specific discretization for the LU basin was applied using the sub-basin boundaries and the provincial political boundaries. There are 11 river systems in the basin:

- East Azerbaijan province (5):1) Aji Chai upstream of dam;2) Aji Chai downstream of dam, 3) Sofi Chai upstream of dam, 4) Sofi Chai downstream of dam;5) Ghaleh Chai, Mardogh Chai, Leilan Chai
- West Azerbaijan province (5): 1) Zarrineh Rood downstream of dam, 2) Mahabad upstream of dam, 3) Mahabad downstream of dam,4) Shahr Chai;5) Simineh Rood, Gedar, Barandooz Chai, Rozeh Chai, Nazloo Chai and Zoola Chai
- Kurdistan province (1): Zarrineh Rood upstream of dam

These systems are suitable to represent the water resource potential of the basin. The LU basin includes 23 cities and water use data is available for each on the city scale. Water use for a river system is estimated by combining the total city water consumption. Thus, the main geographical unit is the river system and these will be summed up to indicate the available water resources and consumption at provincial and basin scales.

2.2. Water resource potential and water consumption

Stakeholders identified potential water resources and water consumption figures for each of the three provinces over the course of several meetings. The final agreement is shown in Table 1 and also applies to the DRMLU.

Table 1. Outcome of Water resources allocation for the lake and users and consumption in LU (MCM/yr)

	East Azerbaijan	West Azerbaijan	Kurdistan	Total
Water resources potential	1361	3983	1583	6927
Agricultural water consumption	1042.5	1914.5	623.9	3581
Drinking/industry water consumption	480	198	0	678
Quota for LU water requirement	270.5	1870.5	959.1	3100

3. Report 2: DRMLUB Workshops

Interaction between stakeholders was crucial to the DRMLUB. The project commenced by evaluating the project framework at a 4-day workshop held on Kish from 6-10 February 2011 (Figure 3). Sixty representatives of basin stakeholders and Iranian drought experts plus drought experts from Spain (for MEDROPLAN) and Australia participated. The main topics of the workshop were:

- Current drought management in LU basin
- Drought monitoring and forecasting for LU basin
- Review of past drought measures in LU basin
- Introduction MEDROPLAN drought guidelines
- Review of drought management in Murry-Darline basin (Australia)

Figure 3. LU basin stake holder meetings for drought management**.**

Three questionnaires were prepared to collect participant viewpoints, experiences, and comments to help ascertain if the project framework their needs and plans. Two additional workshops in October and November 2011 provided the preliminary results of the project to the stake holders and got their feedback.

4. Report 3: Trends in Hydro-Climatic Variables

This study investigated possible causes of LU decline by estimating trends in the time series for hydro-climatic variables of the basin. Four non-parametric statistical tests (Mann-Kendall, Theil-Sen, Spearman Rho, Sen's T) were applied to estimate trends in the annual and seasonal time series for temperature, precipitation, and streamflow at 81 stations throughout the basin. The results showed significant increasing trends in temperature throughout the basin and area-specific precipitation trends (Figure 4).

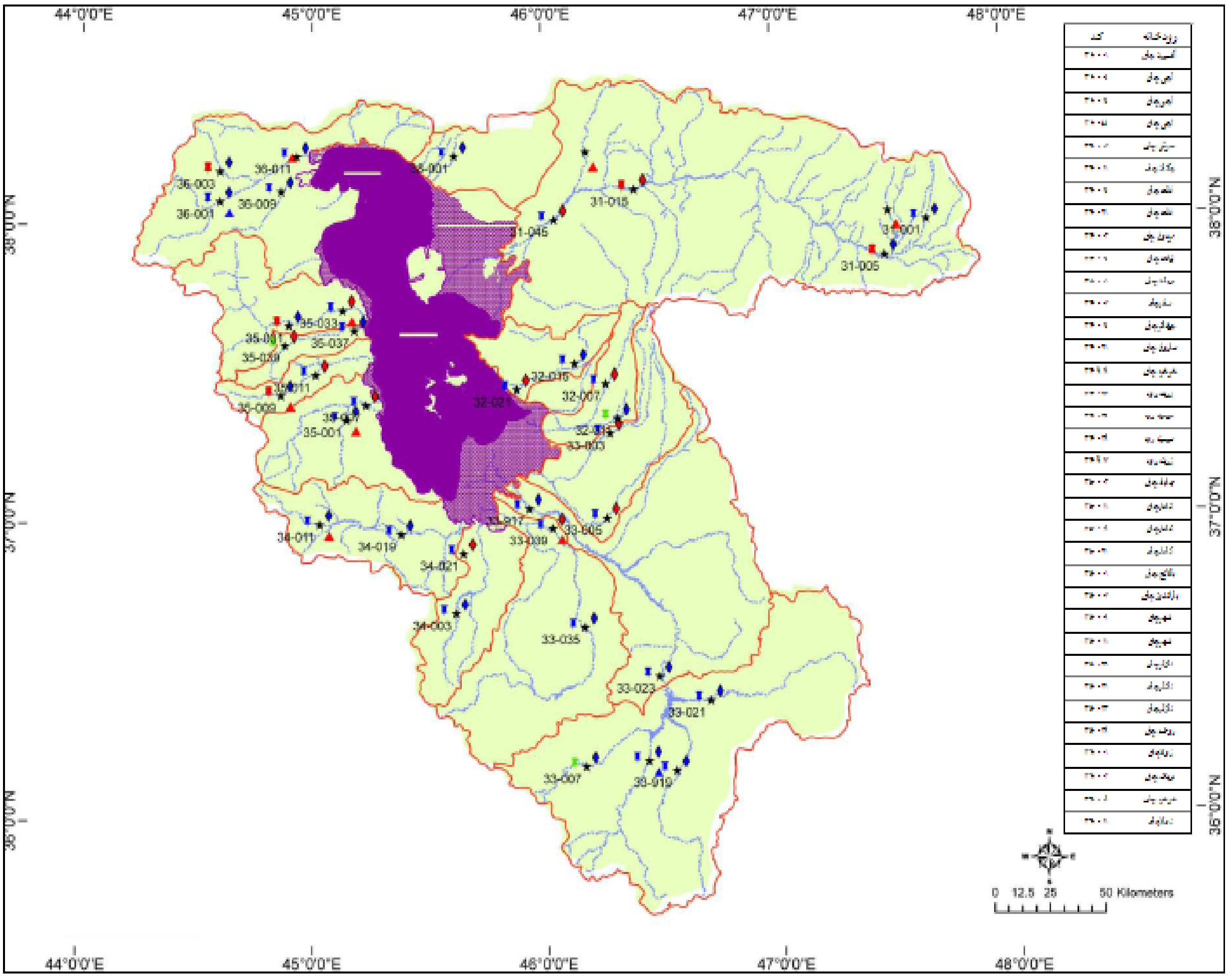


Figure 4. Trends in hydro-climatic stations of LU basin (▲ = significant increase in temperature; ♦ = significant decrease in discharge; ■ = significant decrease in rainfall)

The tests also confirmed a general decreasing trend in basin streamflow that was more pronounced in the downstream stations. This can be attributed to over-exploitation of the upper sub-catchments. The homogeneity of the monthly trends was also evaluated using the Van Belle and Hughes test (Van Belle and Hughes, 1984). Temporal analysis for basin temperature and streamflow detected significant increasing trends beginning in the mid-1980s and in 1995. In general, this research work showed that the decline of the lake level is related both to an increase in basin-wide temperature and over-exploitation of the water resources caused by an increase in area under cultivation over the last four decades. Figure 5 shows the increase in irrigated areas from 1976 to 2011 based on Landsat imaging (Fathian, 2012).

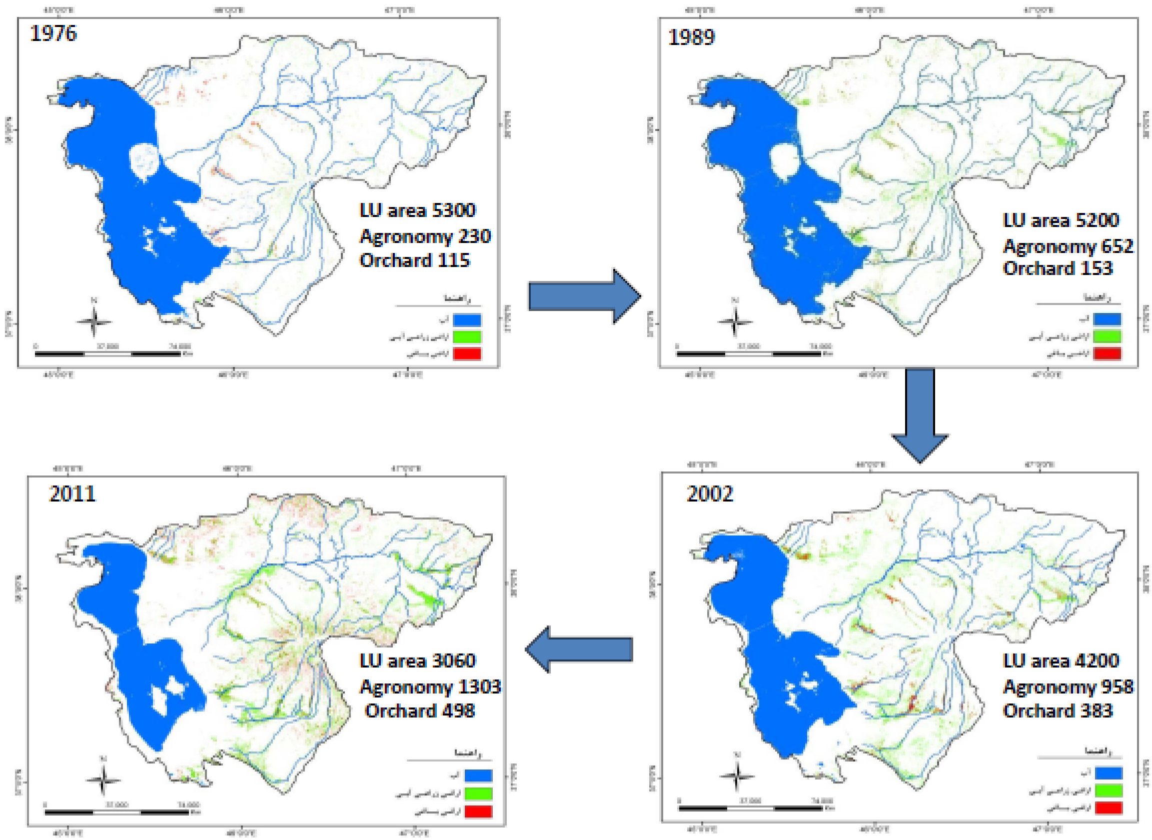


Figure 5.Decrease in LU surface area and increase in irrigated areas in AjiChai river system from 1976 to 2011 based on Landsat imaging (Fathian, 2012)

Time series for terrestrial water storage (TWS) from the Gravity Recovery and Climate Experiment (www.grace.jpl.nasa.gov) satellite were also evaluated. These showed a decline in TWS and a significant correlation with the water level of the lake (Farokhnia and Morid, 2011).

5. Report 4: Drought Behavior

The standard precipitation index (SPI) (Mckee, et al., 1993) and deficit index (DI) (Prudhomme and Sauquet, 2007) were used as meteorological and hydrological drought indices to evaluate drought throughout the basin and compare the behavior of the three provinces. Rainfall and discharge variation over time showed an increase in the intensity and duration of drought in the basin. Before 1980, the duration of drought averaged less than one year; recent records show an increase of up to 4 years.

A comparison of drought in stations in the east (East Azerbaijan), west (West Azerbaijan) and south (Kurdistan)using cluster analysis (Ahamdzadeh and Morid, 2011) show that the behavior of drought in the south differs slightly different from the east and west, but not significantly enough to be a factor in drought planning. Figure 6 shows the standard average annual precipitation and discharge at the provincial stations and demonstrates the difference.

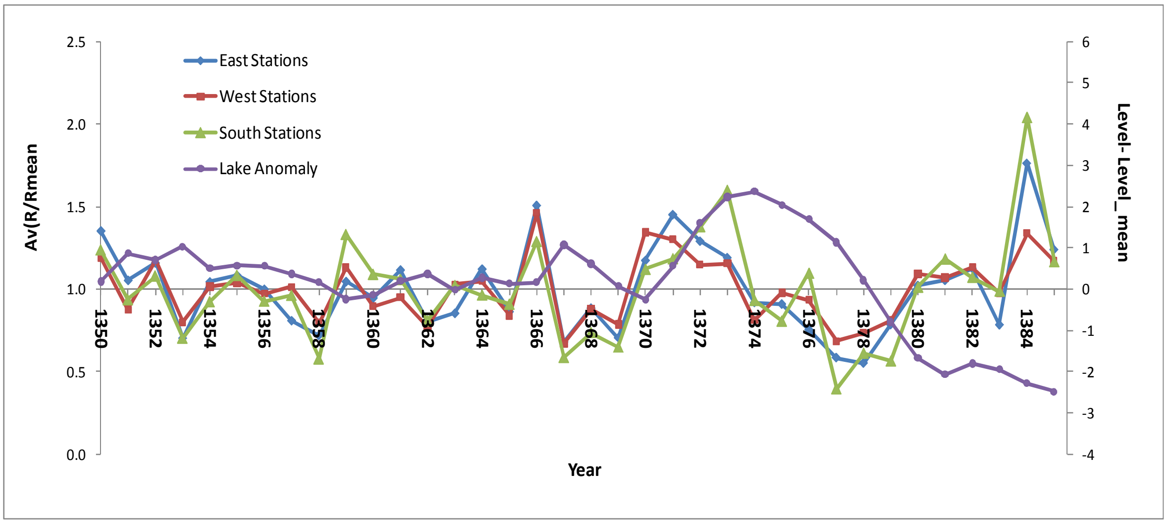


Figure 6. Mean standard annual average of precipitation in east, west and south stations.

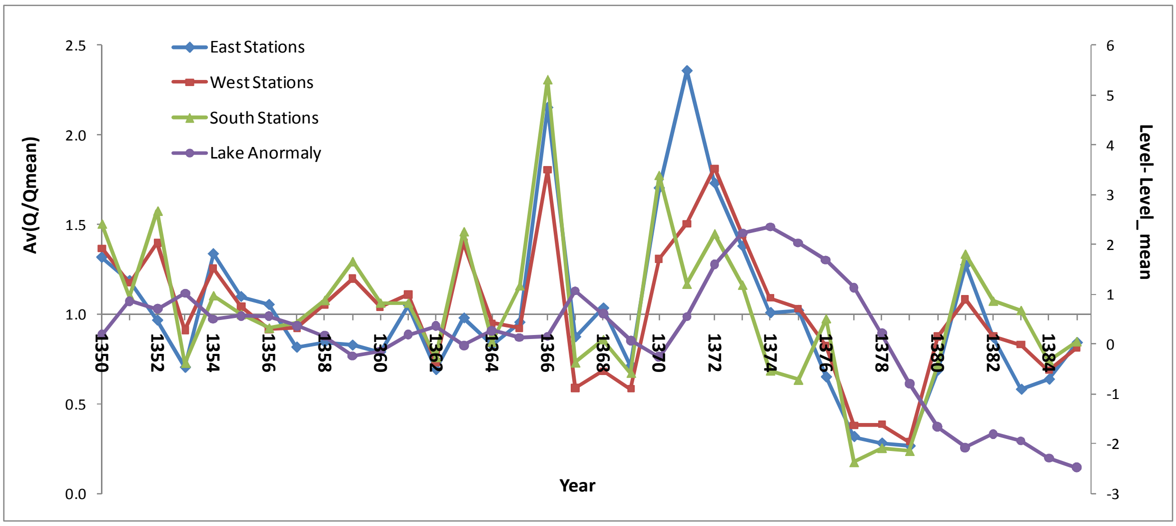


Figure 7. Mean standard annual average of river discharge in east, west and south stations.

To generate a drought scenario, intensity-duration-frequency analysis was applied to a number of meteorological and discharge stations using two dimensional copulas (Farokhnia, 2008). Figures 8 and 9 show the output for Babrub and Vanyar stations.

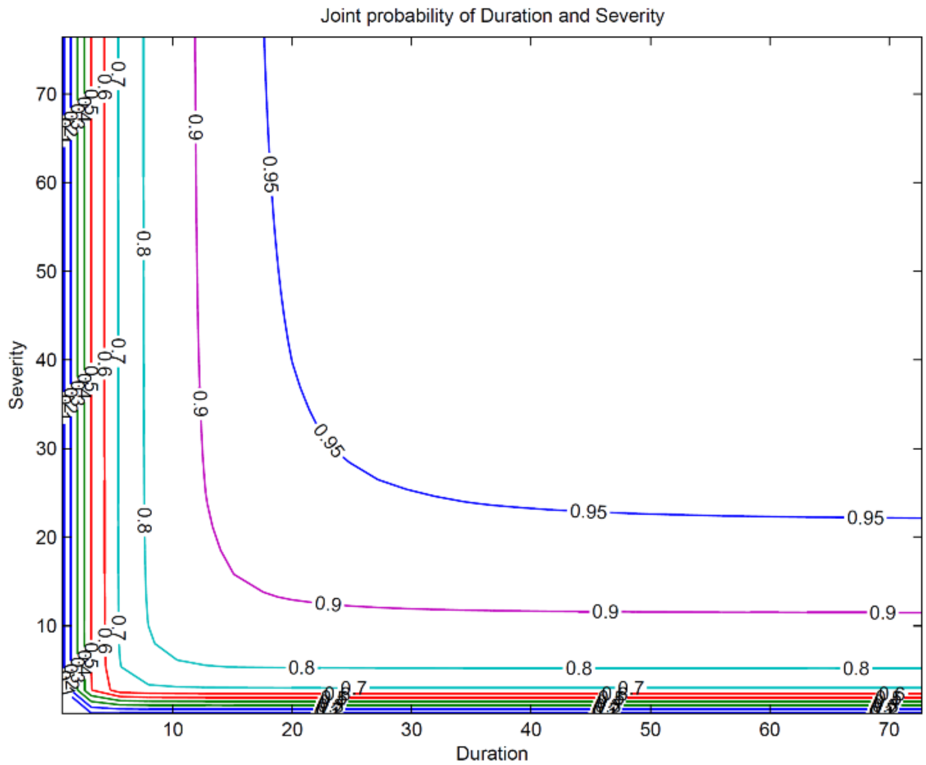


Figure 8. Joint probability distribution of meteorological drought at Babarud station.

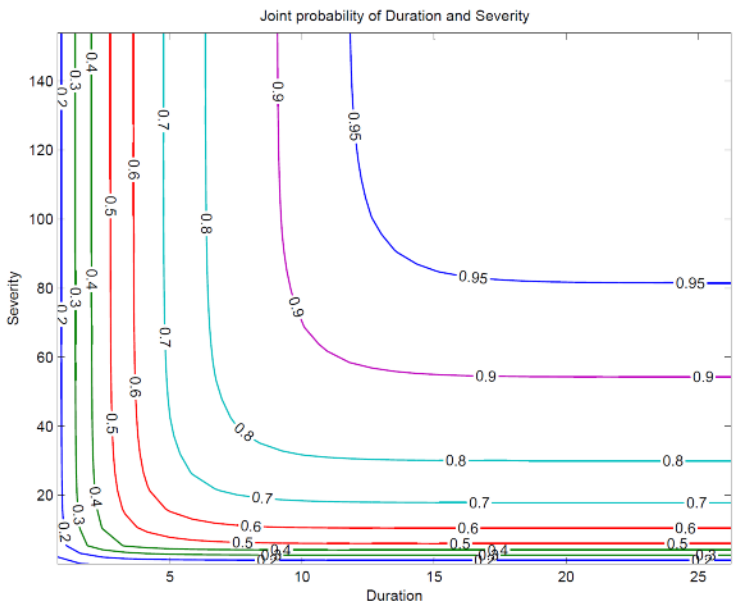


Figure 9. Joint probability distribution of hydrological drought at Vanyar station.

6. Report 5: Drought Management Organization

Institutional guidelines for drought management are more complicated when a region encompasses different political boundaries, as it does in the LU basin. The following steps were used to develop institutional guidelines for the Drought Management Organization (DMO):

- Evaluate guidelines for the organizational component of drought management (10-step drought planning and MEDROPLAN)
- Liaise with basin stakeholders (Feb 2011 and Oct 2011 workshops and individual meetings) to incorporate their viewpoints
- Identify the current institutional framework for drought management for the DMO
- Develop the IMPLUB and apply it to the DMO
- Avoid complicated and parallel structures
- Avoid tasks that are beyond the official capacity of basin organizations
- Identify administrative levels needed for the DMO at provincial, basin and national levels
- Begin implementation of a risk management paradigm instead of crisis management

The completed framework of the DMO is shown in Figure 10.

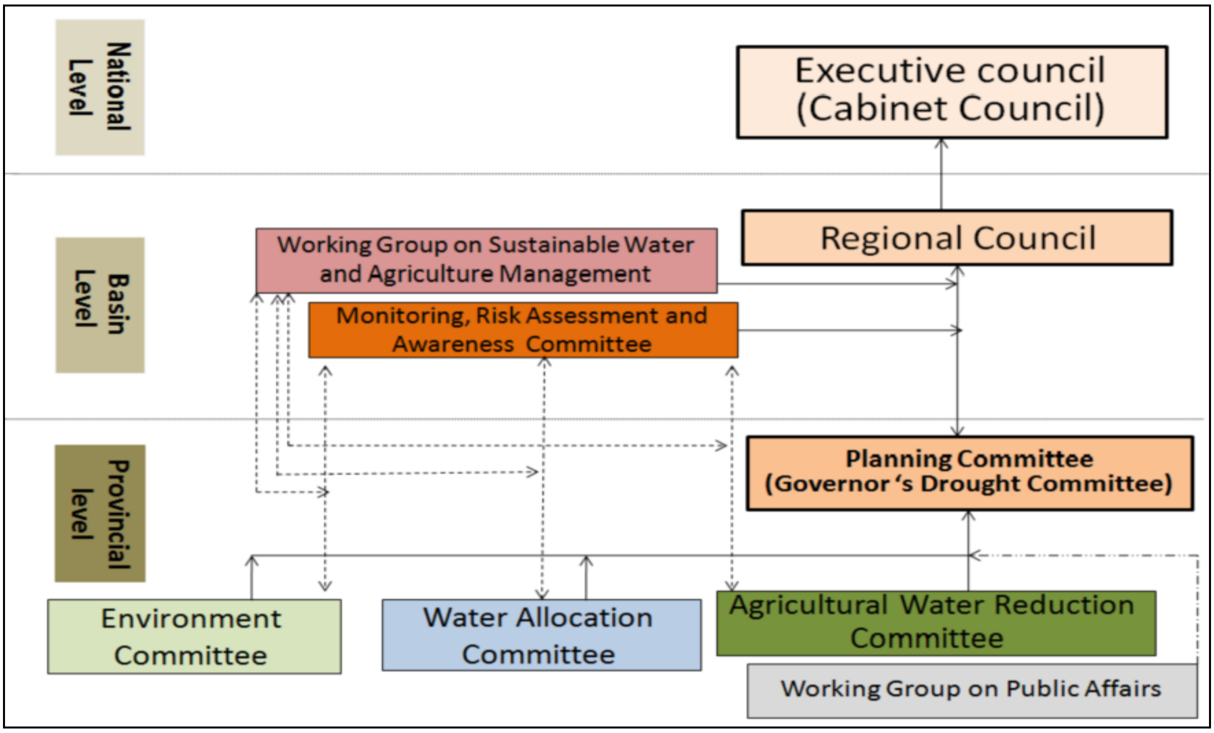


Figure 10. Framework of LU drought management organization.

6.1. DMO Committees

The DMO comprises four main committees; environmental, water allocation, agricultural consumption reduction, and monitoring, risk assessment and awareness.

6.1.1. Environmental Committee: Provincial environmental organizations are responsible for this committee's tasks. Its main duties are:

- Monitor basin river inflow to the lake and preserve LU water allocation
- Establish water hauling programs for livestock from reservoirs and other sources
- Coordinate with the basin Working Group on Sustainable Water and Agriculture Management and other committees

6.1.2. Water Allocation Committee: This comprises the provincial water authorities. Its main tasks are:

- Forecast annual flows using data from the Iranian Ministry of Energy for drought at provincial levels with confirmation from provincial planning committees
- Reduce water allocation to the sectors to accommodate drought level
- Meet lake water requirement
- Implement water consumption reduction measures
- Monitor water quality and quantity in the basin and report to the Monitoring Committee
- Increase water use efficiency of irrigation systems
- Coordinate with the basin Working Group on Sustainable Water and Agriculture Management and other committees

6.1.3. Agricultural Consumption Reduction Committee: This committee is under the supervision of the provincial Agricultural Jihad Organizations and has the following duties:

- Coordinate with the Water Allocation Committee to reduce agricultural water allocations
- Reduce agricultural water use via more efficient irrigation systems and cultivation patterns
- Help farmers implement drought mitigation measures
- Provide relief to farmers affected by drought
- Provide drought insurance for farmers
- Coordinate with the basin Working Group on Sustainable Water and Agriculture Management and other committees

6.1.4. Monitoring, Risk Assessment and Awareness Committee: This committee is centralized and under the supervision of the regional council. Its main tasks are:

- Develop the program database and launch the website
- Prepare hydro-climatic data from the stations and monitor the basin drought status
- Prepare lake level and river inflow information to publish for decision makers, committees, and the public
- Evaluate drought mitigation measures
- Prepare reports for the regional committee, the cabinet and other authorities
- Coordinate with the basin Working Group on Sustainable Water and Agriculture Management and other committees

6.2 Planning Committee

The execution and operation of the committees will be established in each province. The DMO recommends only one centralized monitoring committee for the basin. Coordination between the committees will be done by the Planning Committee in the provincial governors' offices. The committee is chaired by the governor and its members are representatives of the provincial organizations. The main tasks of the Planning Committee are:

- Report the drought level
- Report the provincial drought status to regional and cabinet councils, the parliament, and relevant national organizations
- Carry out the provincial commitment to meet the LU water requirement
- Prepare and substantiate the provincial drought plan; evaluate the performance of provincial organizations
- Coordinate implementation of contingency measures by provincial organizations
- Financial and legislative support for drought planning and affected farmers
- Implement insurance and loans for drought-stricken farmers
- Maintain relations with provincial drought and regional committees
- Evaluate drought measures/planning after drought

Coordination of the provincial committees at the basin level is done by the Working Group on Sustainable Water and Agriculture Management. The main considerations are policy making and technical issues. Coordination on the national level is done by the Cabinet Council.

However as it is argued by Hashemi (2012), the design of the governance system in LUB should be viewed as experiments and since the socio-political and environmental and ecological setting are changing, we can assume that "*no specific set of rules will produce the same distribution of benefits and costs over the time*" (Ostrom, 2005). Therefore, in future, there might be a need to redesign the proposed set up.

7. Report 6: Drought Monitoring System for LU Basin

Drought monitoring is an essential to any drought contingency plan. For the drought management plan of LU basin (DRM), both meteorological and hydrological indicators were needed. Possible meteorological indicators were the DI, percent of normal (PN), SPI, China-Z index (CZI), modified CZI (MCZI), Z-score, and effective drought index (EDI) (Morid et al., 2005). Possible hydrological drought indices were the Chang method (Chang and Kleopa, 1991) and the hydrological DI (Prudhomme and Sauquet, 2007). The SPI, DI and EDI were selected for the LU basin system and specific software was developed (UDMP) (Figure 11).

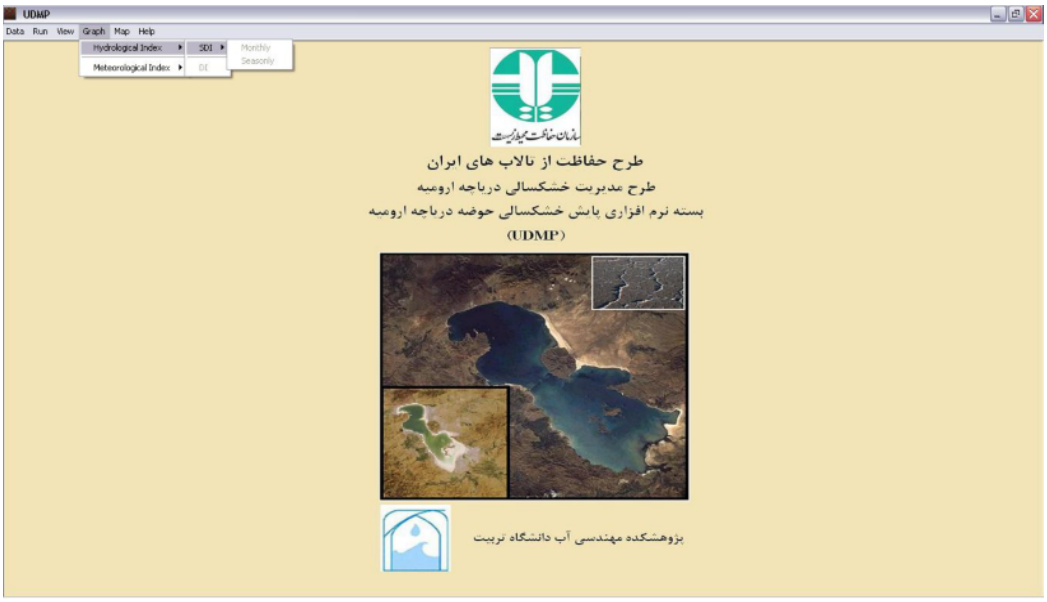


Figure11. Interface of Urmia drought monitoring package

UDMP monitors drought on any time scale (daily, weekly, monthly, yearly) using daily rainfall and discharge data. The results can be presented as maps to monitor drought and compare meteorological and hydrological drought throughout the basin, as is shown for September to November 2005 in Figure 12. This comparison can be helpful in distinguishing climate driven drought from river overdrafting.

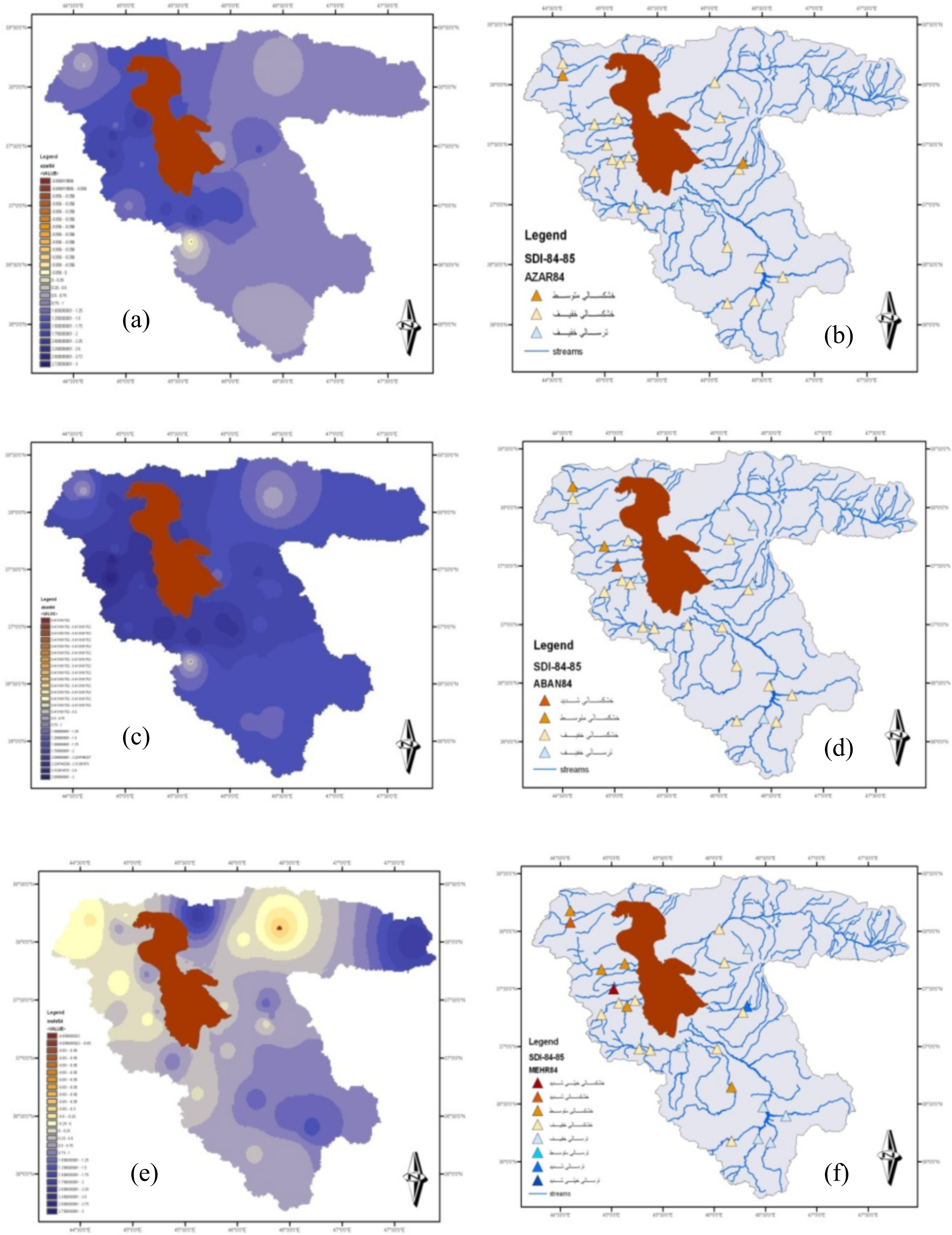


Figure 12.LU basin meteorological and hydrological drought maps (respectively) for 2005: Sep. (a), (b); Oct. (c), (d); Nov. (e), (f)

8. Report 7: Agricultural Water Allocation Model for Drought

8.1. Methodological approach

Deficit irrigation and reducing the area under cultivation are major measures that can be taken to mitigate drought impact on the agricultural sector in the current status of the basin. The report implements an approach based on optimization methods to manage agricultural water demand during water scarcity to minimize damage.

The model is based on two modules. First one determines irrigation scheduling for the dominant crops during the growing season based on available water resources. The objective function maximizes the ratio of actual yield per unit area (kg ha^{-1}) to maximum yield per unit of area (kg ha^{-1}):

$$MAX : \frac{Y_{ac}}{Y_{\max c}} = 1 - \sum_{g=1}^{n} Ky_g \left(1 - \frac{ETa_{c,g}}{ET\max_{c,g}}\right) \quad (1)$$

where $ETa_{c,g}$ and $ETmax_{c,g}$ are actual and maximum evapotranspiration for growth stage g of crop c in stage g (mm/10 days) respectively; Ky_g is the water sensitivity coefficient for growth stage g; and n is the total number of growth stages. Maximum evapotranspiration for growth stage of each crop is determined as:

$$ET\max_{c,t} = Kc_{c,t} \times ET_O \quad (2)$$

Where $Kc_{c,t}$ is the crop coefficient and t is the operation time (one year). Reference crop evapotranspiration (ET_0) is calculated using the Penman–Monteith method (Allen et al., 1998). The 10-day (irrigation period) values of Kc over the growing period are calculated by the method described by Doorenbos and Pruitt (1984).

The second module maximizes the total benefit of the crops within each river system:

$$MAX \left\{ \sum_{k=1}^{K} F_k(V_k) A_k Y_{\max k} P_k \right\} \quad (3)$$

where k is the total number of crops, A_k is planted area for each crop (ha), $Y_{max\,k}$ is maximum yield (kg(ha^{-1})), P_k is the marketing price per kg, and $F_k(V_k)$ is the crop production function(relation between maximum relative yield and allocated irrigation water). To define $F_k(V_k)$, the first module was executed for crops at different water volumes and their respective yields were calculated. More details about this approach and the modeling system are available in Moghaddasi et al. (2010).

8.2. Agricultural data

Over 35 different crops are cultivated in the basin; it is not possible to model all of them directly, thus eight were selected as representative of basin crops. These were wheat, barley, onion, potatoes, tomatoes, sugar beets, alfalfa and apples. The agricultural data collected was cultivation pattern, area under cultivation, fallow area, crop calendar, maximum crop yield, crop water requirement, irrigation efficiency, and crop water stress during growing season. The minimum geographic unit for agricultural water consumption is the city scale (Section 2.1) and the analyses were done at this level.

8.3. Agricultural water management strategy

Two strategies for water allocation to Lake Urmia were considered. The first meets almost the entire 3100 MCM allocation per year LU water requirement, except for severe drought, when water may be diverted for orchards (LUWF). The second reduces the LU water allocation up to 35% according to drought severity (LUWP). These strategies have been shared with the stake holders during project workshops.

The second strategy puts less pressure on the agriculture sector. In this strategy, the remaining available water can be used to meet agricultural needs according to the following land and water management options:

- Accommodate more types of crops and reduce cultivated area (uses optimization model and deficit irrigation) (LWM1)
- Accommodate more area under cultivation and reduce the variety of crops planted (uses optimization model and deficit irrigation) (LWM2)
- Eliminate some land under cultivation in accordance with the amount of water available (no optimization model or deficit irrigation) (LWM3)

The agricultural managers, thus, have different options for water allocation and can better manage drought. These policies can be adjusted in the model so that the total water consumption is equal for each.

8.3. Drought levels

To manage drought and agricultural water allocation, four levels of drought were agreed upon by the stakeholders. The levels are based on the available/forecast water resources, with the fourth level being only enough available water to maintain orchards and none for annual crops. There is one level more severe in stream gauge records; this was assigned to level five.

8.4. Agricultural water allocation

The optimization model uses different outputs to aid stakeholders in managing the LU basin efficiently, in addition to the six strategies described above. These are:

- Mitigation measures (deficit irrigation and reduction in cultivated area) for each drought level (Table 2)
- Total irrigation water and distribution throughout the growing season for the representative crops (mm/ha) at each drought level (Table 3)
- Efficient use of cultivated area for each crop at each drought level (Table 4)

9. Report 8: Drought Levels at Provincial Scale

Drought levels and mitigation at the provincial level were estimated by compiling past records for the river systems. Two strategies for LU water allocation were implemented (full and partial allocation of the 3100 MCM LU water allowance). Since LWM1 to LWM3 have same total water consumption, they do not affect the results of this section (Tables 5-8).

Presently, Kurdistan has water reserves in excess of demand. As shown in Table 6, no measures are currently required there for drought at any level; however, drought contingency plans are being developed.

Table 2. Drought thresholds and measures for Aji Chai (upstream of dam) river system for LUWF and LWM1.

	Agronomy (MCM)	Drinking (MCM)	Orchard (MCM)	Lake (MCM)	Available water (MCM)	Drought level
Normal	168	28	35	119	350	0
Deficit irrigation* level 1 and reduce cultivated area	125	28	28	119	300	1
Deficit irrigation level 2 and reduce cultivated area+	79	28	24	119	250	2
Omit annual crops	0	28	21	119	200	3
Omit annual crops and reduce LU water allocation	0	28	21	107	150	4

*Table 3; +Table 4

Table 3. Water distribution (mm/ha) between crops based on LU full water allocation and third irrigation water management.

Crop	Normal	Drought Level 1	Drought Level 2	Drought Level 3	Drought Level 4
Wheat	360	268	0	0	0
Barley	270	201	0	0	0
Potatoes	756	0	0	0	0
Tomatoes	780	0	0	0	0
Alfalfa (1st cut)	370	275	174	0	0
Alfalfa (2nd cut)	420	313	198	0	0
Alfalfa (3rd cut)	310	231	146	0	0
Total area	43710	40484	22632	0	0

Table 4. Efficient use of cultivated area (ha) based on LU full water allocation and third irrigation water management.

Crop	Normal	Drought Level 1	Drought Level 2	Drought Level 3	Drought Level 4
Wheat	13677	13677	0	0	0
Barley	4175	4175	0	0	0
Potatoes	2843	0	0	0	0
Tomatoes	383	0	0	0	0
Alfalfa (1st cut)	7544	7544	7544	0	0
Alfalfa (2nd cut)	7544	7544	7544	0	0
Alfalfa (3rd cut)	7544	7544	7544	0	0
Total area	43710	40484	22632	0	0

Table5. Water available for allocation (% of normal) by sector and drought level for West Azerbaijan

Scenario 1: Reduction in Urmia Lake water allocation for drought level 4					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	100	0
Deficit irrigation* level 1 and no reduction in cultivated area	79	100	100	91	1
Deficit irrigation level 2 and reduction in cultivated area	57	100	100	80	2
Deficit irrigation level 3 and reduction in cultivated area	40	100	100	69	3
Omit annual crops	21	100	91	56	4
Scenario 2: Reduction in Urmia Lake water allocation for all drought levels					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	100	0
Deficit irrigation* level 1 and no reduction in cultivated area	86	100	90	90	1
Deficit irrigation level 2 and reduction in cultivated area	72	100	80	78	2
Deficit irrigation level 3 and reduction in cultivated area	63	100	65	67	3
Omit annual crops	31	100	65	48	4

*Reduction in cultivated area by drought level for each river system (Table 3)

Table 6: Water available for allocation (% of normal) by sector and drought level for Kurdistan

Scenario 1: Reduction in Urmia Lake water allocation for drought level 4					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	100	0
Deficit irrigation* level 1 and no reduction in cultivated area	100	100	100	90	1
Deficit irrigation level 1 and no reduction in cultivated area	100	100	100	80	2
Deficit irrigation level 1 and no reduction in cultivated area	100	100	100	71	3
Omit annual crops	3	100	90	58	4
Scenario 2: Reduction in Urmia Lake water allocation for all drought levels					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	100	0
Deficit irrigation level 1 and no reduction in cultivated area	100	100	90	90	1
Deficit irrigation level 1 and no reduction in cultivated area	100	100	80	71	2
Deficit irrigation level 1 and no reduction in cultivated area	100	100	65	57	3
Deficit irrigation level 1 and no reduction in cultivated area	4	100	65	42	4

* Kurdistan currently has water in excess of demand; no water restrictions are required at this stage.

Table 7. Water available for allocation (% of normal) by sector and drought for East Azerbaijan

Scenario 1: Reduction in Urmia Lake water allocation for drought levels 3 and 4					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	100	0
Deficit irrigation level 1 and no reduction in cultivated area	78	100	100	81	1
Deficit irrigation level 2 and reduction in cultivated area	56	100	100	65	2
Deficit irrigation level 3 and reduction in cultivated area	33	100	94	49	3
Omit annual crops	21	100	86	34	4
Scenario 2: Reduction in Urmia Lake water allocation for all drought levels					
Measures	**Agriculture**	**Drinking and industry**	**Lake**	**Ratio of water available water for long term mean (%)**	**Drought level**
Normal	100	100	100	97	0
Deficit irrigation level 1 and no reduction in cultivated area	80	100	90	80	1
Deficit irrigation level 2 and reduction in cultivated area	60	100	80	63	2
Deficit irrigation level 3 and reduction in cultivatedarea	44	100	65	46	3
Omit annual crops	25	100	65	30	4

10. Report 9: Status of LU Provinces and LU under DMO

10.1. Implementation of DMO in LU provinces

Urmia Water Allocation Package (UWAP) was developed to evaluate the LU DMO. The model used data for the last 50 years of data recorded throughout the basin. All results of the agricultural water allocation optimization model (section 8.4) are also embedded in the package, so it is possible to apply an inflow strategy to evaluate its impact on water allocation at the basin, provincial, or river system scale (Figure 13).

Figure 13. Urmia water allocation package interface

The model output indicates the number and level of droughts that the provinces may face. Each time a province falls into a drought level, it will be committed to reduce agricultural water allocation and consequently compensate for some of the drought loss. The higher the drought level, the higher the budget for drought compensation.

Changes in hydrology of the region in recent years are shown along with those for the last 10 and 20 years. The results are shown for East and West Azerbaijan for the LUWP and LUWF water requirement allocation (Figures 14-17). Increased frequency for the higher drought levels is observable in the last 10 years.

In general, LUWF and LUWP can meet 85% and 95% of the LU water requirement, respectively. Satisfaction of the West Azerbaijan agricultural water requirement is 75% and 65% for these strategies, respectively. These ratios are 80% and 75% for East Azerbaijan, which shows lower pressure for its agricultural sector.

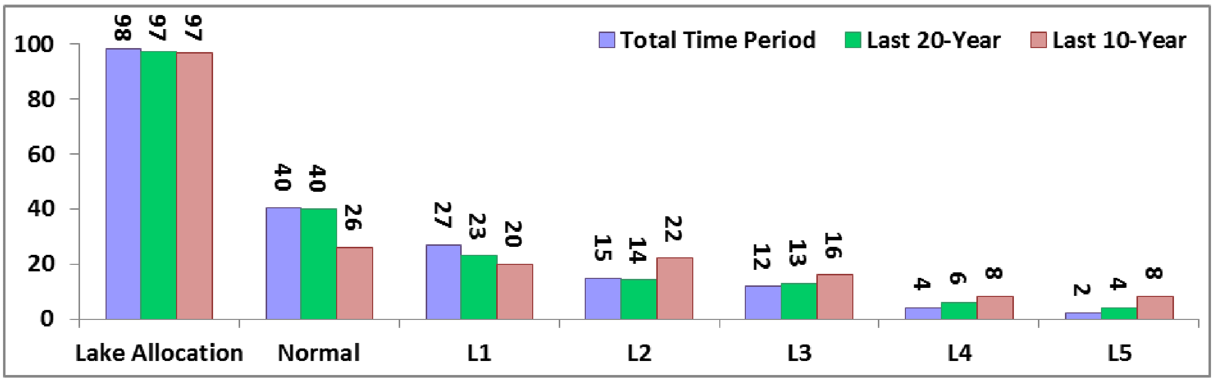


Figure 14. Relative frequency for drought levels in East Azerbaijan under LU drought plan by time period (full allocation of LU water requirement)

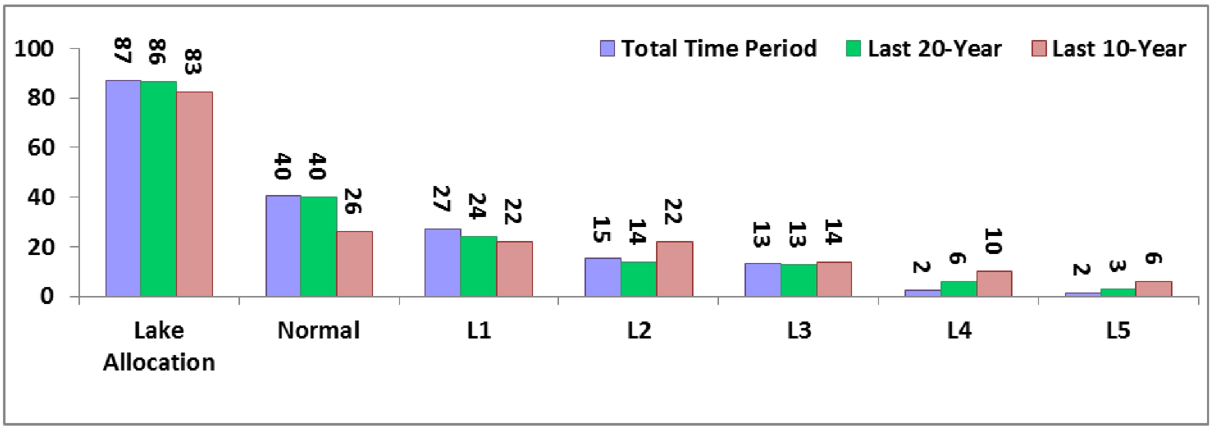


Figure 15. Relative frequency for drought levels in East Azerbaijan under LU drought management plan by time period (partial allocation of LU water requirement)

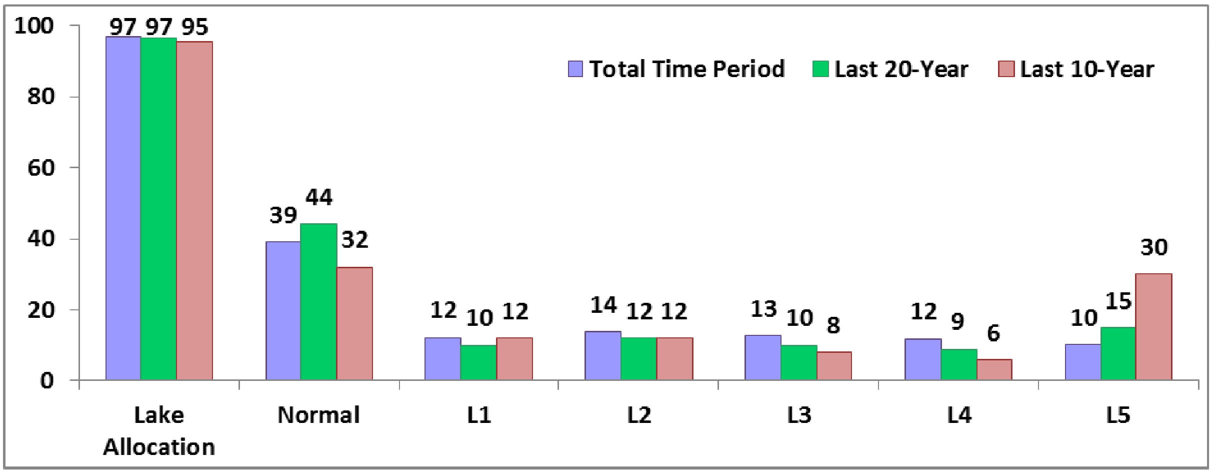


Figure 16. Relative frequency for drought levels in West Azerbaijan under LU drought plan management by time period (full allocation of LU water requirement)

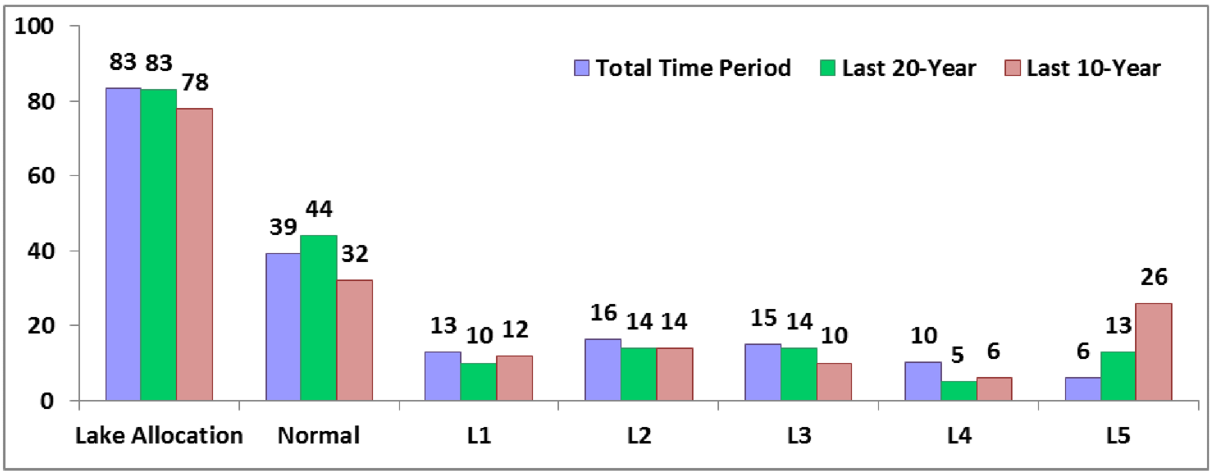


Figure 17. Relative frequency for drought levels in West Azerbaijan under LU drought plan by time period (partial allocation of LU water requirement)

10.2. Modeling of LU surface area

The impact of LU drought management on the LU surface area also requires evaluation. For this, a budget-based model was developed based on the following steps:

- *Generation of river inflows, precipitation and evaporation*: Projected basin river streamflow, precipitation and evaporation are the main inputs for the model and 1000 records for the50 year annual time series were generated to incorporate uncertainty using Monte Carlo simulation.
- *Simulation of LU level change*: LU level changes were simulated using Equation1 as a function of precipitation (*P*), evaporation (*E*), rivers treamflow(R_{in}) to the lake, LU area at *H* level (*A*(*H*)) and time (*t*). Generating the inputs for Equation 1 requires the mean, standard deviation and distribution. Simulation was done once for 50 years of data and once for data from the last 10 years to highlight recent scarcity of basin water.

$$\Delta H = P(t) - E(t) + 0.001.(\frac{R_{in}(t)}{A(H)}) \qquad (4)$$

- *LU water level-area relation*: This was prepared as in Sadra (2004) and Yekom (2004)[1].

10.3. LU surface area under drought management scenarios

Simulating LU surface area was done for six different scenarios:

- Continuation of the current state with no priority for LU water allocation and hydrological conditions of the last 50 years of inflows persisting in the future(50_BAU)
- Continuation of the current conditions with no priority for LU water allocation and hydrological conditions of the last 10 years of inflows persisting in the future (10_BAU)
- Full allocation of LU water allocation and hydrological conditions of the last 50 years of inflows persisting in the future (50_Sc1)
- Full allocation of LU water allocation and hydrological conditions of the last 10 years of inflows persisting in the future (10_Sc1)
- Partial allocation of LU water allocation (up to 65%) and hydrological conditions of the last 50 years of inflows persisting in the future (50_Sc2)
- Partial allocation of LU water allocation (up to 65%) and hydrological conditions of the last 10 years of inflows persisting in the future (10_Sc2)

Figure 18 shows the results of these models using the cumulative density function (CDF) for the next 10, 20 and 50 years.

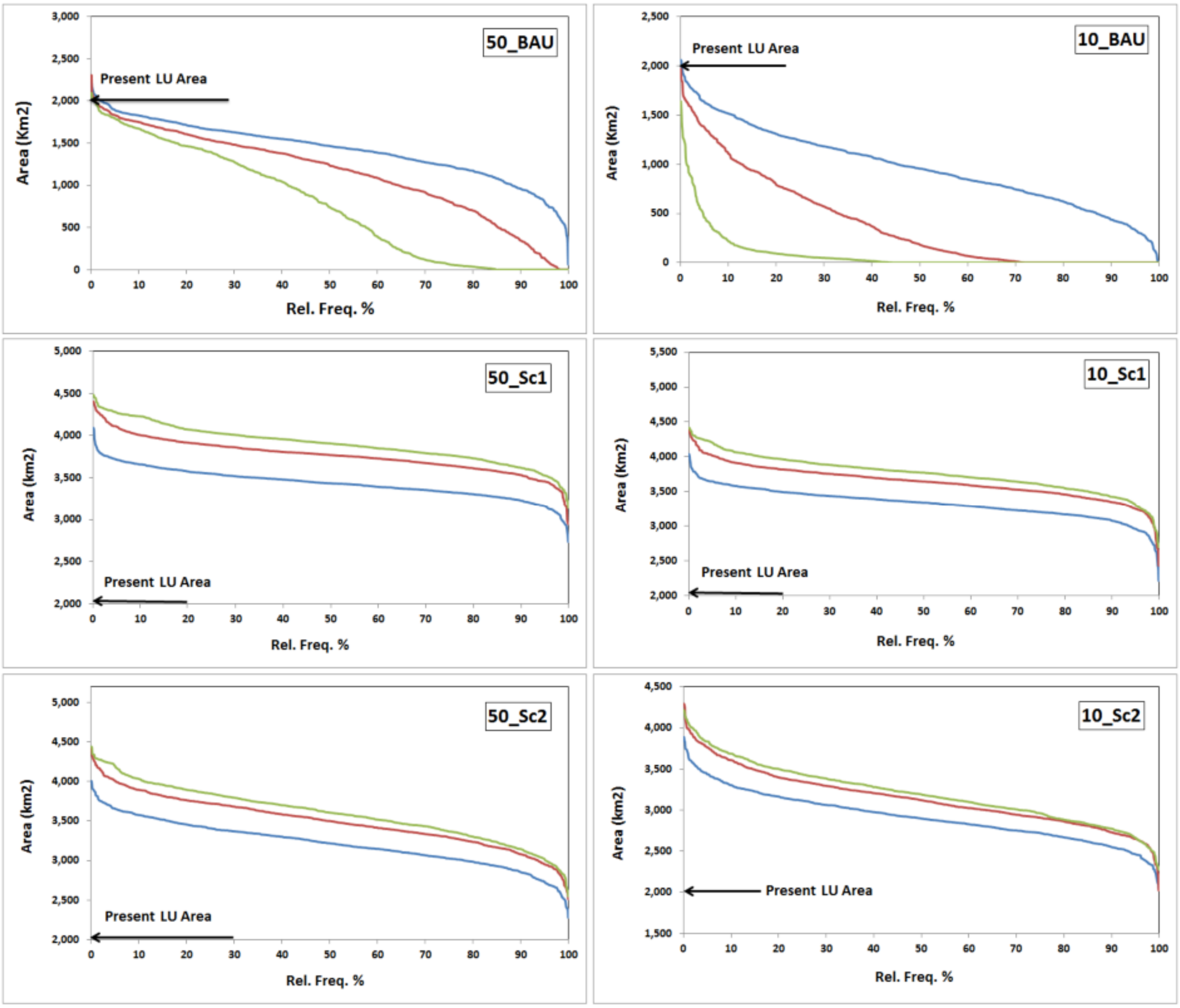


Figure 18. CDF curves for LU area for 10 (—), 20 (—) and 50 (—) year time horizons for different climate and management scenarios

A simpler view of the LU surface area was calculated for the averages of the next 10, 20 and 50 years using 1000 generated time series (Figure 19). Most importantly, this figure reveals that survival of the lake is only possible via the full allocation scenarios (LUWF). The most optimistic of the partial allocation scenarios (LUWP) can barely maintain the current condition of the lake. The figure also demonstrates the catastrophic consequence of the current management program, which will virtually empty the lake.

Figure 20 shows the average expected water inflow to the lake for the various management scenarios. Figure 21 depicts the results of the worst and best basin management scenarios on the LU surface area. The tragic progression of the salt beds is clearly shown in the figure.

11. Report 10: Operational Component of DRM

The operational component identifies both long and short term actions that can be implemented to mitigate the impact of drought. Such actions are essential to the development of specific drought planning and response efforts. The operational component of the DRM, which is based on different international and national guidelines as well as analysis of the different project's workshops, includes six facets that require continuous feedback:

- Communiqués and supervision of DRM by the regional council or the basin governors

- Formation of the DRM and respective committees
- Operation of the basin drought monitoring system
- Definition of conditions and thresholds for the drought levels and identify priorities and mitigation measures
- Preparation for affirmation of the level of drought and implementation of mitigation measures in basin organizations
- Technical and public evaluation of the plan

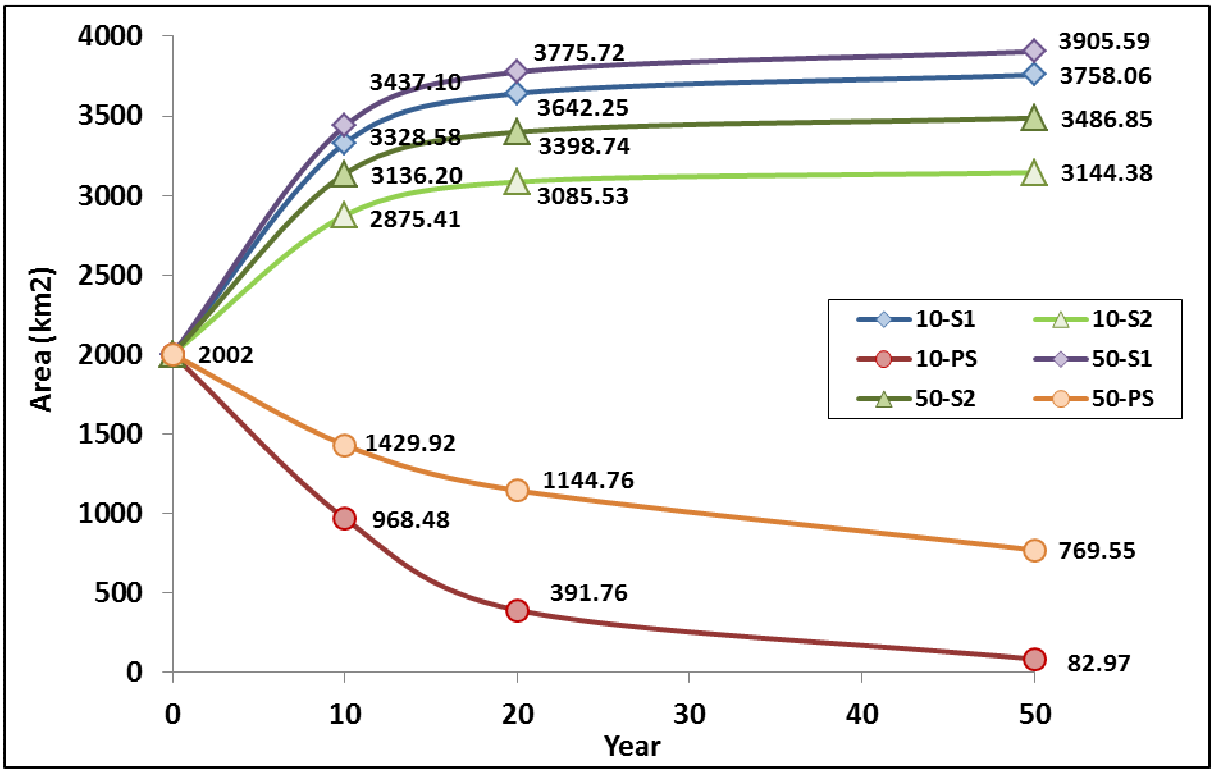


Figure 19. Average predicted surface area of LU for 10, 20, and 50 time horizons for the six management scenarios

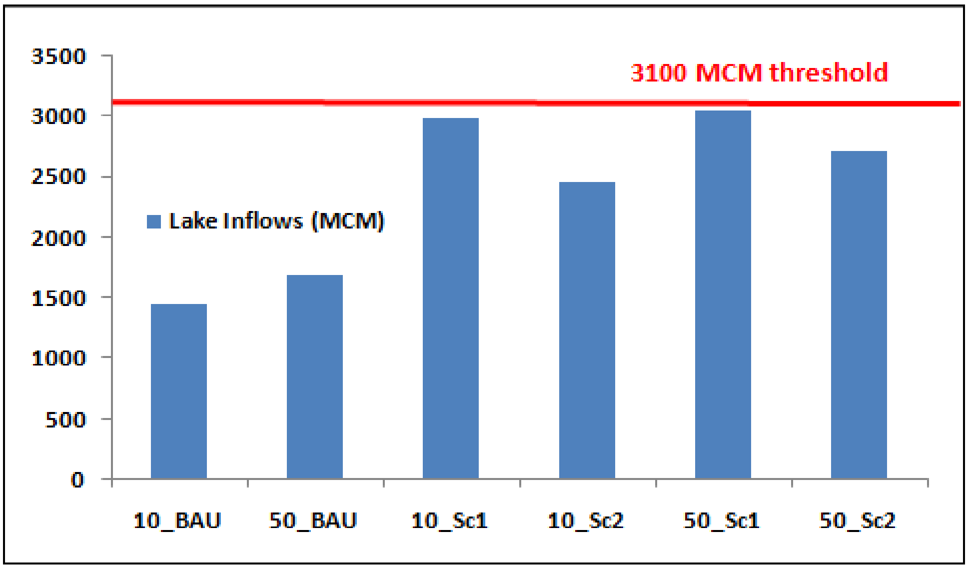
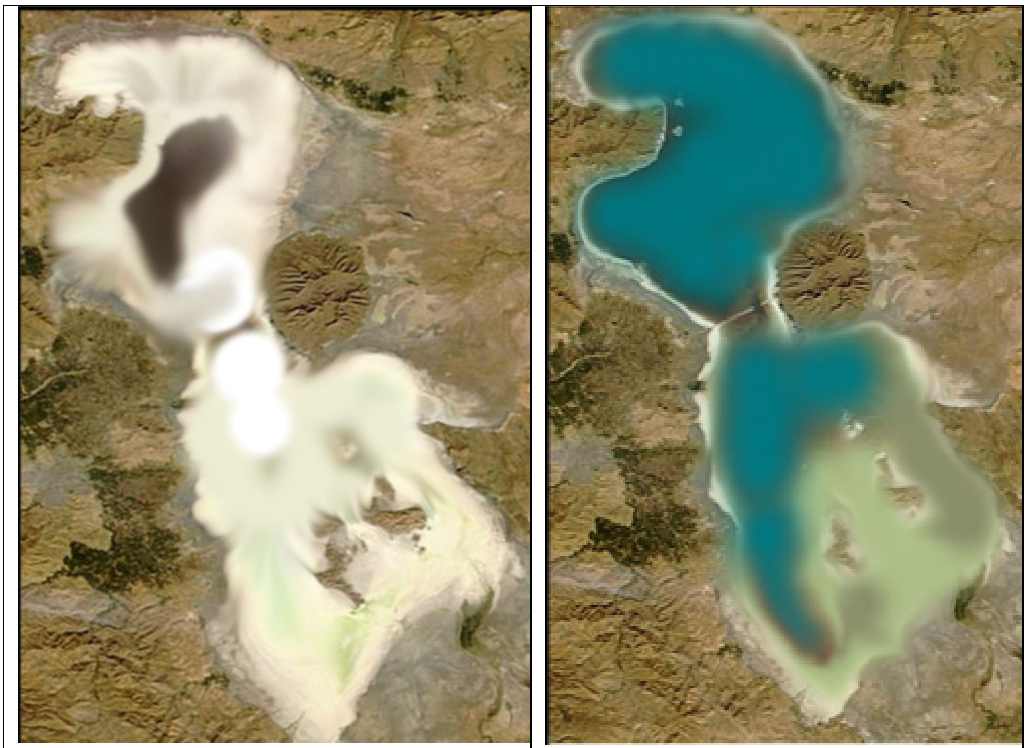


Figure 20. Average allocation of water to Urmia Lake for the six management scenarios



Area: 82.9 km^2 Lake level: 1267.32 m.s.l.e.	Area: 3905.59 km^2 Lake level: 1273.06 m.s.l.e.

Figure 21. Virtual images of LU after 50 year time horizons for worst (10_BAU) and best (50_Sc1) basin management scenarios

11.1. Drought declaration

The formal declaration of drought is both controversial and significant. The DRM addresses this key issue by linking technical indicators to define the drought level, as shown in Figure 22. The decision is mainly based on the river flow forecasts by the Ministry of Energy at the beginning of the growing season. Other hydro-climate information and drought indices are also considered. The DRM emphasizes the smooth transfer of data and information between the different facets of the drought management organization. After deciding on the drought level, each committee has specific duties that are defined before drought occurs (DRM paradigm). They must present their progress, obstacles, financial and legislative requirements to the planning committee.

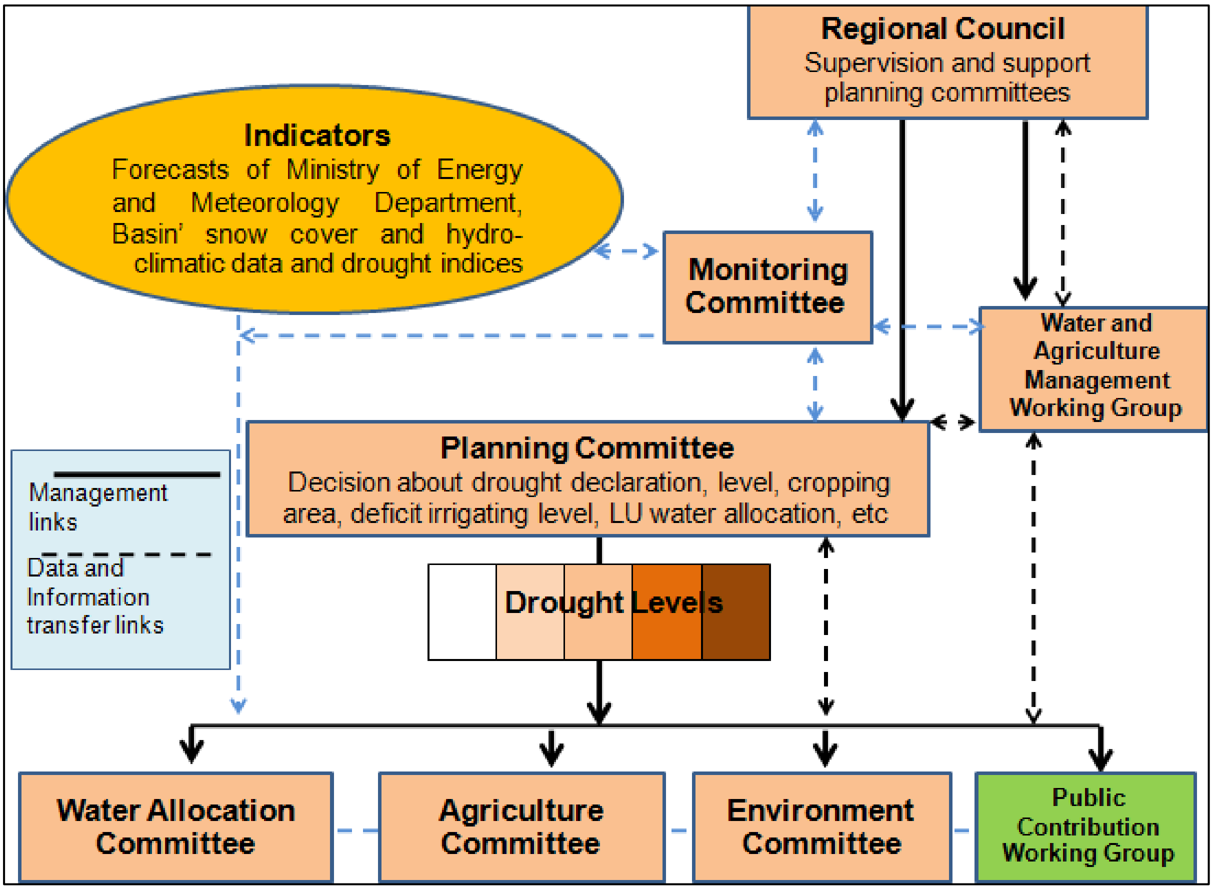


Figure 22. Steps for drought declaration, implementing drought measures and role of committees

11.2. Evaluating implementation of actions

Figure 23 is a general representation of the steps for implementing LU drought management actions. Note that drought planning should be done during normal conditions before a drought occurs. The drought mitigation measures can be classified as: 1) supervision and coordination; 2) monitoring and implementation of mitigation measures during drought; 3) post-drought evolution; 4) planning mitigation measures before drought. These are be implemented by the committees described in Report 5.

12. Conclusion and Remarks

This report summarizes the ten reports of the Urmia Basin Drought Risk Management project, part of an international program to save Lake Urmia. This program, the Integrated Management Plan for Lake Urmia Basin, is under the supervision of the Iranian Environment Organization and the UNDP/GEF/DOE. The following can be concluded from these reports:

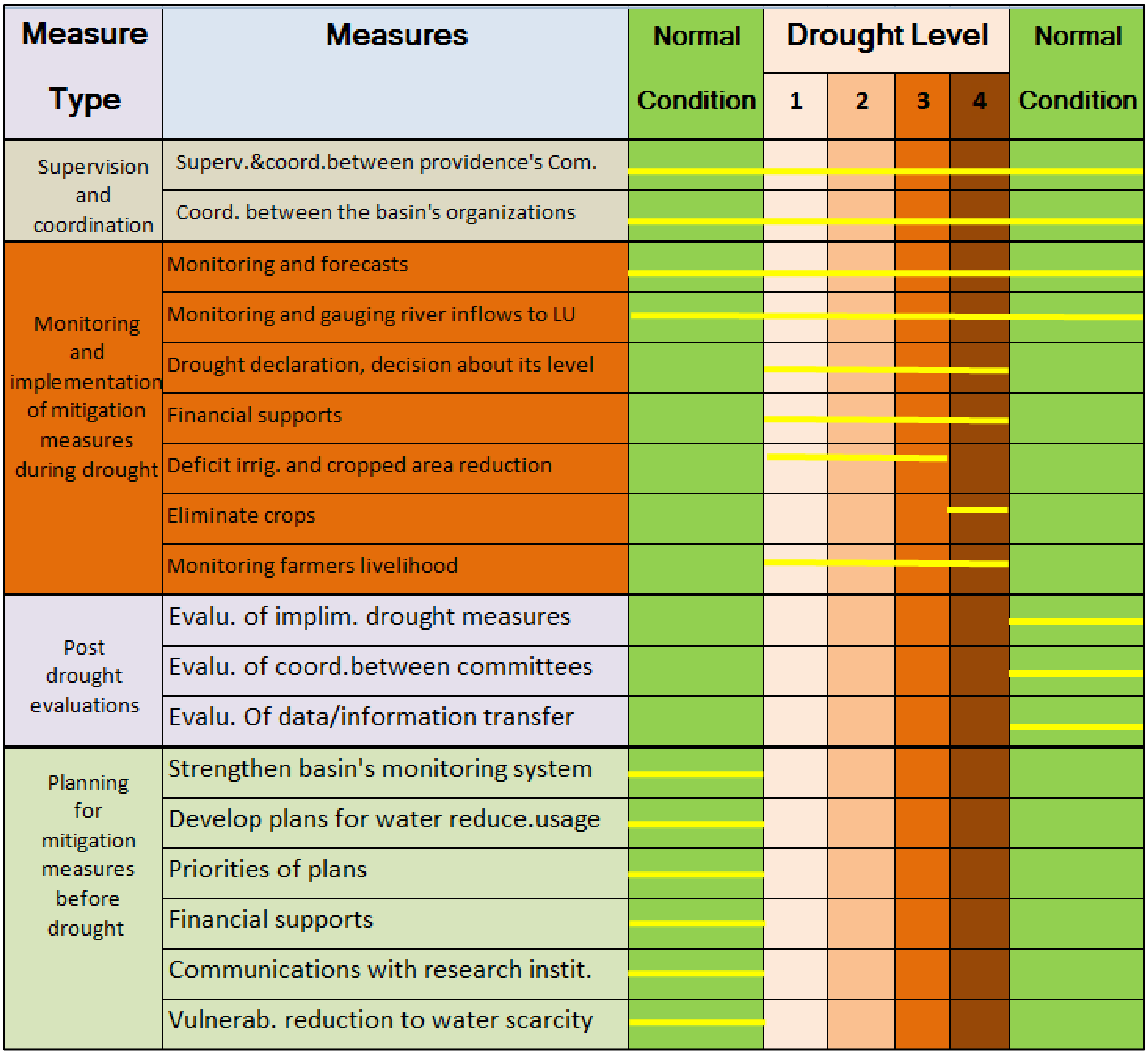


Figure 23. Steps for implementing drought management actions

- The decline of the lake level is related both to an increase in temperature basin-wide and over-exploitation of the water resources caused by the significant increase in cultivated area over the last four decades. As a result, the potential water resources of the basin are gradually decreasing. It is imperative that all water-related development projects be stopped and new strategies developed to reduce agricultural water consumption.
- The complex political situation of the basin with three provinces and governors complicates basin water management, especially during drought. The project suggests an organizational framework for drought management that can rectify some of the problems experienced in drought management. Implementation of this organization can improve drought management and water resources management under normal conditions.
- A drought monitoring system has been developed for the basin with meteorological and hydrological indices that enable basin managers to track drought using multiple indicators and distinguish climate-driven drought from that caused by overdrafting of water resources.
- At present, deficit irrigation and reducing the area under cultivation are the main operational measures to mitigate the impact of drought and provide adequate lake

water allocation. An optimization model was developed to simulate this task at the city and river system levels.

- The project suggests a four-level drought warning system and measures to reduce water consumption at each level. To reduce water consumption, strategies for water allocation to Lake Urmia were considered at each level: 1) full allocation of 3100 MCM per year LU water allocation and 2) up to 35% partial allocation of the LU water in accordance with drought severity. Three agricultural water management policies have been also defined. These measures can remedy deficiencies in the drought plan and this has been received positively by stakeholders.
- Simulation of the basin 50 year time horizon using uncertainty analysis has shown that the current water consumption in the LU basin will reduce the lake surface area up to 40%over its current size. It must be emphasized that the LU is already at 50% of its maximum area. This will extend the basin salt beds and threaten inhabitants and agricultural land.
- The drought management project assessed two scenarios for water allocation. One allocates nearly 100% of the LU water allocation (3100 MCM) and one reduces the allocation during drought up to 35%. The results show that the first scenario can potentially restore the lake to an area of about 4300 km^2. This is still significantly smaller than the lake area of 5500 km^2 at the beginning of the 1990's. The second scenario mainly prevents a worsening of current levels.
- All simulations were based on the fundamental assumption that agricultural and industrial/urban water consumption will remain constant. An increase in these levels will endanger the environmental and agricultural health of the region.
- It is assumed that pressurized irrigation can save water in the basin and increase river inflows to the lake. This alternative requires further investigation. Some research indicates that such an irrigation system only improves water efficiency at the field level and is not effective at the basin level, especially when the source of irrigation water is both surface and ground water, which interact (Nilson, 2003; Ahmadzadeh, 2011; Ziyaee, 2012).
- A number of software packages were exclusively developed for this project, making it very flexible in allowing change in the geographical units, hydrological conditions, and new policies. Moreover, as it is recommended that the drought management be updated and modified as the models are updated and new information becomes available.

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