Agricultural Water Use in Lake Urmia Basin, Iran: An Approach to Adaptive Policies and Transition to Sustainable Irrigation Water Use

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Content

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Faramarzi, N., 2012: Agricultural Water Use in Lake Urmia Basin, Iran: An Approach to Adaptive Policies and Transition to Sustainable Irrigation Water Use. *Department of Earth Sciences Master Thesis in Sustainable Development at Uppsala University,* No. 107, 59 pp, 30 ECTS/hp

Abstract: The Lake Urmia positioned in a closed basin in north-west Iran, positioned at altitude 1250 m above the sea level, and has been rapidly drying since 1990. The lake water level has declined to 1271.58 m in 2008 from the last highest record 1277.80 m in 1994. The lake water volume has fluctuated during the observation period and shows a drop from of 32 to 14.5 million cubic meters, while the lake salinity has increased from 205 to 338 g/l due to the evaporation and water inflow reduction. In the Lake Urmia basin, there has been an increase in public awareness of the possible environmental threat and the unpleasant socio-economical consequences on the region's inhabitants.

The main aim of this study is to assess the current water use pattern in the Urmia Lake basin system with emphasis on the agricultural sub-system, and to propose adaptive measures and sustainable water management scenarios. The study shows that the main cause for these changes are the diversion of rivers and streams for agricultural irrigation; agriculture is a sector with one of the highest water demands, and frequent drought in early 2000s exacerbated the situation. In addition, a growing population and the increased development of agricultural land has led to an increase in unsustainable practices which have an unpredictable impact on the Lake Urmia ecosystem. This study investigates sustainable water use strategies for Lake Urmia basin, and considers economic and environmental factors, including the loss of valuable ecosystems that highlights social and ethical issues for the current and coming generations.

Keywords: Sustainable Development, Lake Urmia Basin, Sustainable water management, Sustainable agriculture, Irrigation water management, Adaptive policies, Sustainability

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Summery: Lake Urmia an inland lake located in North West of Iran, positioned at an altitude of 1250 m above the sea level. Lake Urmia basin is a closed drainage basin and all the streams and rivers end up to this lake has been rapidly drying since 1990. The lake water level has declined to 1271.58 m in 2008 from the last highest record 1277.80 m in 1994. The lake water volume has fluctuated during the observation period and shows a drop from of 32 to 14.5 million cubic meters, while the lake salinity has increased from 205 to 338 g/l due to the evaporation and water inflow decline. In the Lake Urmia basin, there has been an increase in public awareness of the growing stress on water resources, environment and all the challenges that could easily become crisis for the region's inhabitants.

The main aim of this study is to assess the current water use pattern in the Urmia Lake basin system with emphasis on the agricultural sub-system, and to propose adaptive measures and sustainable water management scenarios. The study shows that the main cause for these changes are the diversion of rivers and streams for agricultural irrigation; agriculture is a sector with one of the highest water demands, and frequent drought in early 2000s exacerbated the situation. In addition, a growing population and the increased development of agricultural land has led to an increase in unsustainable practices which have an unpredictable impact on the Lake Urmia ecosystem. This study investigates sustainable water use strategies for Lake Urmia basin, and considers economic and environmental factors, including the loss of valuable ecosystems that highlights social and ethical issues for the current and coming generations.

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List of abbreviations

EIA	Environmental Impact Assessment
GDP	Gross Domestic Product
GWP	Global Water Partnership
GEF	Global Environment Facility
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integration Water Resources Management
UNDP	United Nation Development Program
SPI	Standard Precipitation Index
SIPA	Standard Index Annual Precipitation

1. Introduction

1.1 Water scarcity and water management

Water is essential for the environment, human health and development, but it is a finite and vulnerable resource. Water resources are fundamental in supporting sustainable human development; sustainable water management can make a big difference in people's livelihood and their surrounding environment. Societies will not be able to approach development goals unless adequate water resource management is promoted, where water resource management is a combination of several items including the development of infrastructures, the distribution of resources, the facilitation of effective water use, and the prioritization of financial support (Muller, 2009).

At the start of the 21st century, humans on every continent face challenges in the form of food scarcity and water scarcity, which are highly interlinked with each other and exacerbated by climate change and global warming. Water scarcity is one of the main issues that the world is facing. According to UN-Water, "*Around 1.2 billion people or almost one-fifth of the world's population live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers*)" (UN WATER, 2012). Water scarcity is a circumstance that concerns the quantity and the quality of the available water resources. Degraded water resources become unavailable for more stringent requirements in many regions of the world, while water use has been growing and resulting in scarcity, not only in arid and semi-arid areas, but also in rainfall abundant regions (Pereira et al., 2002).

Water scarcity, caused by humans and by nature, has increased worldwide and many regions such as Aral Sea, has been faced with water shortage. Water scarcity is caused by imbalance between availability and demand, degradation of surface and groundwater quality, inter-sectoral competition, inter-regional and international conflicts (Pereira et al., 2009). Water shortage, caused by groundwater overexploitation, reduces reservoir capacities over a period of time when the demand on the resources is greatest (Pereira et al., 2002). For instance, diverting surface waters and exploiting groundwater without sufficient care can lead to water scarcity. A recent assessment estimates that half of the world's population will live in water-stressed river basins by 2025 (Millennium Ecosystem Assessment, 2005).

The risk for water scarcity increases the need to achieve sustainability in water resources, and this is one of the main challenges facing different sectors in societies. Most societies deal with the consequences of the poor management of water resources, which are among others the pollution of rivers and the degradation of catchment areas. Poor water management is often characterized by a lack of consultation and coordination among stakeholders, often leading to inappropriate investments, poor regulation, insufficient institutional capacity and different attitudes; therefore, in order to deal with these problems, all societies need to consider the strategies which properly address management of scarce and valuable resources, including water (McKinney, 2011).

The existing climate change scenario has potentially affected water resources. Climate change represents one of the main impacts on extreme weather conditions and also on shifting seasons, as well as increases in temperature and sea level changes. For countries with an arid and semi-arid climate (e.g. Iran), the existing climate change scenario could represent a major challenge in water management, since an imbalance is likely to arise between available water resource and existing demand. With rapid population and economic growth, the increasing demands on agricultural productivity and food security affect the availability of water resources. Water supports the socio-economic development of societies and an integrated water management is required in different sectors to reach the concept of sustainable development, especially with regard to agriculture. Indeed, agriculture is one of the water demanding sectors (Muller, 2009). To achieve the contexts of sustainable development, the resilience of water resources should be assessable, where resilience is defined as "*…the capacity of a system to undergo change and still retain its basic function and structure… it's the capacity to undergo some change without crossing a threshold into a different system regime"* (Walker and Salt, 2006). According to resilience theory (Walker and Salt, 2006), social ecological systems are complex adaptive systems, meaning that they are dynamic and change in non-linear and unpredictable ways. A social ecological system is a system where human (social) and natural (ecological) systems are embedded to each other (Walker and Salt 2006). According to the Millennium Ecosystem Assessment (2005) "*resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics*." The way to approach this resilience could be specifically addressed by adaptability "*the capacity of people in a social-ecological system to manage resilience e.g. through collective action*" and transformability *"the capacity of people in a social-ecological system to create a new system when ecological,* *political, social or economic conditions make the existing system untenable"* (Folke lecture notes, 2010).

Resilience helps us to understand the human interaction with environment and help us to learn our way to look for the feedbacks of complex system to achieve sustainability in long run. Growing population and socio-economic development has increased the demand on provisioning services provided by wetlands (Lake Urmia Basin) such as water supply and food (Millennium Ecosystem Assessment, 2005). Hence, resilience in water resources management is really important to observe the feedbacks of the socio-ecological system to help the system maintain in its self organizing caring capacity without shifting to another system. The way to maintain the resilience of socio-ecological system is not just adaptive management also transition to the new practices and look for new ways to approach problems that help systems (water resources) function as they should function.

1.2 Aim of study

This study addresses Urmia Lake, Iran, which has been shrinking in size primarily the result of economical development policies and urbanization in the last decade. Water management issues lie at the heart of the problem, as the shrinking lake is the result of an increased water use and a water deficit in the Urmia lake drainage basin, which has produced a shortage of water for agriculture and irrigation. In determining the sustainability of water resource system, the growth and development in the region is evaluated to avoid catastrophic environmental, social and economic consequences of the mismanagement of water resources.

It is estimated that a growing population in the Lake Urmia basin, followed by rapid urbanization, will raise the population of the area from 5.9 million (2008) to 7.1 million by 2020 (Hashemi, 2008). Similarly, the industrial sector is expanding in the eastern part of the lake basin i.e. East Azerbaijan (Hashemi, 2008). The increasing population, air and water pollution, habitat fragmentation, and global climate change act as additional hazards impacting the region's economy, residents and wildlife, so water management is a critical issue that needs to be addressed in order to maintain the vitality of this region. Therefore, the aim of this study is to assess the current water use pattern in the Urmia Lake basin system with emphasis on the agricultural sub-system, and to propose adaptive measures and sustainable water management scenarios. To achieve the aim of the study, the following tasks have been performed:

- Investigation of the water balance for Lake Urmia
- Assessment of agricultural water use in the Lake Urmia basin
- Assessment of performance of water management activity in Lake Urmia basin
- Identification of sustainable water management options for agriculture

The main goal of this thesis is to improve water management in the Urmia Lake basin according to the sustainability of water resource management on the river level, basin level and farm level.

2. Background

The Lake Urmia basin in the North West of Iran is a closed drainage basin (i.e. no outlet) with an area of about 51876 km^2. As seen in the Figure 1, the Lake Urmia basin is located in north west of Iran with high mountain areas, foothills, and plains. Lake Urmia contains 102 islands, located at an altitude of1250 m above sea level (Eimanifar, 2007) with the surface water level at 1271.58 m above the sea level in 2008. The catchment area is shared between the three provinces West Azerbaijan (21500 km^2), East Azerbaijan (19000 km^2) and Kurdistan (5000 km^2) (Yekom Consulting Engineer, 2005). Lake Urmia is the second largest inland salt lake in the world, and receives water from 17 major rivers, 12 seasonal riveres and 39 floodways (Hashemi, 2009). The rivers and streams in the catchment discharge to this lake pass through agricultural land, and urban and industrial areas (Eimanifar, 2007). In addition, the lake is an important and valuable ecosystem:"*Urmia Lake, the largest inland lake in Iran, with unique ecosystem value and ecological character, has been given National Park status and has been protected since 1963, when the Kaboodan Island or Ghoyoon Daghi was declared as a protected area.* Moreover*, the Lake was listed as a Ramsar Site (wetland of international importance) in 1975 and as a UNESCO Biosphere Reserve (17 January, 1976)"* (Yekom Consulting Engineers, 2005). Wetlands are crucial ecosystems because they provide ecosystem services that contribute to human well-being. The ecosystem services that provided by wetlands are provisioning, regulating, supporting and cultural benefited people with water supply, water purification, climate regulation, recreational opportunities, and turism (Millennium Ecosystem Assessment, 2005). Moreover, the lake and surrounding freshwater wetlands support large populations of water birds.

The Urmia Basin possesses fertile agricultural land that is supported by irrigation provided from water storage in several dams. Also, the lake provides a suitable climate for tourism and tourist activities, and the Urmia Lake coast usually attracts visitors during June, July and August (Matzarakisb, 2009). The lake supports an ecosystem containing the endemic brine shrimp *Artemia urmiana,* which are considered as a key species in the aquatic food chain in the lake, as they provide with nutritious value for flamingos and water birds (Nazaridoust, 2007). Due to the high salinity of the lake, the lake and surrounding wetlands are used by local people for harvesting salt.

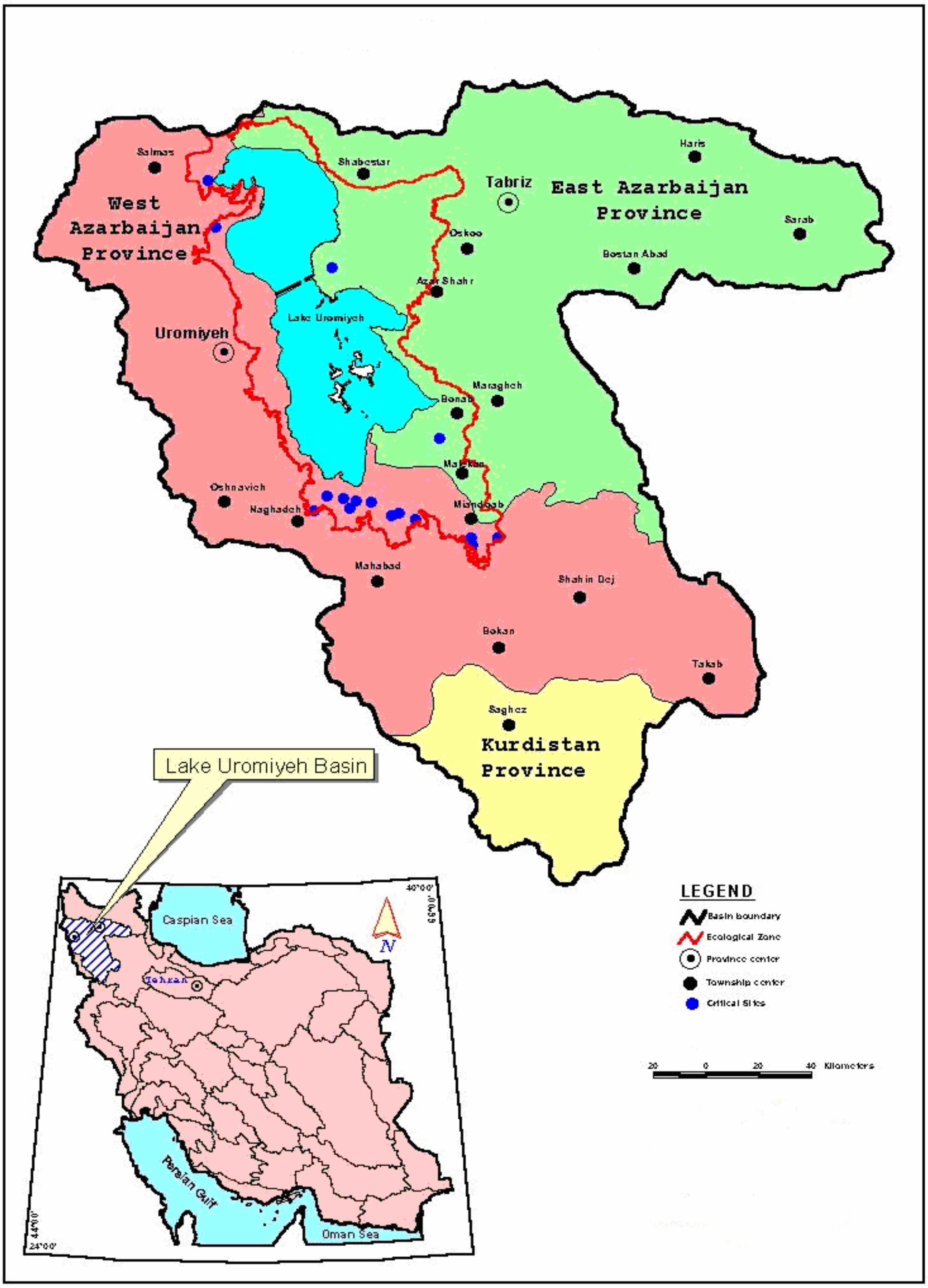

Figure 1. Lake Urmia basin map (Yekom Consulting Engineer, 2005)

3. Research process and methods

The material presented in this report is primarily obtained through a review of the available literature, followed by its interpretation in terms of water management.

3.1 Literature review

Several government-based reports and articles have reviewed to determine how the cases have been analysed so far. The reviewed reports are from Ministry of Energy and the Water Research Institute of the West Azerbaijan Water Authority-, which is provided in 9 volumes by Yekom Consulting Engineers (2005). This is one of the most comprehensive descriptions since 2004 at the local and national level that has covered different aspects of Lake Urmia basin, including social economic and environmental to some extent. Also, very useful data has been provided by Hashemi (2008).

Several literatures reviewed to understand the way to approach water resources management and applied to the case study such as (Pereira, 2009; Muller, 2009; UN water, 2011; Emanifar, 2007, etc) and referenced to them in different sections.

Data on the Aral Sea has been used in this study in order to study rehabilitation progress in the last decades (McKinney, 2011; McKinney et al., 2003; Micklin, 2010). The Aral Sea has been shrinking during the last 50 years, since 1960s, and is located to the west of the Caspian Sea and to the east of the Kopet-Dag, Pamir, and Tien Shan mountain region (McKinney, 2011). It is shared among 5 countries of the Independent states of Former Soviet Union. The management decisions to obtain sustainable water management in the Aral Sea could be relevant in the Lake Urmia basin since both of them are significantly degraded by the consequence of water withdrawals and water diversion to meet irrigation needs for development and growth. Moreover, articles about sustainable development have been studied in order to identify the definition and to verify how this unavoidable term could be implemented in reality.

3.2 Hydrological study and analysis

Several projects and studies from the Agricultural of Jihad Organization, Natural Resources and Watershed Management Organization have done in the region to determine the water inflow to the lake. To calculate the estimated available water in the region data from a number of the hydrometric and precipitation stations have been collected. The Lake Urmia Basin includes 11 subbasins with 17 main rivers, 12 seasonal rivers and 39 streams (Hashemi, 2008). Along the rivers, several hydrometric and precipitation stations are located, but due to some technical issues they do not work efficiently or differ in the records. In this thesis, to minimise the errors, the 12 main rivers are selected based on the highest water inflow according to the available reports and studies (see table 3). The amount of water inflow to the lake is calculated from the hydrometric stations for 12 selected rivers for the period (1990-2004) provided by Water Policies and Allocation Commission the Lake Urmia Basin hydrologic study in 3 volumes (2010). Also the precipitation of the two main cities on both sides (Tabriz and Urmia) of the Lake was obtained from the internet for the period (1990 2010) and annual and monthly precipitation calculated.

In order to better understand the historical changes in the Lake Urmia basin, several graphs and tables are prepared with the available data, such as water level, the lake surface area, river water inflow, and agricultural land. Several graphs, tables and analyses provided from different reports have been compared with results being interpreted in this thesis to identify and address the existing situation. In the Hydrology chapter, the required data from Lake Urmia Basin hydrologic study in 3 volumes (2010) has been collected to estimate the trend of water inflow from 12 main rivers into the lake for 1990 to 2004; this is compared with the Yekom Consulting Engineering report (2005) which has provided the water inflow and evaporation for a 39 years period into the lake. The SPI and SIPA analysis results provided by Yekom Consulting Engineering are used interpret previous climate scenarios.

3.3 Interviews

The first step interviews consist of a range of questions to the local authorities, local correspondents and correspondents who are cooperating and involving in the water resources and agriculture in the Lake Urmia Basin. Generally, the purpose of these interviews was to obtain detailed information on Lake Urmia Basin which can later be used directly to compare the available information and find out the specific techniques to improve water use in the region. In July 2011, the interviews with candidates were arranged by Dr. Hashemi with East Azerbaijan and West Azerbaijan Agricultural Jihad Organisation, West Azerbaijan Ministry of Energy Organization, and East Azerbaijan Conservation of wetlands Organization. The next step questions were asked to obtain information on agriculture practices and water use in the region from the my former colleagues and local experts to seek the impact of Lake Urmia Basin changes during the time period on the surrounding farms in the region.

4. Theoretical framework

4.1Sustainable Development

The concept of Sustainable Development is highly relevant with the rapid increase in awareness of environment conservation and depletion of resources. Discussions often centre around how our decisions could lead us to a sustainable society and preventing the degradation of finite resources, while from an economic point of view our common resources are the only source of development and economic growth (Dresner, 2002). According to Dresner (2002), different arguments illustrate the concept of sustainable development: environmentalists believe that sustainable development is a tool for policymakers to extract more resources; on the other hand, economists believe that the concept of sustainable development makes us too cautious toward future generation and involves moral issues which limit progress. Regulation and legislation on socio-economic development build up the idea that how development could be sustained with environment and numerous defined to enhance sustainability. However, all the interpretations to achieve sustainable development sharing principles that remain similar to *"Our Common Future",* known as the Brundtland report, which illustrates new solutions for social and environmental problems caused by economic growth. Development is defined as being able to "*meet the needs of the present without compromising the ability of future generations to meet their needs*" (i.e.Brundtland's Commission, 1987). Sustainable development concept attempt to moderate human needs and their desire for the better life and social equality in generations' with possible extended to next generations (i.e.Brundtland's Commission, 1987).

4.2 Principles for sustainability

Sustainability involves different terms to describe and implement strategies and policies to define the principles of sustainable development as an essential framework in the study of complex systems. The principles for sustainability could be classified to include environmental, ecological, economic, and social dimensions (Lukman, 2007). Environmental principles are terms that describe environmental performance, in order to minimize the use of hazardous or toxic substances, resources and energy. Ecological principles consider all human interactions with surrounding natural systems in order to understand their relationship. Social principles includes social responsibility, health and safety, taxation and reporting to stakeholders (Lukman, 2007). Economical principles are terms to understand the process of economical development in a social and environmental point of view (Lukman, 2007). The principle of sustainable development implemented to our societies may improve the vision of development for the future, and requires changes in the life style and thinking in human societies. The absence of sustainable development in the Lake Urmia Basin, with water as a key component of development, requires a comprehensive sustainable development framework in the pattern of water resources management at the regional and national level so as to improve the quality and quantity of groundwater and surface water as a part of sustainable development.

4.3 Integrated Water Resource Management

Integrated Water Resource Management (IWRM) is defined as "*a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment*" (GWP-TAC, 2000). The availability of water in terms of both quality and quantity differs from region to region because of climate, but availability may change over time within a region due to climate variability and climate change. Water management is required to support social, economic and environmental development and in a broader context achieve sustainable development (Muller, 2009). Proper water management is especially critical in areas where there is a growing population, where there is an impact from climate change, and in areas afflicted with poverty where food security an effective distribution of water for agriculture irrigation and sanitation must be prioritized. IWRM seeks to approach the objective of sustainable development and an optimum balance between economic efficiency, social equity and environmental sustainability (Muller, 2009). Hence, IWRM integrates the contribution of users and policy makers from different sectors in the decision-making process. IWRM, contrary to traditional and conventional management, requires a holistic and systematic integrated approach to prioritize the social and economical challenges of each country. The IWRM approach facilitates the achievement of sustainable water management in the Lake Urmia basin by supporting the use of water resources for the people, agricultural lands and national development goals. The optimum goal with the application of Integrated Water Resources Management is to create a common approach in terms of infrastructure, institutions (governance), environmental laws, and water resource endowments to build capacity and plans and make changes for monitoring and implementing roles and practices (Muller, 2009).

IWRM can be considered as a type of adaptive decision making to manage resilience in water resources systems. Adaptive management is a coexisting approach by learning and management based on our understanding and responsibility of our natural resources system (Williams, 2011). Building resilience in water resources system by adaptive planning requires participation of all the stakeholders for better understanding of their decisions and plans in the system. For instance, the impact of river water diversion for irrigation and construction of dams to supply water for development purposes must be accurately evaluated to prevent negative impact on other services. This exclusive approach requires collective responsibility and respective roles identified which can help to make more efficient use of water and its distribution more equitably. Consequently, it strengthens the protection of water resources and puts less pressure on ecosystems.

5. Hydrology of Lake Urmia Basin

This chapter addresses the climatic and hydrological conditions in the basin and how changes in these conditions may have resulted in the declining water levels in Lake Urmia. These conditions may be exacerbated by an increasing water demand in the region with a growing population; the population was 4.8 million in 2002 and is estimated to reach to 7.1 million in 2020 (Hashemi, 2008). This could result in a major water imbalance in Lake water level and environmental problems.

Lake Urmia is a shallow lake lying in a closed basin in the north west of Iran which receives surface inflow of rivers and streams, but has no surface outflow. Lake Urmia has a depth of about 6 m to 12 m and the length is about 140 km and width 85 km. The region has a semi-arid climate with agriculture land mainly in East Azerbaijan. The lake surface area is about 5320 km^2 which is 10 % of the total basin area and Lake Urmia contains about 32 billion m^3 water (Yekom Consulting Engineer, 2005). The great anthropogenic impact in the basin is the construction of the 15 km Shahid kalantary highway in the early 1990s across the lake which split the lake into two parts (35.5% in north and 64.5% in south) (Yekom Consulting Engineer, 2005).

5.1 Geographical conditions and climate

Iran has the advantage of a wide spectrum of meteorological and hydrological conditions, and has primarily an arid and semi-arid climate. The climate in Lake Urmia basin is harsh and continental (Eimanifar, 2007), and this geographical condition makes its climate quite distinct in different regions. Winters are cold with snowfall and during December and January temperatures are below zero. Mild spring continues with hot and dry summers (see Figure A1 Appendix 1).

The annual average precipitation in Lake Urmia basin is about 200 to 300 mm (Eimanifar,2007). Figure 2 shows the annual precipitation during 1998 – 2008 for eleven cities in the Lake Urmia basin. The location of these cities is shown in Figure 1 and in Figure A2 in Appendix 1. Two of these cities, Tabriz and Urmia, have an average annual precipitation of 247 mm and 268 mm, respectively, during this time period (Freemeteo, 2011, internet). During a typical year, the basin receives most of its precipitation during the fall and winter months, although there is quite some variability in the monthly values (see Figures A3 and A4, Appendix 1). The average temperature varies from 0 to -20^{o}C in winter and in summer time it reaches to 40°C (Eimanifar, 2007). Precipitation and temperature may vary due to the climate and geographical conditions.

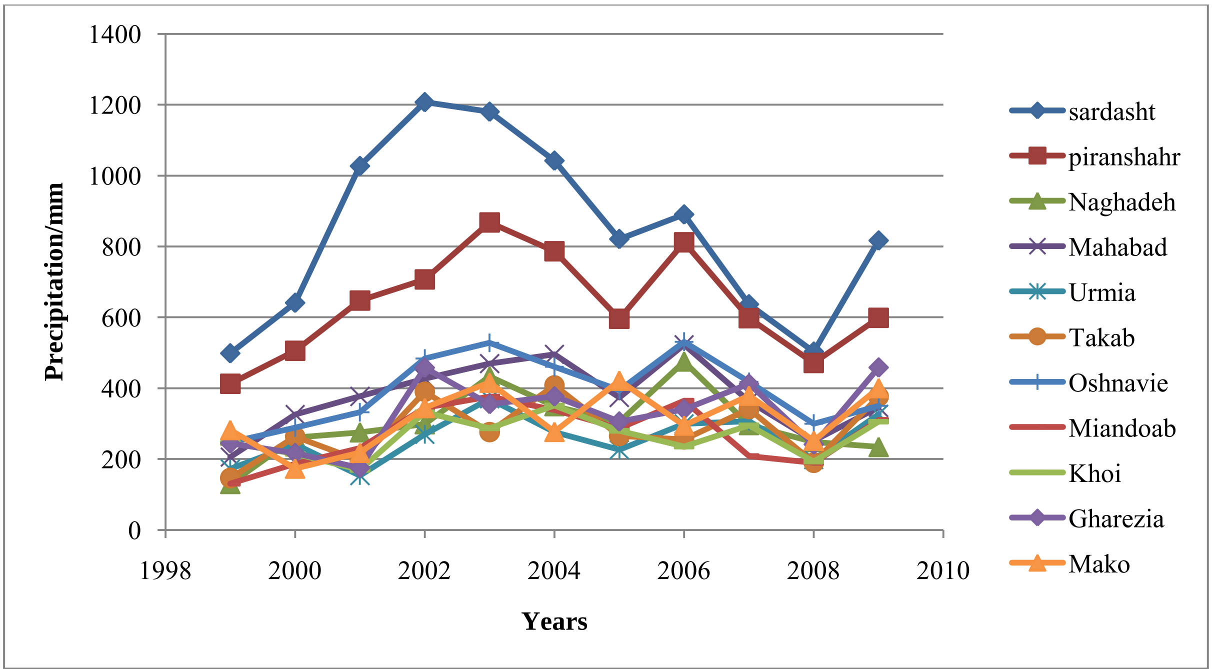

Figure 2. Annual precipitation at 11 stations in the Lake Urmia basin. Data from Natural Resources and Watershed Management Organization (2011)

As can be seen from the precipitation data in Figure 2, annual precipitation varies between the stations. Notice that Urmia basin is located in mountain area and the precipitation will be different due to the locations. The variability of rainfall from one location to another is significant that could be related to the altitude , latitude and longitude. Among them altitude could have great impact. For example, in West Azerbaijan (Band Urmia and Golmankhaneh) and East Azerbaijan (Sharafkhaneh) are three locations on two different sides of the lake which have significant differences in precipitation (see Table 1 and Figure A5, A6 in Appendix 1 for locations).

Table 1. The annual precipitation in Band Urmia, Golmankhaneh and Sharafkhaneh on two sides of the Lake Urmia Data from Natural Resources and Watershed Management Organization (2011)

	Altitude	Longitude	Latitude	2002	2003	2004	2005	2006	2007	2008
Band Urmia	1390	37.5	45.0	425	398.5	366.5	335	797	450.5	215
Golmankhaneh	1252	37.5	45.0	269	79.5	203.5	328.9	654.5	260.6	121.3
Sharafkhaneh	1270	38.2	45.5	295	319.5	258.5	174.9	241.1	284.4	174.5

Additional examples of the effect of station location are Piranshahr (1480m elevation), Sardasht (1500 m elevation) and Naghadeh (1340 m elevation) that are three cities in the West Azerbaijan located in the mountain area (See Figure 2). Piranshahr and Sardasht are two cities located on south west of Lake Urmia nearby Oshnavieh, Mahabad and Naghade cities (Figure 1 and Figure A2, A7 in Appendix1 for locations). The region has cold winter and mild summer and the altitude has made considerable difference in the rainfall rate during the time.

The annual potential evaporation (Figure 3) in the basin was at highest in 1999 at about 1571.0 mm (Yekom Consulting Engineer, 2005); this coincides with a period when precipitation was lower than average (see Figure 2) for the period 1999 - 2009.

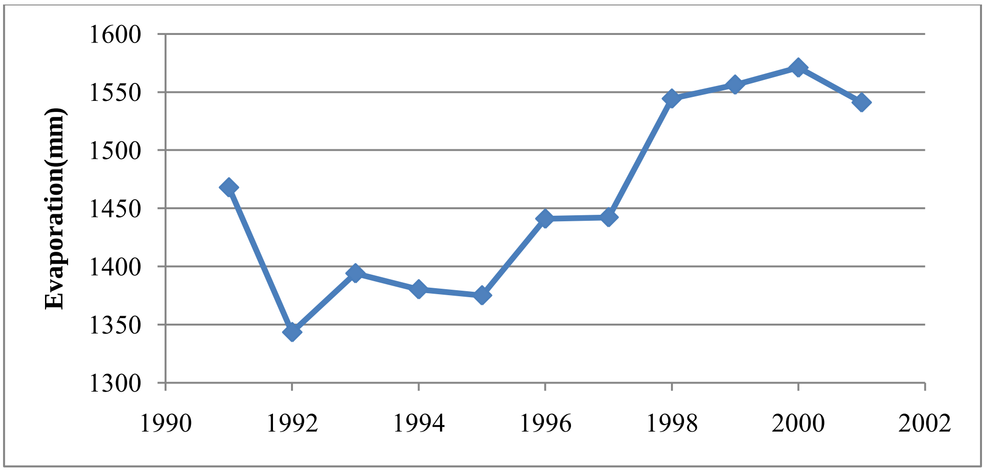

Figure 3. An annual evaporation trend in Lake Urmia basin Data from (Yekom Consulting Engineer ,2005)

5.2 Changing lake levels and river flow

Lake Urmia is in a closed basin with inflows of more than 17 main rivers and over 30 seasonal rivers, which means that the only outflows are by evaporation. Lake Urmia is a shallow lake located in mountain area where water size has declined over the last two decades; in the shallow regions the shrinking areas were more significant. The lake surface areas have been relatively constant at 5300 km^2 during the period 1969 - 1998 (Figure 5; UNEP, 2012). Since 1998, the lake has shrunken to the less than its half size, as estimated area from the satellite data, and was about 2366 km^2 in August 2011 (Figure 5; UNEP, 2012). From the available reports and studies, Lake Urmia was at its highest water level in 1995 1277.49 m above the sea level (Figure 6; Natural Resources and Watershed Management

Organization, 2011). As can be seen in aerial photographs in Figure 6, Lake Urmia basin has decreased in surface area mostly from the south and east part between 2006 and 2011.

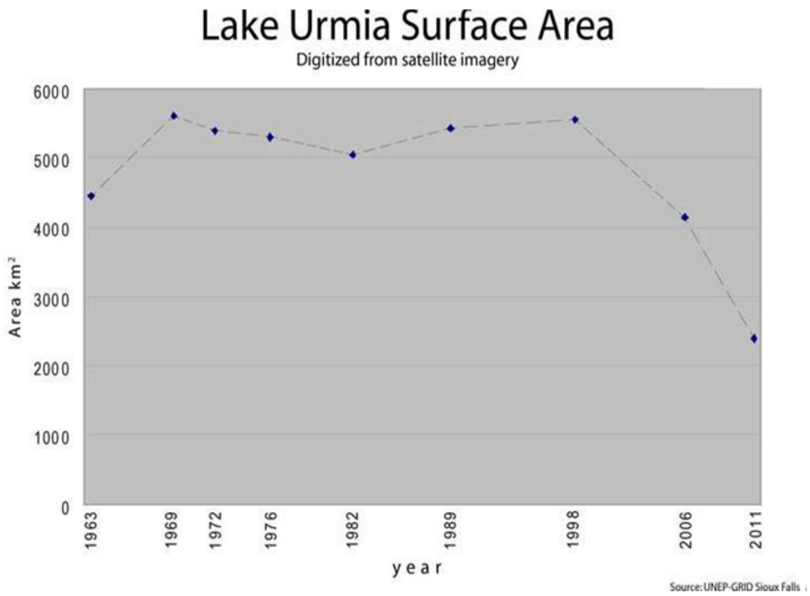

Figure 4. Surface area estimated Data from landsat imagery (UNEP, 2012)

Table 2. Surface area estimated Data from (Yekom Consulting Engineering, 2005)

Year	1988	1989	1994	1995	2000	2002
Lake surface area/km2	6300	5863	5900	6500	5080	4200

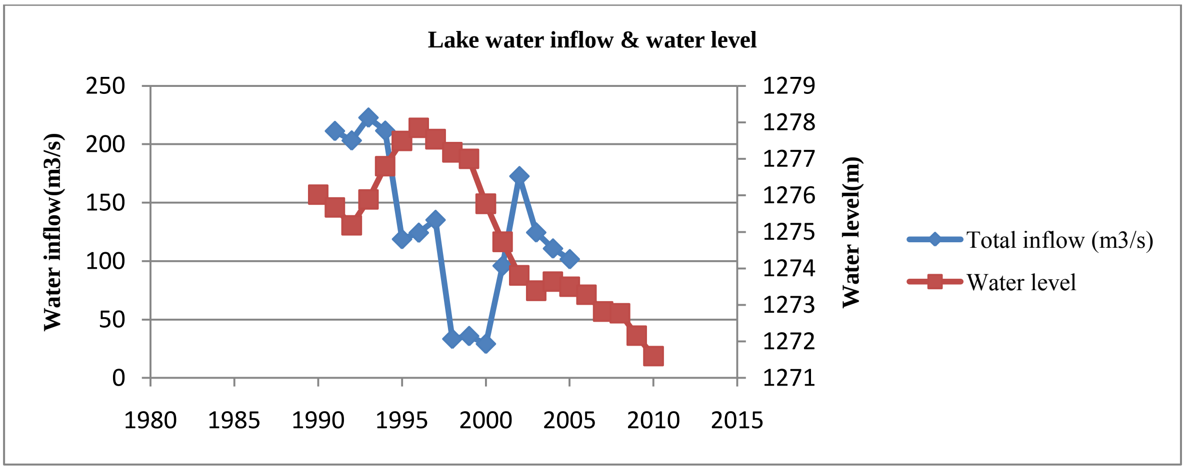

Figure 5. Lake water inflow and Lake water level. Data from Natural Resources and Watershed Management Organization (2011)

Table 3.The water inflow to the Lake Urmia Data from (Yekom Consulting Engineering, 2005)

Year	1978	1986	1993	1998	1999	2000
Water inflow to the Lake(MCM)	13526.7	10725.82	8845.49	586.34	439.97	341.2

According to the provided data, Lake surface area has declining from late 1990s based on Yekom (2005) and UNEP (2012) landsat analysis; though these two reports do not show same data (see Figure 4 and Table 2). Shrinking of the Lake surface area could be address to the low water inflow to the lake precisely from mid 1990s which water level dramatically has dropped up to present (see Figure 5 and Table 3). In addition (see Table 2 and 3) from Yekom (2005) shows that Lake surface area shrunk during period of 1988 -1989 as the water flows significantly dropped.

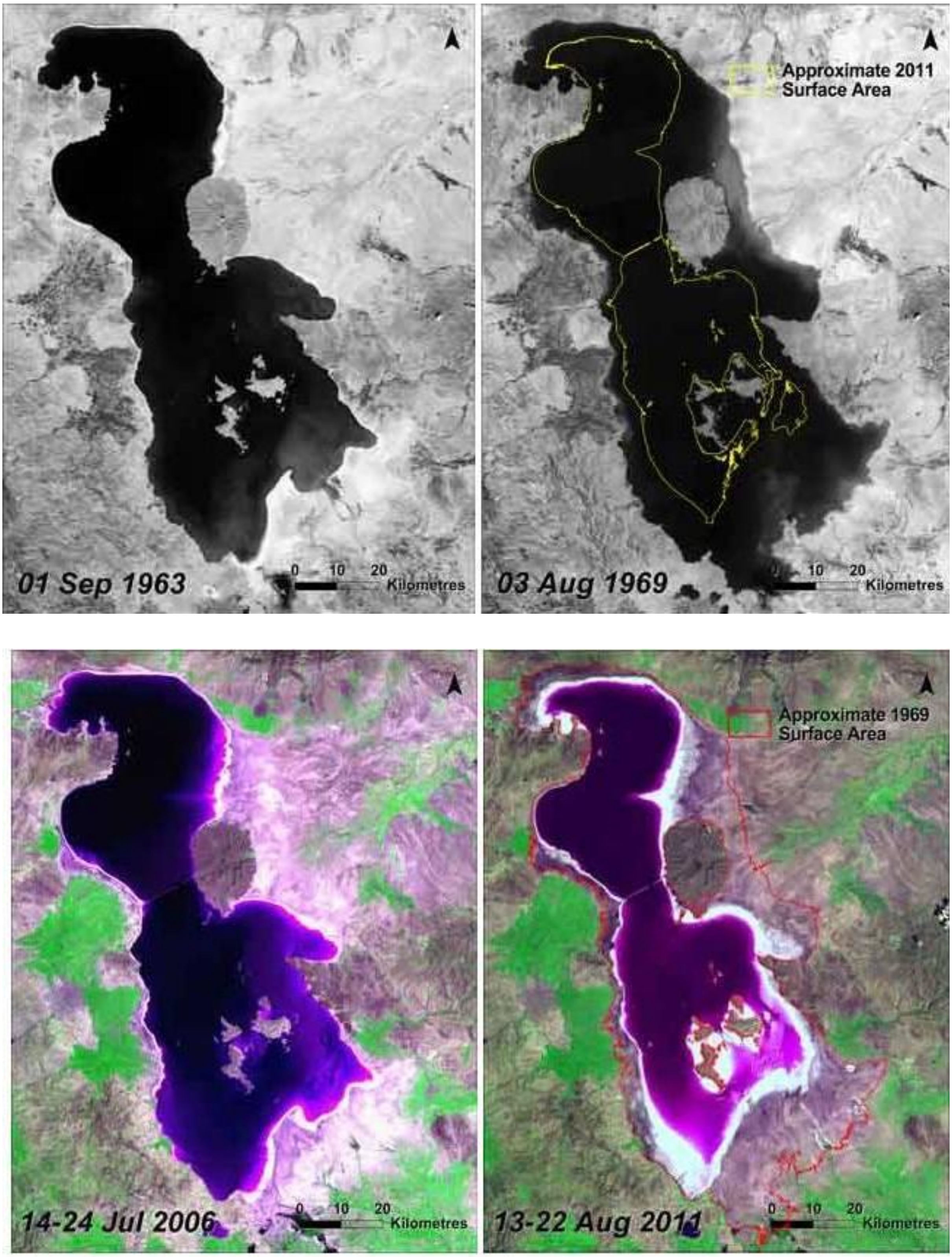

Figure 6. Landsat image of Lake Urmia (Source: 1963 Image: ARGON data from USGS; 1969 image: Corona data from USGS, visualization by UNEP GRID Sioux Falls; 1972-2011 images: Landsat data, 2011 image: visualization by UNEP GRID Sioux Falls

As the surface area of the lake has decreased, its surface elevation has decreased as well (Figures 4 and 5). The decrease in surface area is the result of decreasing river flow to the lake (Figure 5) combined with high evaporation (Figure 3) and lower than average precipitation (Figure 2). The estimated water inflow to the lake from 17 main rivers from the Water Research Institute data was about 667.7 MCM in 1990 and water inflow has dramatically decline almost to its half 392.4 MCM in 1995 although water level did not change in the same fashion during this period (Figure 6). Data on the main rivers discharging to Lake Urmia are presented in Table 4 and can be comparised with Figure 5 that verifies that the lake surface area has decline trend from 1998 up to present time. As shown in Table 4, average discharges for the period 1990 – 2004 are lower than the average discharge for the entire period 1967 – 2002. The Lake water level has dramatic decline since 1990s as water inflow declines from 1995 which could exacerbated with severe drought in 1998-2001 up to present time (see section 5.4).

Table 4.The number of main rivers inflow to the Lake Urmia basin – categorize based on high water inflow

Rivers	Basin area km^2 [1]	Average flow (1967-2002)[2] m^3/s	Average flow (1990-2004) m^3/s	Total dissolved solids, average for 39 years (1967-2002) (g/l)
Zarineh Rood	11000	64.96	61.33	272
Simineh Rood	3500	16.93	3.09	260
Nazloo Chai	1960	13.31	7.39	261.1
Aji Chai	9200	13.18	10.87	3220.3
Godar Chai	N/A	12.62	9.75	244
Mahabad Chai	850	9.18	7.97	365.7
Barandooz Chai	1200	8.85	7.75	277
Shahr Chai	960	5.38	5.26	167.2
Zola Chai	200	4.57	1.74	550.5
Sofi Chai	1800	4.05	3.99	233.2
Mardoogh Chai	983[3]	2.66	2.53	224.9
Ghaleh Chai	600	2.00	1.51	266.5
Lailan Chai	900	1.78	1.74	N/A
Daryan Chai	2194[4]	0.49	0.59	N/A
Azarshahr Chai	278	N/A	1.85	216.9
Roze Chai	328.10[5]	N/A	1.22	422.8
Kherkhere Chai	N/A	N/A	1.14	N/A

[1] (Waterplan, April 2010)

[2]Courtesy of WRI,2005- The status of Water Resources in the Lake Urmia Basin, Mukhtar Hashemi

[3] Yekom, 2005

[4] Yekom, 2005

[5] Yekom, 2005

5.3 Lake water salinity

Lake Urmia is a hypersaline Lake with a unique ecosystem. The brine shrimp species *Artemia urmiana* is the only aquatic organism in Lake Urmia. According to some studies (e.g. WRI, 2005) the average TDS (Total Dissolved Solids) was about 222.6 g/l during 1993-2004. As shown in Table 4, average TDS concentrations in the inflowing rivers are quite high. Gradually with decreasing the water inflow and water volume, the TDS reached to 338 g/l in January 2008, which is beyond the *Artemia urmiana* ecological threshold. The Abbaspour and Nazeridoost (2007) study shows that *Artemia urmiana* are sensitive to NaCl (salt) which means that the amount of NaCl in the water should not be more than 240 ppt (parts per thousand) which is consider as *Artemia urmianasu* ecological threshold (Abbaspour and Nazeridoost, 2007).

5.4 Drought cycles

To understand the drought process in Lake Urmia Basin, it is important to study available reports on precipitation, temperature and available climatic simulation analyses considering the time scale from 1990 up to present. This study used the provided data from Yekom report (2005); the monthly precipitation records for 51 stations over 30 years was used to evaluate and assess the drought over the past time (Yekom Consulting Engineer, 2005). The Yekom report indicated that the Lake Urmia basin has had two drought periods, when the water inflow to the lake dropped from 8845.49 MCM in 1993 to 341.2 MCM in 2000 (Yekom Consulting Engineer, 2005). The Yekom study assessed the drought and wetness in the basin according to SIAP and SPI models, based on the probability of an observed precipitation in the time period. SPI (Standard Precipitation Index) is a way to measure and identify the drought condition through the past precipitation data "*The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive*" (McKee et al., 1993). SIAP (Standard Index Annual Precipitation) is a similar unit except it considers precipitation on annual time scales, while SPI considers with 1, 3, 6, 9, 12 and 24 month time scales. As shown in Figures A8 and A9 (Appendix 1), SIAP and SIP show that since 1986-2001 the basin experienced variety of climate condition, extremely wet to extremely dry. The basin was faced with frequent drought conditions in 1998-2001, while 1998-1999 were years with extreme drought conditions in most regions in the south and west. The findings of the Yekom (2005) study are supported by the precipitation data shown in Figure 2, where precipitation is low at the beginning of the time series. The drought condition during that period would have a high impact on water inflow to Lake Urmia.

6. Agricultural sector in Lake Urmia Basin

The worlds' growing population requires the expansion of agricultural land to reach the growing food demand; however, restrictions such as drought and water scarcity are key challenges to feeding a growing population (Kamal and Siddigui, 2009). In the Lake Urmia Basin, a growing population, socio-economic development and the expansion of agricultural land to provide food have led to water stress.

For the time period 1997 to 2007, the FAO (2008) has reported in the AQUASTAT Program (Global information system on water and agriculture) with cooperation of several country profiles in the Middle East. Information has been acquired from this report on agricultural water use in Iran, and attempts are made below to extend this data to agriculture water use in the Lake Urmia Basin.

Iran is located in the Middle East with about 1,75 million km^2 total land (FAO, 2008). The 29 percent of total land in Iran which is about 510,000 km^2 is allocated to the agriculture (FAO, 2008). According to the 2005 national statistics, the population was 69.5 million (FAO, 2008). In 2005, agriculture is one of the active sectors on which 6,689,000 million people are economically dependent (FAO, 2008). Therefore, with population growth and increasing demand for food, more land will be used for agriculture cultivation and there will be a high pressure on natural resources, especially water. Lake Urmia basin is just about 3 percent of the total area of Iran (FAO, 2008), with about 51,876 total km^2 and 18,702.86 km^2 agricultural lands in East Azerbaijan and West Azerbaijan, respectively (Ardakanian, 2005). Agricultural land management commodities in Iran are individually owned by farmers (about 99 percent) (Ardakanian, 2005) and farms tend to be small units (FAO, 2008). To some extent it is not possible to estimate the number of the farms, due to the inheritance of land. Farms are transferred as property and divided between the family members. According to the FAO (2008), "From 1960 to 1993 the number of farming units increased from 1.8 to 2.8 million units, with the average area per unit decreasing from just over 6 hectares to less than 5.5 hectares". The Lake Urmia basin supports a variety of production and activities, mainly alfalfa, wheat, vegetables, sugar beet, apples, pears, grapes and horticulture as well as livestock.

Agriculture can be considered as the primary water imbalance driver in Lake Urmia Basin. In addition to the decrease in water flow to the lake, the main impact of irrigation mismanagement is the resulting soil salinization due to the poor water irrigation, and soil erosion due to overcultivation which puts too much stress on a fragile environment (Pereira et al., 2002). According to local farmers near Lake Urmia, basin crop yields are decreasing, and this is believed to be due to soil salinization and decreases in water quality (interview findings, July 2011). Thus, waterlogging and soil salinization are considered as major challenges in Iran (FAO, 2008).

Water stress in the Lake Urmia basin required the adaptation to sustainable irrigation management practices, which lie under the concept of sustainable development expressed by Cai et al. (2003), *"Sustainable irrigation water management should simultaneously achieve two objectives, sustaining irrigated agriculture for food security and preserving the associated natural environment."* Improving irrigation practices would be appropriate to reduce this stress on Lake Urmia and its ecosystem and sustain the regional well-being.

6.1 Irrigation and irrigation practices

The agricultural sector is one of the most important economic sectors in Iran, and has substantially expanded in the last two decades. Agricultural production accounted for 23 percent of the Gross Domestic Product (GDP) in 2007, increasing from 9 percent in 1992 (FAO, 2008). About 90 percent of the water resources are allocated to the agriculture sector (Ardakanian, 2005). In 2004, as can be seen from Figure 9, 92.2% of total water withdrawal goes to the agriculture sector in Iran (FAO, 2008). However, this sector could not meet the required production demand in the country and Iran is dependent on imported agriculture production. In many countries irrigation is considered as one of the effective methods to increase agriculture productivity. However, irrigation efficiency in Iran is about 33 to 37 percents and about 50 to 60 percents of water in irrigation is insufficiently used (Ardakanian, 2005). Iran agriculture is highly dependent on irrigation practices due to arid and semi-arid climate, and crop production in the Lake Urmia basin is dependent on both rainfall and irrigation systems. However, the irrigation efficiency in West Azerbaijan is just about 28-41 percent (Ardakanian, 2005). There are a number of reasons for the low efficiency of irrigation in Iran, where a primary cause is that the agricultural sector is not aware of potential water conservation practices. In addition, the development and assessment of technologies to increase food production per units and to reduce the consumption of excessive water are needed. Good infrastructure is required for irrigation distribution with minimize loses (evaporation).

In Lake Urmia Basin, several dams and dikes have been constructed mainly for water diversion and water storage for agricultural purposes. The first and secondary downstream canals are a modern system, but the area has traditional irrigation systems and water is distributed through the open canals built by farmers. Figure 7 shows that localized irrigation such as drip and sprinkler irrigation account for about 5% and 3%, respectively, of total irrigation practices in Iran, while 92% is allocated to the surface irrigation. If we can assume that the irrigation practices for all of Iran (Figure 8) apply to the Lake Urmia Basin, then surface irrigation predominates and localized irrigation and sprinkler irrigation is less common.

According to the Millennium Ecosystem Assessment (2005) groundwater, has crucial role in water supply, providing water need for irrigation, domestic and industries. In spite of this fact, to support the sustainable groundwater use economical drivers such as suitable pricing and monitoring often has not been sufficiently applied. In 2003 in Iran, 81,300 km^2 of total arable land allocated to irrigation agriculture and the amount of water required for irrigation is provided by surface water and groundwater at the proportions of 38% and 62%, respectively (FAO, 2008). Irrigation is more dependent on groundwater supplied by wells, qantas and springs compared to surface water since irrigation agriculture receives approximately 62% water use from groundwater according to the FAO (2008). In Lake Urmia Basin, groundwater which recharge through the basin, considered as abounded supply and farmers design their own systems to withdraw water from groundwater and rivers to their lands and there is thus little regulation of water withdrawals.

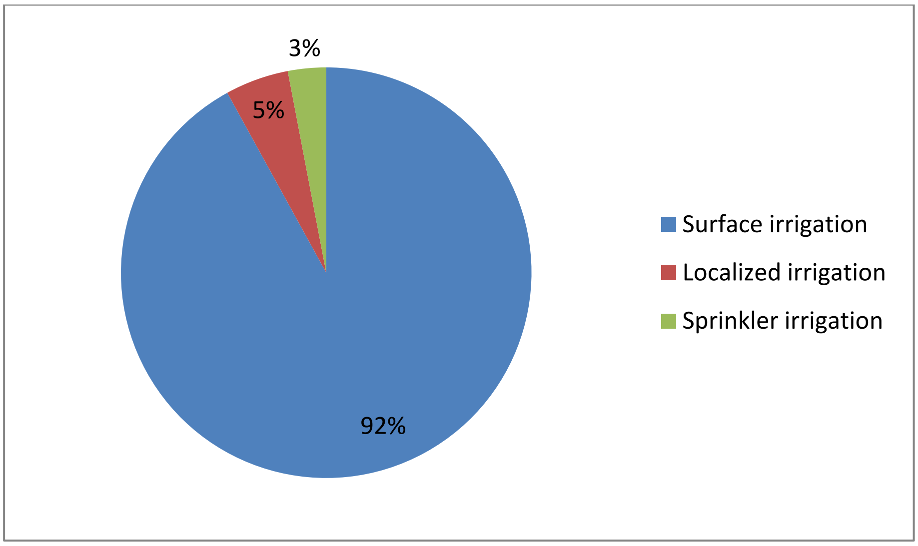

Figure 7. Water withdrawal by three main sectors in 2004. Data from FAO (2008).

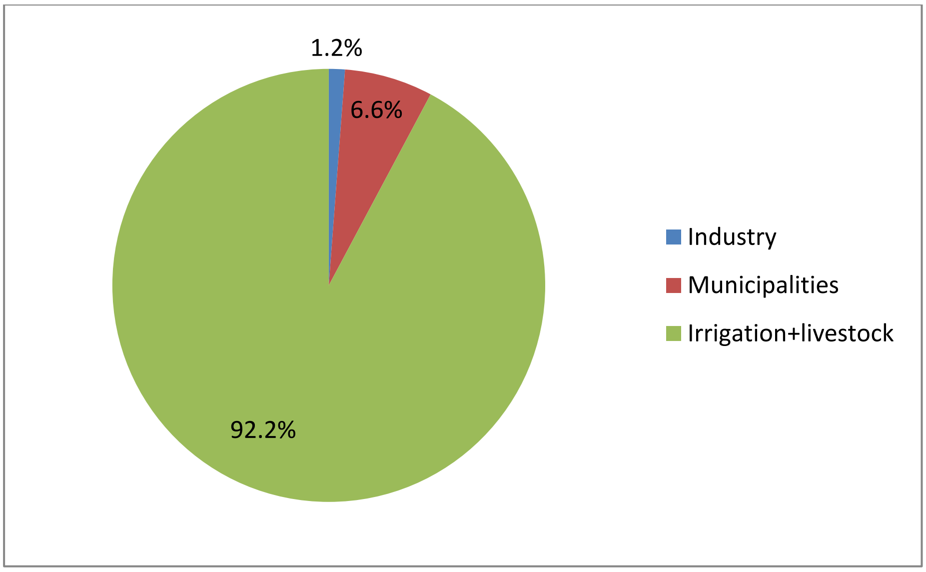

Figure 8. Iran irrigation practices in 2003. Data from FAO (2008).

As in all of Iran, agriculture in Lake Urmia basin is managed at the farm level. The irrigation water system in Lake Urmia basin is constructed using traditional practices in most farms and many of the farms in the region tended to be small, with walls around the fields. The agriculture cultivation is supported by rainfed agriculture and irrigated agriculture. The required irrigated water mostly pumps out from ground water or from the surface water. The data collected from Agriculture Jihad Organization (2011) shows the expansion of irrigated agriculture in last two decades in two provinces East Azerbaijan and West Azerbaijan (see Table 5 and Figure 9).

Table 5. East Azerbaijan and west Azerbaijan agricultural land for period 2007-2009. Data from Agricultural Jihad Organization, 2011

Year	Irrigated land/ha	Rainfed land/ha	Total land/ha
2007	682,834	1,128,046	1,810,880
2008	1,221,177	1,221,177	2,442,354
2009	1,633,719	1,221,177	2,854,896

As can be seen (Table 5) total agricultural use of land increased in both East Azerbaijan and West Azerbaijan. The proportion of rainfed agriculture land has declined since 2007 in both side of the Lake Urmia and stay in same level in 2007 and 2008. However, the irrigated agricultural land developed significantly. Also, (Figure 9) compare trends in irrigated agricultural land expansion for East Azerbaijan and west Azerbaijan.

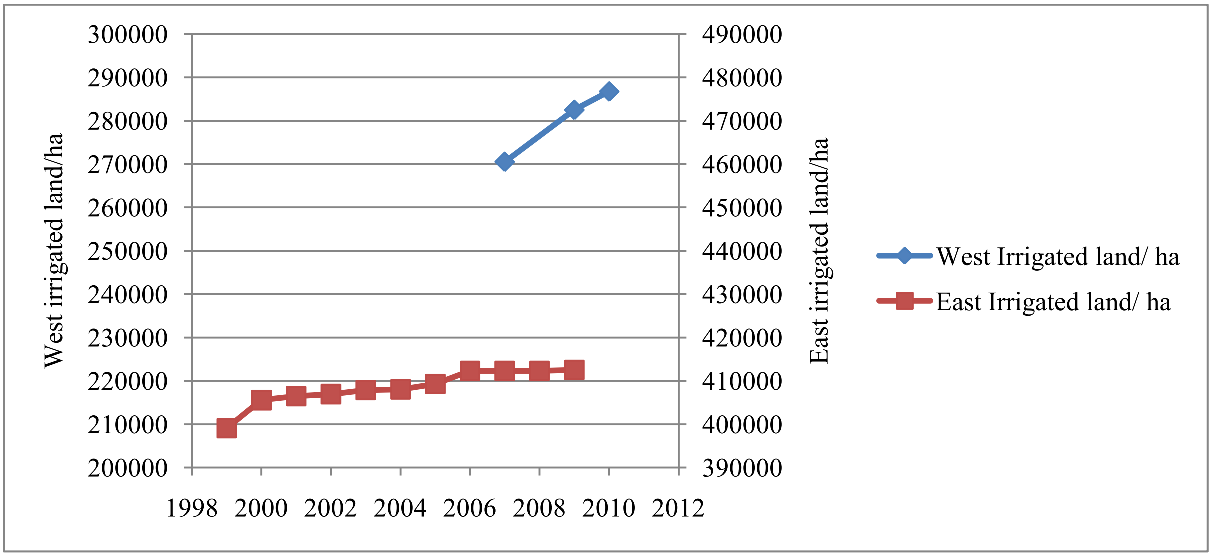

Figure 9. East Azerbaijan and West Azerbaijan agricultural land, Lake Urmia Basin. Data from Ministry of Agriculture (2011).

According to Hoghoghi (2011), the total irrigated land in Lake Urmia basin in the 1979 was about 150,000 hectares and reach to 400,000 hectares in 2006 (Table 5). The total agricultural land in the three provinces East Azerbaijan, Waste Azerbaijan and Kurdistan expanded as well. Meanwhile, the groundwater withdrawal increased from 1.8 billion cubic meters to 5.5 billion cubic meters (Hoghoghi, 2011).

During 1979-2006, considered as an agricultural boom in the region and in the whole country, the total agricultural land in three studied provinces had expanded from 417,000 hectares to 879,000 hectares from 1979 to 2006. Thus, all the provided data in the reports shows the agricultural land development is significant, but there are some discrepancies and the figures that are reported (compare with Figure 11).

Table 5. The expansion of agricultural land in last two decades in the West Azerbaijan, East Azerbaijan and Kurdistan (Hoghoghi, 2011)

	Region total agricultural land/ha	Irrigated land/ha	Irrigated land in basin/ha
1979	417,000	158,000	150,000
1990	765,000	306,000	N/A
2006	879,000	415,000	400,000

6.2 Wetlands

Wetlands provide a number of ecosystem services (e.g. provisioning, regulation, cultural, and supporting) that contribute to water supply, water purification, climate regulation, food regulation, costal production, recreational opportunities and tourist interaction. Due to importance of wetlands' role, wetland management is associated with human well-being (Millennium Ecosystem Assessment, 2005). In many countries, population growth and economical development could be considered as potential driver of wetlands degradation. Also, expansion of agricultural land leads to major wetland loss. In many countries irrigation is potentially considered as an effective tool to increase agriculture productivity and employment, or more generally as socio-economical development. Hence, in the regions where the agricultural sector could be considered as a major threat to the wetlands, a plan for the sustainable use of wetlands and their resources, to improve human well-being, is required (Millennium Ecosystem Assessment, 2005).

7. Results and recommendations

The increasing demand for water, and issues of water scarcity or reduced water access, are becoming major economic development challenges for societies and increase the global attention on policymakers to seek sustainability in water consumption (Loucks, 2000). This report strives to define the existing problem and seek for feasible solution in the Lake Urmia Basin, which is faced with water shortage due to human activities and drought. This section presents the impact of main drivers of environmental problems in the Lake Urmia Basin and discusses some challenges and existing problems and uncertainties. Also, the section offers some solutions from other existing cases around world and lessons from their experiences toward better water management.

7.1 Recent management plans for Lake Urmia Basin

There are several factors that can explain the dramatic reduction of water inflow to Lake Urmia from mid 1990s. Human impacts (economical and social development along with increased agricultural production) have hand in hand with natural impacts (periods of significant drought) in the region led to lower flows to the lake. To meet the serious water scarcity challenge in Lake Urmia, the government identifies several technical and institutional measures, the "Integrated Management Plan for Lake Urmia Basin, 2010," prepared in cooperation with governmental organizations, NGOs and the local communities of the Lake Urmia Basin. Several reports, such as the Yekom Consulting Engineer report (2005), Integrated Water Resources Management for Lake Urmiyeh Basin by Pandan Consulting Engineer (2005) and several other reports by the Ministry of Energy, organizations and scholars, have attempted to identify the problems and propose key solutions. At present, there are potential solutions that need to be effectively carried them out by decision makers.

The cooperation between Department of Environment, UNEP and gef in Conservation of Iranian Wetland Project has proposed the Integrated Management Plan for Lake Urmia Basin with the goal "*To establish an ecosystem based management for the lake and its satellite wetlands within the context of all stakeholders including local communities*." The Integrated Management Plan for Lake Urmia Basin has identified a 25 year vision for Lake Urmia Basin with three main objectives:

1. *Public awareness and participation for preserving Lake Urmia Basin and satellite wetlands.*
2. *Sustainable management of water resources and land use*
3. *Conservation of biodiversity and sustainable use of the wetlands resources*

7.2 Effect of agriculture and dams on the lake water balance

The decreasing inflows from the main 17 rivers could be because of the expansion of agriculture land. Figure 9 shows the development of the agricultural land in the East Azerbaijan over last 10 years and West Azerbaijan in the last 3 years. In fact, the expansion of agricultural land in the three provinces located in the basin has a great impact on the lake water balance. As shown in Figure 5, there is a decreasing water level and water inflow trend from 1990s. The large scale water demands for human purposes increased water withdrawal from the rivers and groundwater and also increase water diversion for irrigation and other purposes. This is exacerbated by drought condition in some periods, which altogether have an impact on the lake water balance. Indeed, the SIAP and SPI analysis (Yekom consulting engineers, 2005) shows (see A8 and A9 Appendix 1) that during the period 1998-2001, the Lake Urmia basin was faced with a moderate to extreme drought. Despite the water inflow peak in 2002 (Figure 5) and the greater than average precipitation (Figure 2), the lake could not recover from the depleting trend.

Agriculture, industry and infrastructural development could have consequences on the environment of the region and also on the Lake Urmia water balance. Dams have a significant role in controlling water reserves in Iran, and water resource development plans in Iran are mainly focused on regulating and controlling (FAO, 2008). Dams have been built as infrastructure and a number of dikes have been built as agriculture expanded in the region. The infrastructure of dams and dikes and other development drivers are considered as contributors to significant degradation and loss of inland wetlands and species (Millennium Ecosystem Assessment, 2005). Dams interrupt the connectivity of river system and change the ecosystem by biodiversity defragmentation such as disturbing fish spawning, migration and habitat loss on species. In addition, dams with large reservoirs change the seasonal flood regimes which alter the accumulation of sediments required for agriculture productivity (Millennium Ecosystem Assessment, 2005).

The location of dams in the Lake Urmia basin is illustrated in Appendix 1, Figure 10. Data on dams have been provided in the Yekom report (2005) and Iran Integrated Water Plan (2012) and includes diversion dams, storage dams and their operation, providing a clear history of the terms of operation and complete construction time. Zarine Roud (Shahid Kazemi) and Mahabad dams were constructed during 1970 and 1969, respectively, on the Mahabad and Zarineh Roud rivers. These rivers discharge to the southern basin of Lake Urmia in Kurdistan province and have the highest proportion of water inflow to the lake. Alavian (see Figure A12 Apendix 1) on Sofi Chai and Hassanlou (see Figure A13, Appendix 1) on Godar Chai were completed in 1994 and 1999, respectively.

Since the 1990s, a number of dams have been completed or are under operation. However, the outcomes of dams in terms of operation and complete construction time are less clear. Yekom report (2005) divided them to 6 existing storage dams, 10 existing diversion dams and 29 storage dams under construction or planning to be constructed. The Iran Integrated Water Plan (2012) report provides the number dams as 23 planning to be constructed, 4 operation and 5 complete dams. However, in the Ministry of Energy (Water Recourses and Development Plan Institute) website the number of completed dams including storage and diversion dams and dikes is noted as 48 dams and number of planning to be constructed dams 41 and 10 operation dams.

Figure 10. Mahabad Dam (Aziz Nasuti, 2012)

7.3 Agricultural practices in Lake Urmia Basin

The agriculture cultivation in the basin is supported by rainfed agriculture and irrigated agriculture. Irrigation is operated independently in separated basins, and water withdrawals from separate sources by electric pumps is based on time sharing or ”the water delivery time” (FAO, 2008). This water allocation is based on farmers’ irrigation water right which is usually based on their land area. The irrigation network starts from reservoirs with stored water and were usually built for irrigation development. Note that in most cases the primary and secondary canals are with good construction but the rest are built by land owners with little knowledge of proper construction methods and they could easily collapse and should be rebuilt during the time (FAO, 2008). Therefore, water conveyance over long distances by open cannels is a primitive distribution system and evaporation is responsible for much water loss.

As can be seen, irrigation has increased in both West Azerbaijan and East Azerbaijan, therefore the water availability in the downstream areas has been severely decreased. The expansion of agricultural land after the hydrometric stations could be considered as one of the major problems to estimate the amount of water inflow to the Lake (Yekom Consulting Engineer, 2005). Water discharge from the rivers and canals are also a problem, and the recent droughts in the region have had significant impact on rivers inflow and lake water balance. For instance, in recent years there is no water flow into the lake from the Mardogh Chai River after Baba roud station (Yekom Consulting Engineer, 2005).

Supporting services provided by wetlands, have vital role in recycling, treating and detoxifying a variety of pollution and wastes accumulation. Also reduce nutrient concentration specifically nitrite (Millennium Ecosystem Assessment, 2005). Irrigating agricultural lands could be a major cause of the rapid depletion of the Lake Urmia in parallel with natural changes. The poor drainage system and overexploitation and contamination caused by nutrient loading from agricultural products such as fertilisers and pesticides from the farms to the rivers due to the overapplication of these chemicals. Hence, the low inflow in the rivers increases the accumulation of chemicals and salinization in the area and increases the pollution of surface waters, ground water and the soil system which may adversely affect the health of human beings and the ecosystem. In addition, several dikes in the basin might reduce the water flows and the low water inflow to the lake from rivers and canals, caused by the overuse of water or natural process (drought), might lead to the accumulation of large amount of chemicals around the farms. Increasing the amount of these chemicals increases the threat to human health in the local level and enters into the agriculture cycle and food system at the larger scale. Moreover, this situation is exacerbated due to the poor irrigation practices and this will damage the soil and lead to salinization (Cai et al., 2003) .

7.4 Planning for water distribution

The Lake Urmia basin with widely different agricultural production requires an irrigation scheme to improve productivity and efficiency. The agriculture sector is a high water demand sector and a good irrigation plan is essential to achieve sustainable agriculture to some extent, since irrigation is seen as beneficial by farmers.

7.4.1 Water and sustainability

The concept of Sustainable Development by Brundtland in 1987 has become the target for managing the natural resources: "*The development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" The Brundtland commission thereby opens the dialogue that there should be a balance between economic development and preservation of the environment. The challenges facing water resources such as the impact of climate change, growing population and so on, increase the necessity of accurate management of water resources. The concept of Sustainable Development contributes to achieve environmental sustainability and helps to achieve the resilience in complex systems (systems which human and nature are interacting with each other) (Muller, 2009). The objective is not the development of water resources on its own, but also development of water resources to support the development of human well-being. To succeed at this, sustainability in water resources strategies should developed from the outside of water sector, such as the development of infrastructure, the allocation water resources to financing arrangements, and the effective use and protection of water resources (Muller, 2009).

The purpose of sustainable water management is to ensure a balance between available water, development and the management of water supply and demand. Indeed, regarding the impact of climate change on water resources, the IWRM concept (see section 4.3) could be considered as an adaptive policy to address the broader social challenge of water resources management as a limited common good, which all societies are dependent on. Agricultural systems and practices have significant impact on ecosystem, and irrigation in some regions is the primarily tool for increasing productivity. In fact, better water management could bring environmental benefit as well as socio-economical benefits and the expansion of agricultural land, development of agriculture system should not conflict with the environment. Therefore, the two main goals that could be achieved by sustainable irrigation water management are food security and preserving the natural environment (Cai et al., 2003).

7.4.2 Problems and suggestion in Lake Urmia basin

Poor irrigation management arises from a lack of good knowledge of irrigation or from ignoring the recommended agricultural practices, since the farmers' agriculture practices are independent of each other and most of the times have a low level of technological sophistication. According to the local authorities and experts, farmers are not aware of the impacts of their practices and most of the time they follow their preferences and benefits. For instance, if one of the crops like sugar beets is profitable in West Azerbaijan, most farmers in the next harvesting year are willing to cultivate sugar beets (Interview findings, July 2011). This could lead to the overuse of pesticides and fertilizers. There is no evidence of efficient drainage management in the basin, the water pollution such as pesticide and fertilizers as well as industrial and domestic waste end up in the streams and rivers without treatment (Eimanifar and Mohebbi, 2007). The possibility of water treatment in the basin could prevent the accumulation of harmful toxic from pesticides, fertilizer and domestic industry. In Lake Urmia, the high level of nutrients and the low water inflows to the lake will causes algae blooms throughout the rivers, streams and the lake in the long run. In the last two years, the algal blooms on the lake surface have made the lake red colored in some areas (Figure 11). Agriculture wastewater treatment is a possible adaptive policy to remove the threat and hazard of toxic compounds in the water that may be harmful for the natural environment and agriculture production. However, the treatment should be economically feasible to some extent (Pereira et al., 2002).

Figure11. Lake Urmia and the appearance of red algae (Nahal Faramarzi, 2011)

Iran is one of the countries that pay subsidies for resource use, especially water resources. The significant subsidies for irrigation in the last decades could be one of the reasons of mismanagement. The cost of irrigation water in 1995 for 1000 m^3 delivered to the farms by the government was about 0.2- 0.3 US dollar and for groundwater withdrawal was about 5-9US dollar (FAO, 2008). However, from March 2011 the subsidies were removed to encourage the individuals and organizations to efficiently use the resources. Thus, we should consider that valuing the water as an economic and marketable good could not be adequate to some extent, as water resources support human well-being and provide ecosystem services (Millennium Ecosystem Assessment, 2005). The low price for water resources increases the misuse of available water, according to the economic theory; *farmers who pay next to nothing for water have no incentive to use it efficiently* (Ray, 2007). One of the feasible adaptive policies in the Lake Urmia basin is the application of water pricing and tax penalties according to the economical value of this vital resource in the region. This would help to minimize water misuse and illegal water use, and monitoring the implemented policies to avoid free riders problems will be required at the regional and farm level. Though, any abrupt removal of agriculture subsidies could highly affected farmers' incomes. Hence, agricultural subsidies could be allocated for development of the necessary strategies in sustainable use of water and land to achieve sustainable agriculture development. Furthermore, agricultural subsidies could be placed for preserving the ecosystem services provided in the catchments that could reduce the speed of the environmental degradation in the basin.

To assess sustainable irrigation in the Lake Urmia basin, the observation of the situation, needs, opportunities and problems are required. Challenges that lie ahead of Lake Urmia as complex system require one to look backward to evaluate the connection of nature and society, and look forward to apply feasible adaptable policies. In the absence of some practices to achieve better water management in Lake Urmia Basin, adaptive policies and strategies might be taken in the context of the legislation in social behavior, economics, and technical issues at the national and regional level (Millennium Ecosystem Assessment, 2005).

7.3.2 Policies for water scarce situations at the farm level

To achieve sustainability in irrigation management, decisions at the farm level of management should be considered. Policies which have been proposed by Pereira et al., (2002) can reduce the water demand at farm level hence, required water well distributed during the growing season. The farmer's participation in their practices and governance benefits social, economic and environmental outcomes. There should be several objectives for water management at the farm level:

- The objective to reduce the demand in irrigation water by reducing the irrigation requirements by adaption of practices and policies. Primarily, in the region faced with water scarcity, changing the crop pattern from high water demand to the lower demand could be applied. In addition deficit irrigation, as provided by English and Raja (1996), is a watering strategy that could be applied to the crops in a water stress situation where crops are deliberately allowed to sustain to some extent of water deficit and yield production. The high performance irrigation system requires development of efficient irrigation system based on the farm and crop field (Cai et al., 2003).
- The objective of water saving and conservation is directed to cultivation practices for minimizing water stress. Treat the drainage water and reuse run off flows. Preventing soil erosion and evaporation by applying surface mulch.
- The objective of a higher yield per unit of water with a deficit strategy which maximizes crop yield based on water instead of land by improving farming practices such as fertilizing, pest and disease control and avoid cultivating crops at critical times.
- The objective of higher farmer income by selecting crops with a high quality of production and income return.
- The regular agricultural scheme prevents the accumulation of hazardous substances from pesticides and fertilizers in ground water and decreases soil erosion. The best time to apply fertilizers, before sowing and before flowering, has to consider (Björklund, 2006).
- The objective of regulating land for surface irrigation and furrow irrigation depending on the slope of the land.

7.3.3 Policies for water scarce situation at basin level

In Lake Urmia Basin, the upstream agricultural water withdrawal from rivers contributes to declines in water level and shrinking surface area of the lake. To achieve sustainable water management at a larger basin scale, water resource pressures and drivers should be identified and decisions should be made in the context of sustainability principles. The objectives of several suggested policies are outlined below:

- The objective is to maximize the use of available water mainly by preventing the losses of useable water to evaporation, requiring an inspection of the canals infrastructure. Ground water management is also needed. For example, the Angas Bremer irrigation district in Australia successfully applied local ground water management as policy. Licensing tools could be applied to control ground water depletion and monitor the users in such way that users should report their consumption and the level of ground water table according to a schedule (Muller, 2009).
- The objective is to improve the economic value of water with the reasonable cost in the local level and impose a tax penalty for illegal water misuses and free riders
- The objective of crop pattern change as an adaptive policy to improve the crop husbandry in the regions faced with water scarcity to minimize water losses
- Improve environmental legislation to prevent wetland degradation in the context of sustainability principles
- Regular control and investment in the operation and maintenance of water resource systems in the basin
- Reduce the loss of nutrients through excessive irrigation since irrigation is an important tool to manage the plant nutrient. Irrigation can also lead to water logging and affects the plant's ability to take up nutrients and renders it more susceptible to pests, insects and diseases.
- The accurate irrigation schemes increases the water availability in the downstream, and prevent the conflicts among the farmers for water withdrawal. Since with unsustainable water withdrawal, the basin would lose its resilience.
- Genetic engineering could increase resistance of cultivated crops to pest and drought and be competitive to weeds. The positive aspects of genetic modification can reduce the use of the amount of chemicals and lowering the chemical pollution in the soil, water and air. This helps to reduce the accumulation of chemicals in the surface water and ground water.

The growing population and urbanization increase the food demand at the national level, and the number of population and the speed of population growth are two components which we should consider. The link between water supply and demand and, especially, water supply and food security strongly require the implementation of a sustainable irrigation water management in the country (Hanjra, Ejaz Qureshi, 2010). To determine the sustainability of water resources, the stakeholders and drivers should achieve the optimum economical growth, social equality and environmental sustainability. To improve water management in Lake Urmia Basin the support of policies and strategic framework at the regional and national level is needed. EIA (Environmental Impact Assessment) could be applied for all environmental policies and decisions to prove if they are applicable or not. The effective governance policies in the national and regional level should be accurately applied to the basin level. The offered practices and policies for the specific problems and development consequences are sound adaptive and integrated approaches to improve water management. The process of water resource management might have changed as we are challenged with complex systems and frequently we should seek new opportunities and solutions.

8. Conclusions

Lake Urmia has been shrinking in surface area and the lake water level has been declining continuously in recent years. In addition, and water salinity is increasing as the result of natural and anthropological drivers in the last two decades. These changes in the lake system have resulted in water scarcity that is challenging in the Lake Urmia basin. The growing stress on Lake Urmia and challenges on the water resources in the basin could easily become a crisis and this socio-ecological system could lose its resilience.

To reach sustainable water management in the basin, comprehensive policies and strategies should be implemented to alleviate the process of degradation. Consequently, for an optimum achievement in water management, we should improve our understanding of the water resources system and improve tools for understanding components of the basin. Lessons from similar cases in the world and their experience to achieve water resources management could be useful.

Despite the importance of monitoring the water use, especially groundwater, unintentionally has not been supported appropriately. The knowledge from different disciplines as well as stakeholders' participation facilitates this target.

Irrigation is one of the important components of sustainable agriculture. Hence, to reach sustainable agriculture water management and building resilience during the time period in basin the sufficient information and knowledge to improve irrigation techniques, agriculture practices and market demand should be considered as adaptive strategies. However, unorganized data on water resources and agricultural land in Lake Urmia Basin are a big obstacle to guide water allocation and planning.

Sustainability in the Lake Urmia basin should be developed at the farm, river basin and at a bigger scale at basin level with social, economical and environmental perspectives to balance the supply and demand management. The loss of Lake Urmia and its unique ecosystem could add to the Aral Sea catastrophe in the region. Consequently, the health problems, child mortality and small family farms would be threatened by both low productivity and incomes which could increases the number of people that migrate from rural to the urban locations, seeking for jobs and accommodation.

The considerable expansion of salt land in Lake Urmia bank in the west and south of the Lake Urmia may have further consequences such as intrusion of salt to the underground aquifers. Also, salt storms in the region have social consequences, similar to those experienced around the Aral Sea.

Particularly in Lake Urmia Basin, population growth and socio-economic development increase the stress on common and shared resources, water, to promote human well-being. Hence, building resilience to the current problems (water level decrease, salinity increase and algal blooms) which Lake Urmia is facing in the heart of Lake Urmia Basin as complex system through sustainable strategies, adaptive plans and transition to practices that increase water inflow to the Lake, control and mitigation of algal blooms and reduce the nutrient loading to the Lake could help Lake Urmia basin to function as it should function. In this process we need to understand how our water use practices effect water resources system and how we can build up partnership among actors and cooperation among stakeholders to save Lake Urmia Basin.

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Appendix

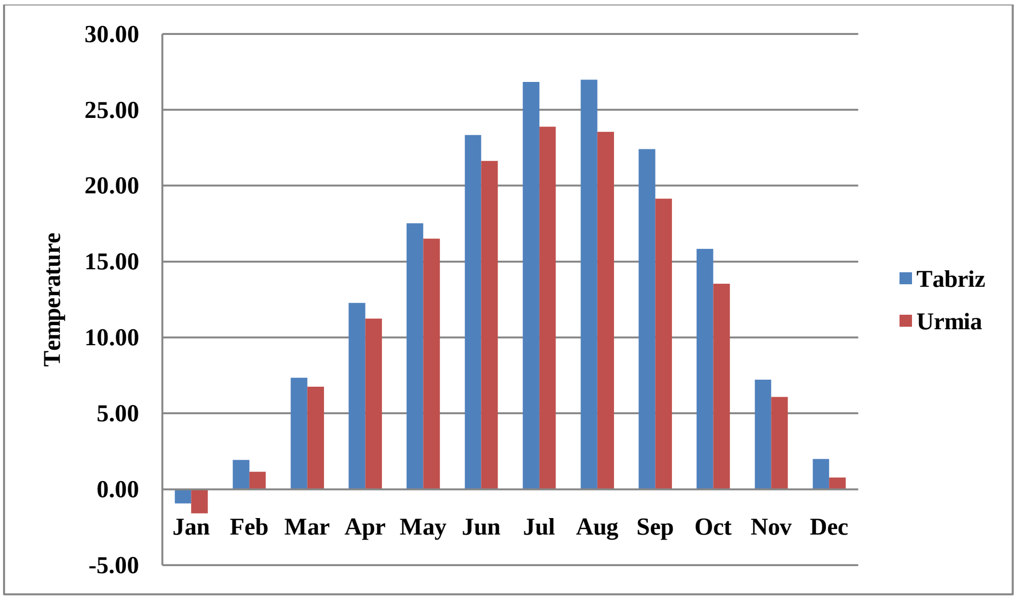


Figure A1. Tabriz and Urmia average monthly temperature for period 2000-2010. Data from Freemeto, 2011, Internet)

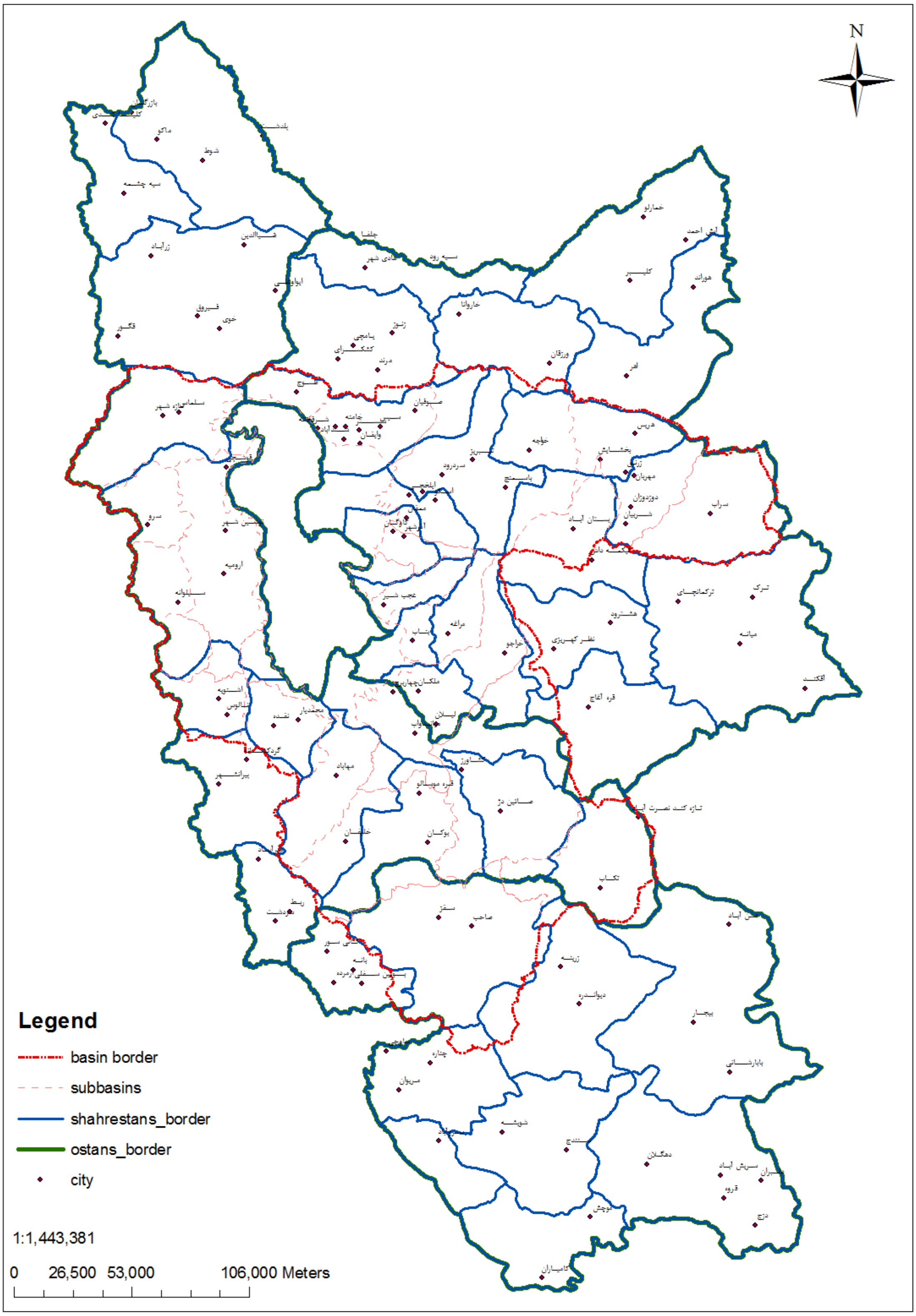


Figure A2. The map of Cities and provinces in Lake Urmia Basin Data from?

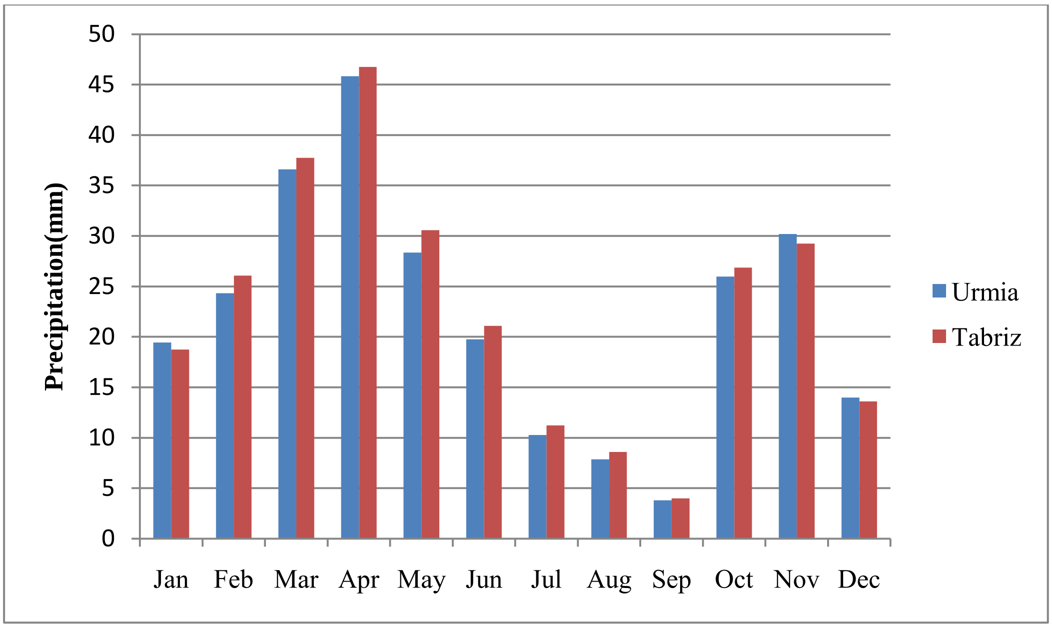


Figure A3. Tabriz and Urmia Average monthly precipitation for period 2000 – 2010 Data from Freemeto, 2011, Internet

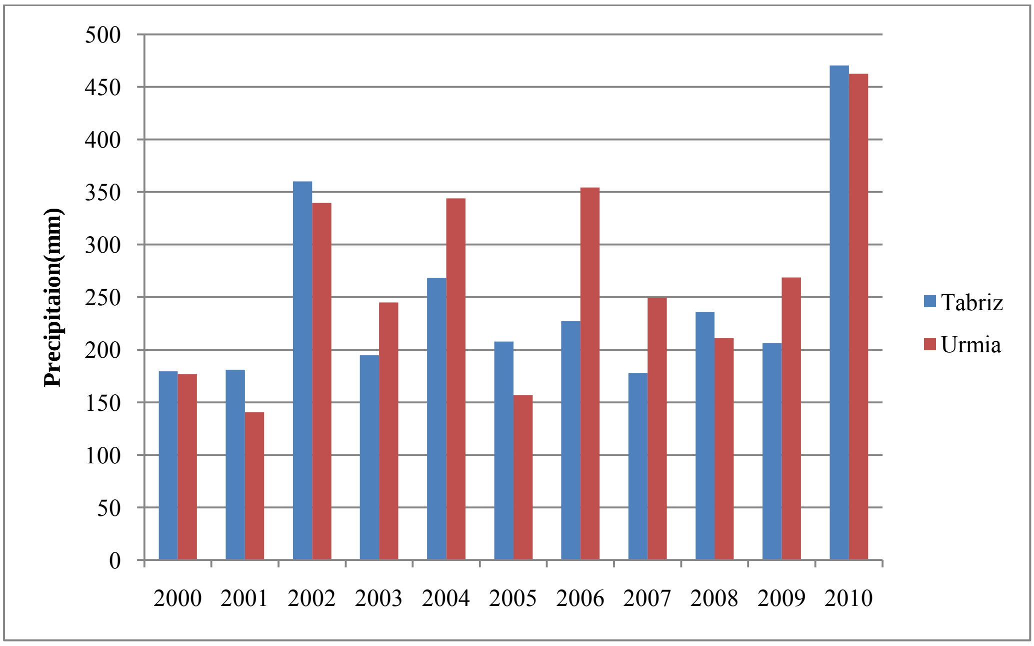


Figure A4. Tabriz and Urmia average annual precipitation for period 2000-2010. Data from Freemeto, 2011, Internet

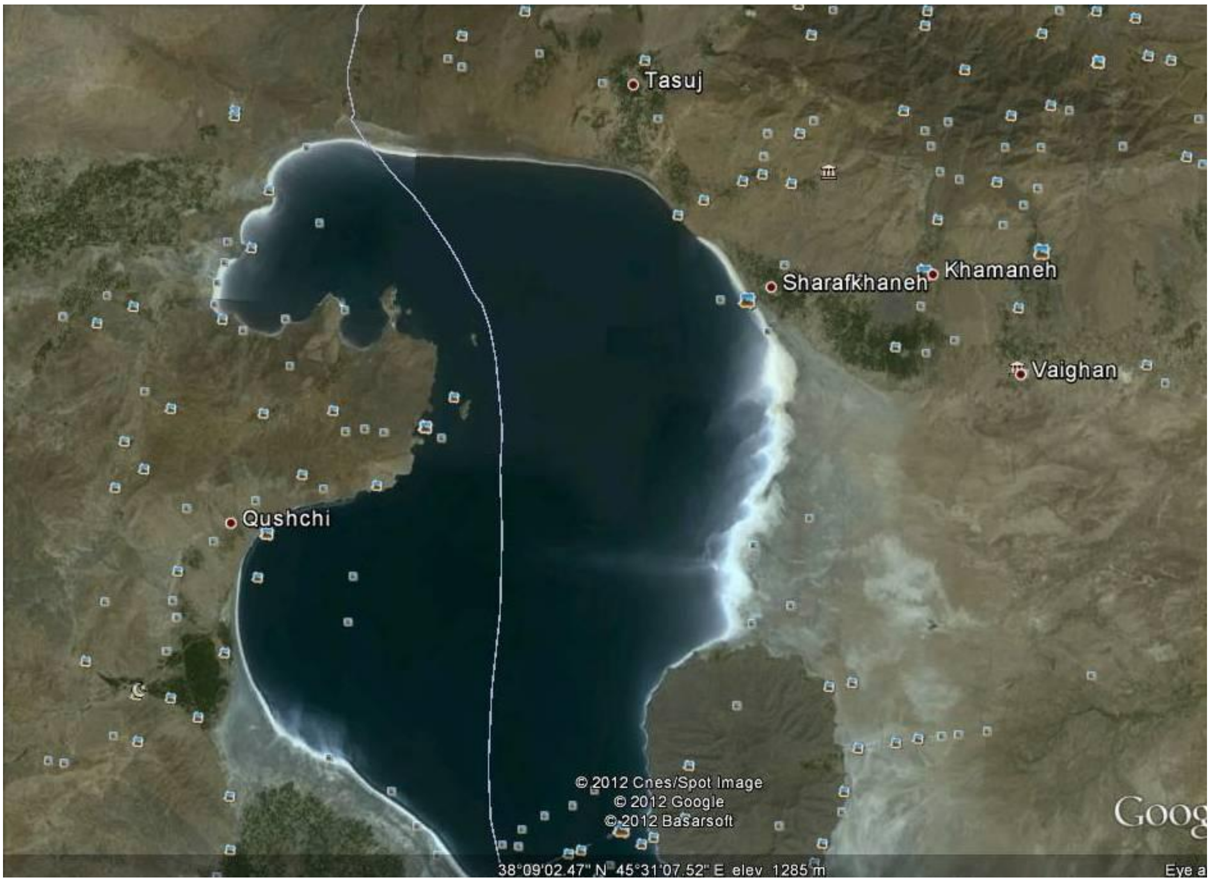


Figure A5. Sharafkhaneh Port Data from (Google Earth, 2012)

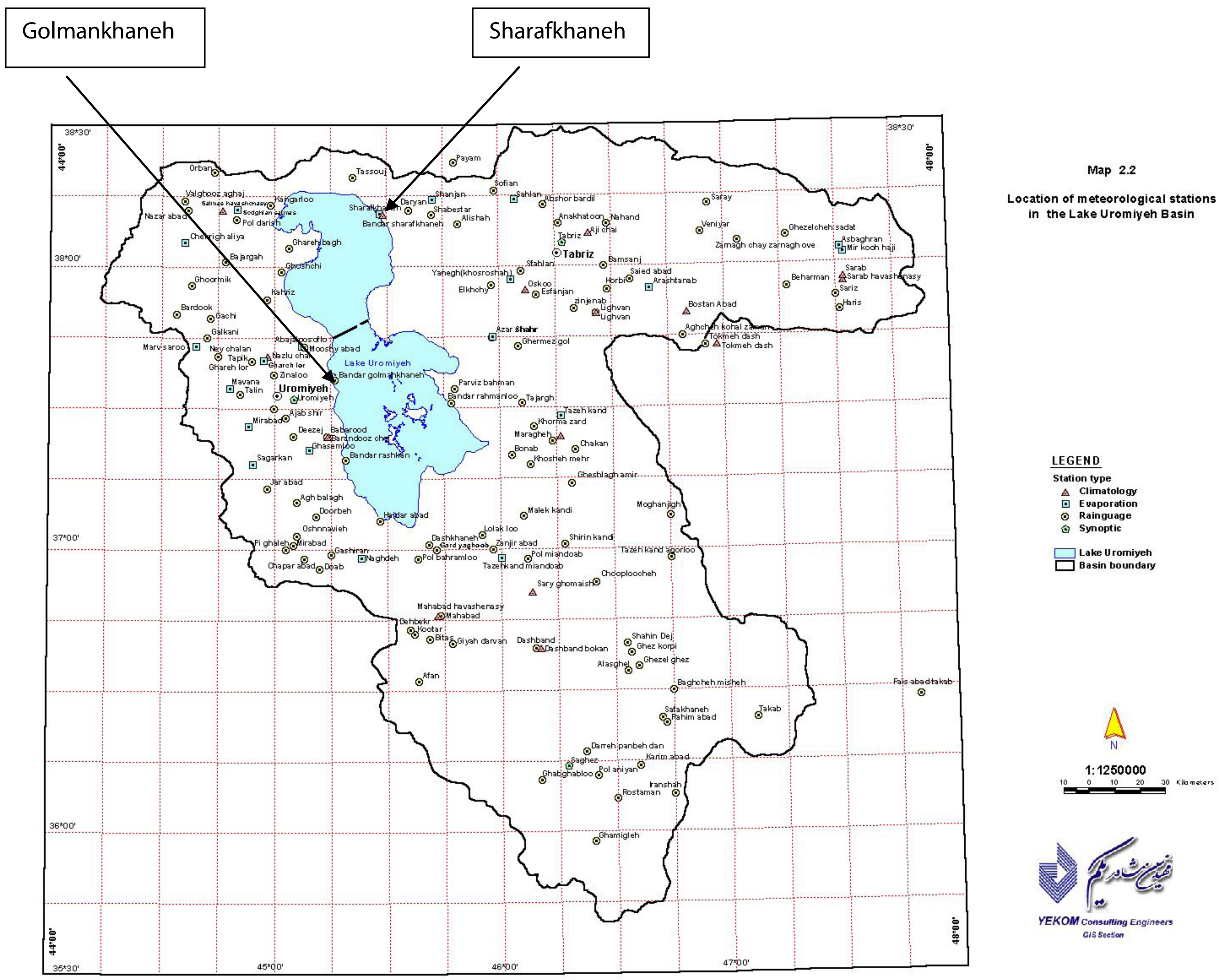


Figure A6.Golmankhaneh and Sharafkhane port Data from (Yekom Consulting Engineer, 2005)

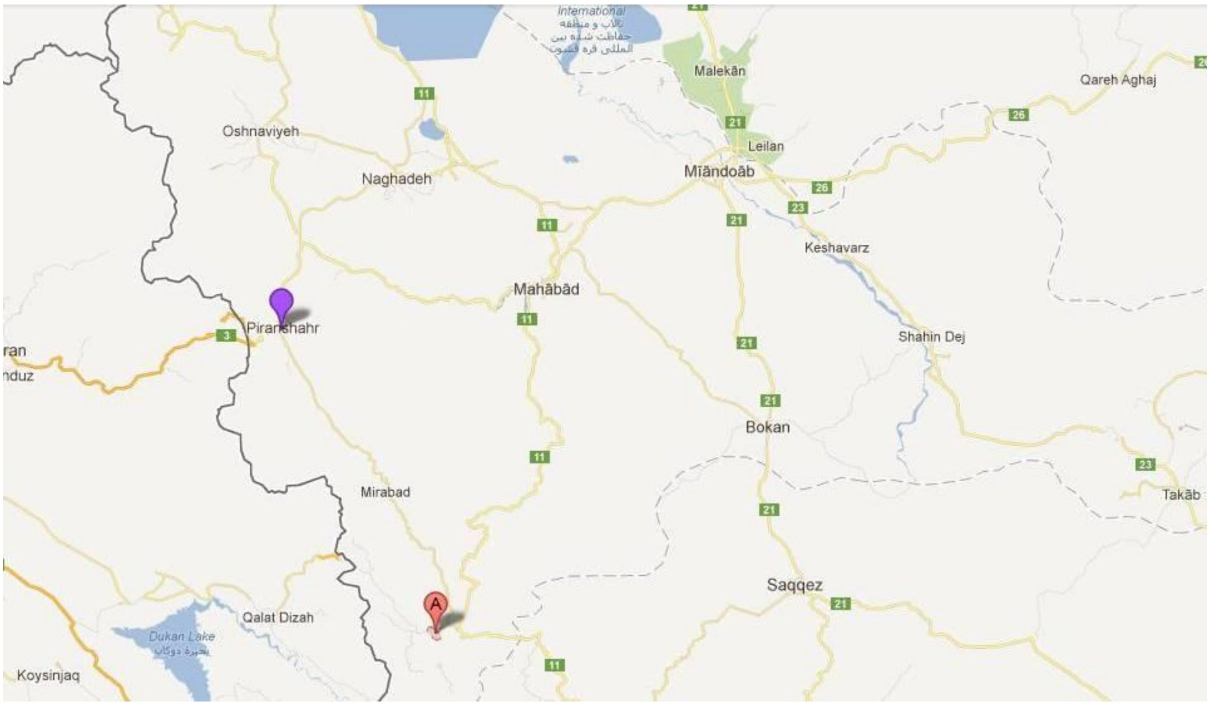


Figure A7. Piranshahr and Sardasht (location A) Data from (Google Map, 2012)

	SPI	Class
	2.0 or more	Extremely wet
	1.5 to 1.99	Very wet
	1.0 to 1.49	Moderately wet
	0.99 to -0.99	Near normal
	-1.0 to -1.49	Moderate drought
	-1.5 to -1.99	Severe drought
	-2.0 or less	Extreme drought

Table 1. "SPI drought severity classes for wet and dry periods" (McKee et al., 1993).

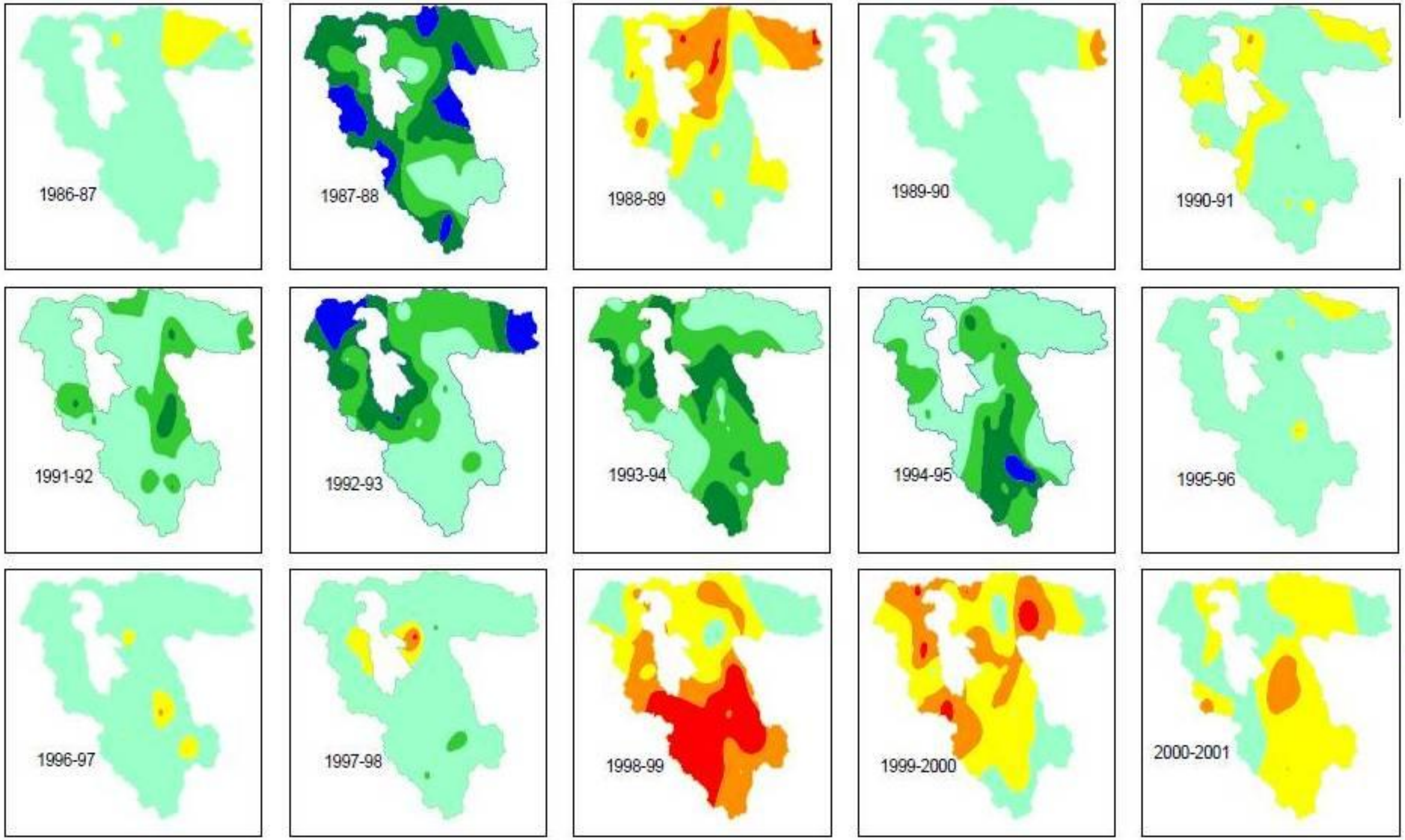


Figure A8. SPI analysis in Lake Urmia Basin(1986-2001) Data from (Yekom Consulting Engineering, 2005)

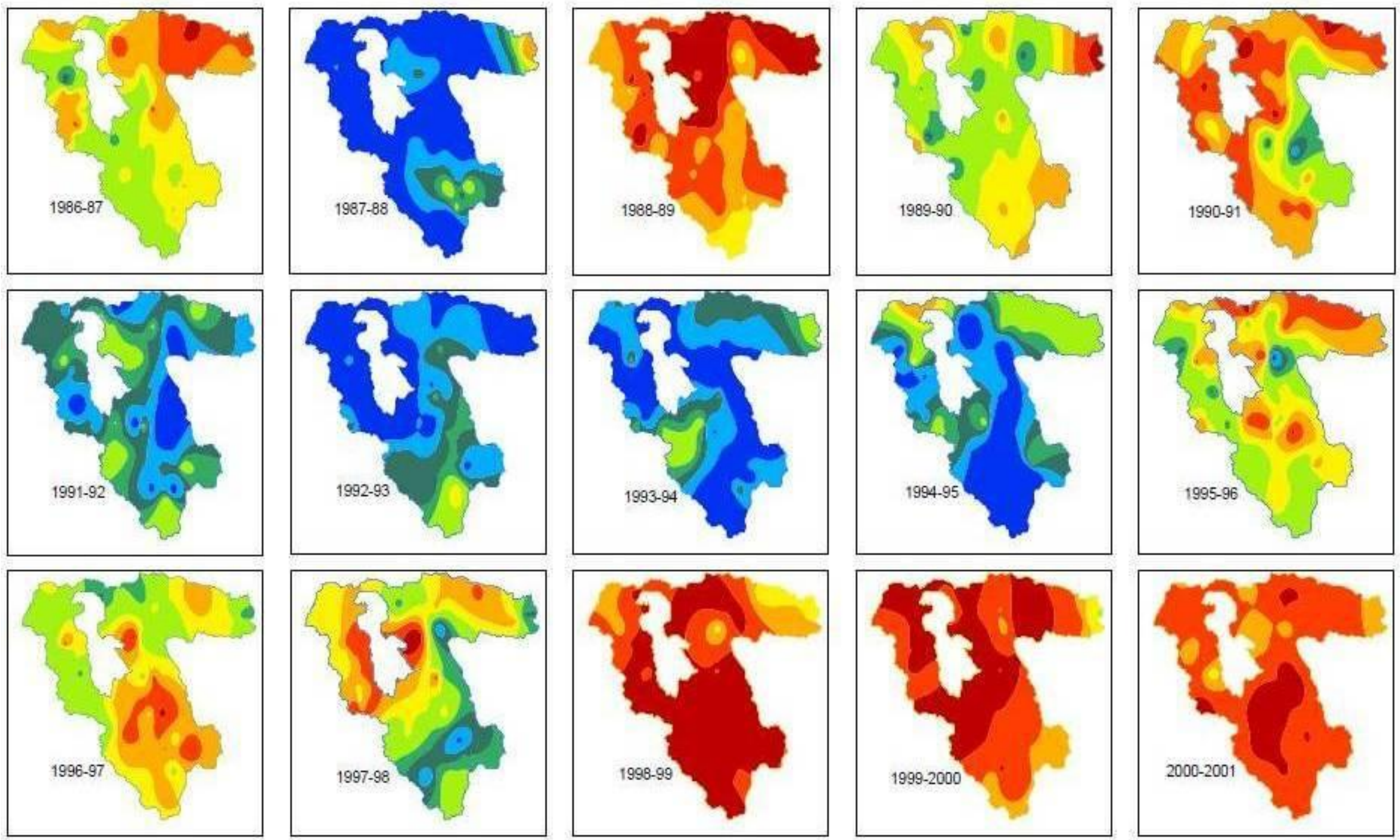
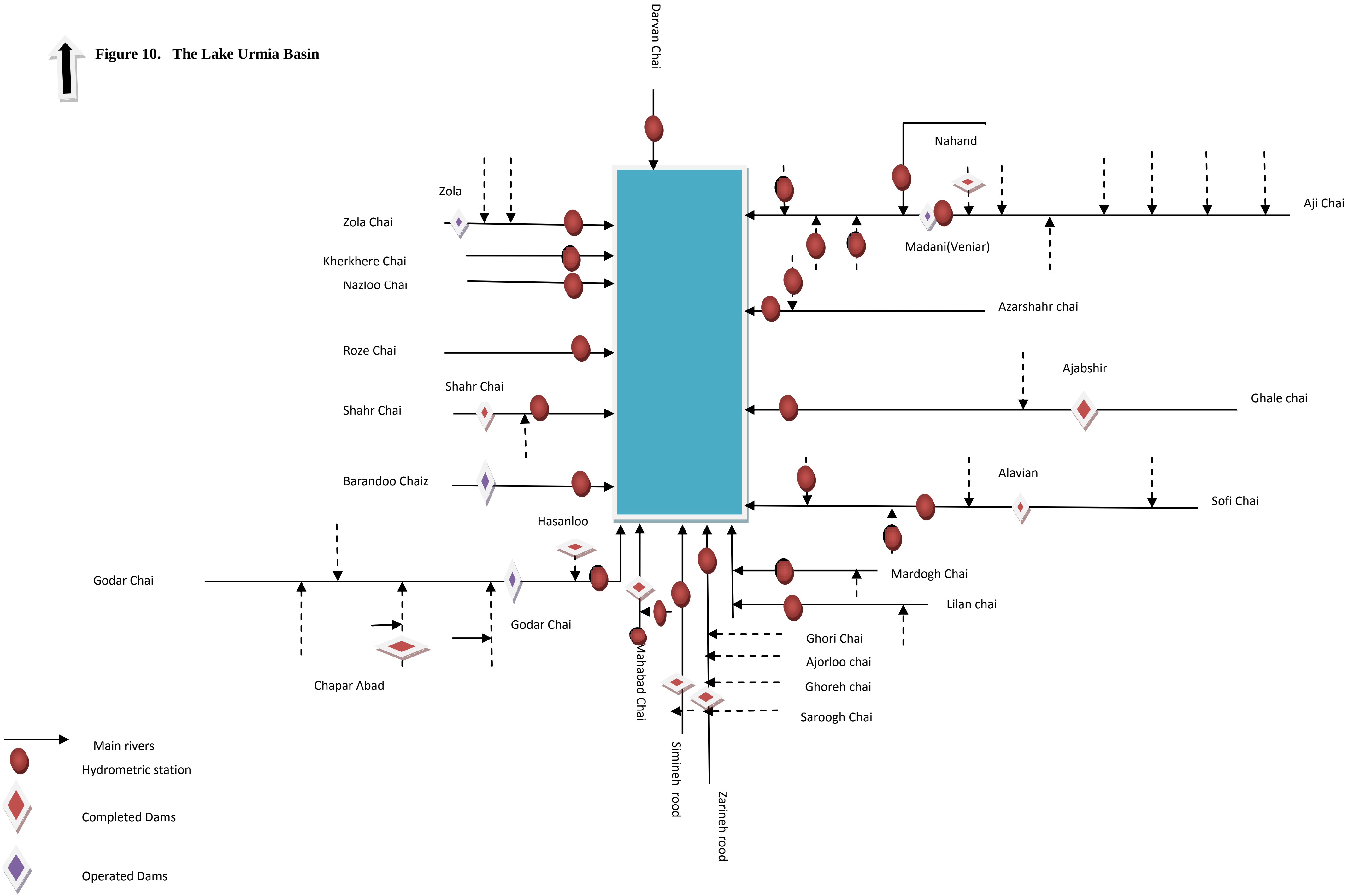


Figure A9. SIAP analysis in Lake Urmia Basin (1986-2001) Data from (yekom Consulting Engineering, 2005)

Figure 10. The Lake Urmia Basin



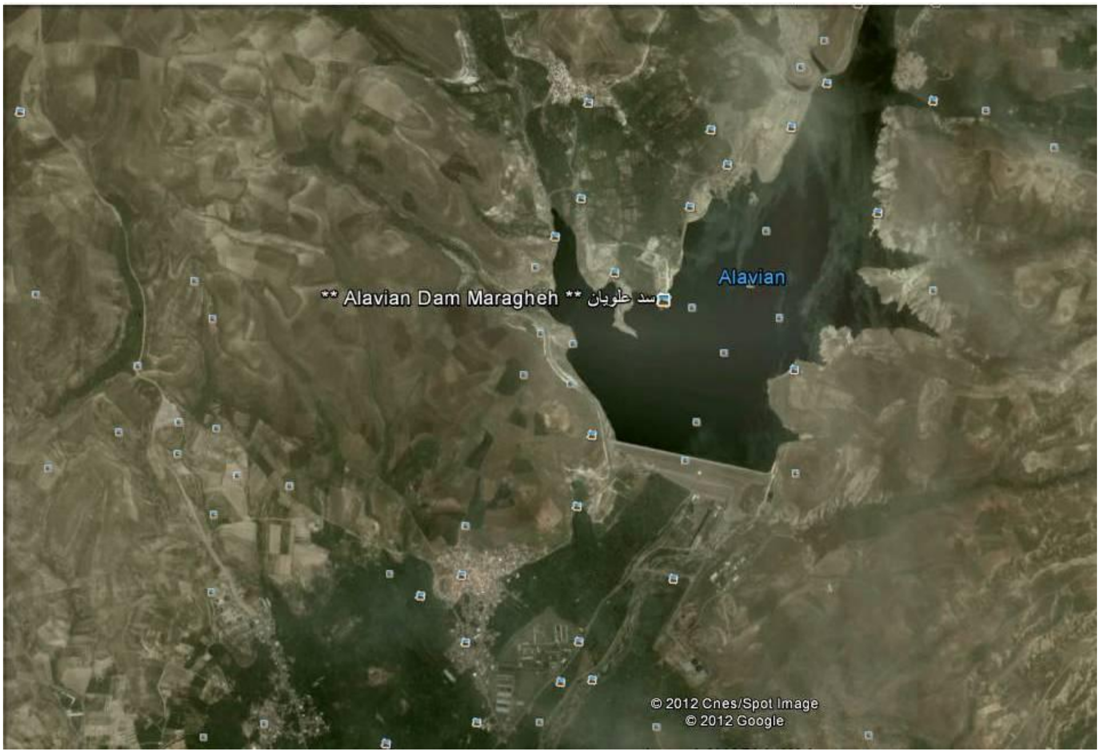


Figure A11. Alavian Dam Data from (Google Earth, 2012)

Figure A12. Hasanlu Dam Data from (Google Earth, 2012)