

Volume 9, Issue 2, 092511 (225-232)

Agricultural Marketing and Commercialization (AMC)



<https://doi.org/10.57647/j.amc.2025.090211>

From Crisis to Sustainability, the Application of the DPSIR Model in Water Resources Management of the Urmia Lake Basin Is Inspired by Global Experiences

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Original Article

Received:
2025-09-26

Revised:
2025-10-01

Accepted:
2025-11-11

Published in Issue:
2025-12-30

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Abstract:

Water is of vital importance to ecosystems and human societies. Global environmental, social, and economic changes, as well as evolving needs, have placed unprecedented pressure on water resources. It is argued that global access to water resources requires sustainable water resource management for future generations. The primary objective of this study is to design a model that promotes sustainability in water resource management for the Urmia Lake Basin, based on the DPSIR model and global experiences. This research is based on library data (literature review). The results of the lessons learned from other countries based on the DPSIR model include policies: water-intensive crops, wastewater control, promotion of sustainable agriculture, pricing reform, inter-basin water transfer, sustainable conservation of water resources, water conservation including: (reducing water consumption in agriculture, developing groundwater facilities, using reservoirs to store groundwater), water reclamation (desalination plants and recycled water) as effective methods in sustainable management of water resources in the Urmia Lake Basin.

Keywords: Water resources management, Sustainability, Urmia Lake Basin, DPSIR model, Global experiences

Cite this article: Chalabi, K., Omidi Najafabadi, M., Farajollah Hosseini, S. J., Allahyari, M. S. (2025). From crisis to sustainability, the application of the DPSIR model in water resources management of the Urmia Lake basin is inspired by global experiences. *Agricultural Marketing and Commercialization*, 9(2), 225-232. <https://doi.org/10.57647/j.amc.2025.090211>

INTRODUCTION

The water crisis in the 21st century will affect many countries in the world, and water will be the most important challenge for countries in this century. The lack of safe and drinkable water will be one of the most important problems for governments in the not-too-distant future (UN, 2024). The population of the world's continents is compared with the amount of water they have available, and the Asian continent has the largest population and will therefore face increasing water demand (Table 1). Almost half of the

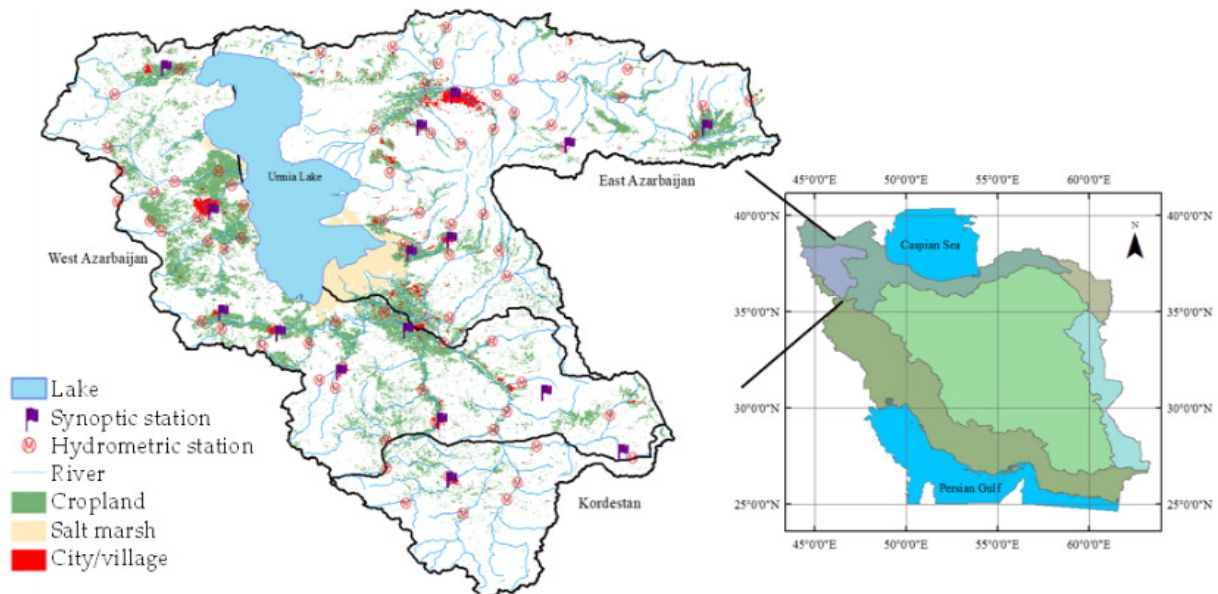
world's population currently faces severe water shortages for at least part of the year (IPCC, 2023). Water stress has important implications for social stability (Zaveri et al., 2021).

Urmia Lake is the largest inland lake in Iran and the second largest saline lake in the world, with a unique ecosystem that plays an important socio-economic and ecological role in the region (Ebrahimi Sarindizaji & Zarghami, 2019; Esmaeil Nezhad et al., 2021). The catchment area of this lake in northwest Iran, in the provinces of West Azerbaijan,

Table 1. Percentage of population and access to fresh water by continent

Amount of water available	Population size	Different continents
36%	60.5%	Asia
15%	7.3%	North America
5%	0.5%	Oceania
8%	11.3%	Europe
5.1%	7%	Middle East

source: (Mishra Binaya Kumar et al., 2021)

**Fig. 1.** Location of Urmia Lake Basin

East Azerbaijan, and Kurdistan, is about 51,876 square kilometers. (Hesami & Amini, 2016; Nasrollahi et al., 2021; Fig. 1) The agricultural sector accounts for about 30 percent of the jobs of the residents of the Urmia Lake Basin (ULRP, 2018).

In the Urmia Lake Basin, the potential of renewable water resources, including the total of renewable surface and groundwater resources, is considered the most important parameter and decision-making indicator in the management of water resources in each basin. The results of the surveys and analyses indicate a significant decrease in the volume of renewable water resources in the basin. Given the 18% decrease in precipitation, the potential of renewable water resources in the Urmia Lake Basin has decreased from 8875 million cubic meters to 7024 million cubic meters. Therefore, the volume of renewable water resources in the basin has decreased by about 1850 million cubic meters, equivalent to 21%. This decrease in the renewable water resources of the basin confirms that the management of water resources in the lake basin is facing a very serious challenge, and it is necessary to adopt and implement the necessary measures and arrangements to increase the efficiency in the use of limited water resources (West Azarbaijan Province Regional Water Company, 2024). The surface of Urmia Lake on 2 November 2024 was 850 square

kilometers, and its volume was 1.14 billion cubic meters. Its level in September 2024 was 1270.14 cubic meters, which is lower than in previous years, according to the table below (Table 2).

To conserve water resources, maintain production, and reduce negative environmental impacts, sustainable water management is essential (Carlisle, 2016). Sustainable water resource management is a process that involves the development and management of water, land, and other resources to maximize economic benefits and social services in an equitable manner, without threatening the sustainability of living ecosystems (Attwa et al., 2021). Accordingly, we need to use a model that can be used with an applied approach as a tool for decision-making and the development of management and executive programs. In fact, this method identifies and examines the causes of the phenomenon, the measures and policies adopted, and even those needed. In this study, we will use the DPSIR (Driving Force-Pressure-State-Impacts-Response) model to implement the research objective: Creating sustainability for the management of water resources in the Urmia Lake basin using global experiences.

LITERATURE REVIEW

The experiences of some countries in the field of water resources management are as follows:

Table 2. Water level of Urmia Lake

Level	date
1271.53	2020/3/19
1271.39	2021/3/19
1270.73	2022/3/19
1270.52	2023/3/19

source: (<https://ulrp.sharif.ir>)

Asia (Middle East countries (Saudi Arabia and Iraq), Asian countries (India and China):

Asian countries (China and India):

China:

Fu et al (2021) concluded in their studies that, considering that more than 60% of China's population lives in water-scarce sub-basins and there is high inequality in water scarcity between sub-basins, inter-basin water transfer is a solution used as a socio-economic-environmental approach that directly provides external water supply and reduces water scarcity in receiving basins. In general, inter-basin and intra-basin water transfer (especially from water-rich southern China to water-scarce northern China) reduces the spatial distribution of water demand and leads to a reduction in water scarcity inequality. About 53% of the population has benefited from the reduction of water scarcity in the receiving sub-basins.

Zhang & Oki (2023) concluded in their studies that, given the increasing consumption in the agricultural sector, the inefficiency of water resource use, and the low effective utilization rate of irrigation, the sustainable policy of agricultural water pricing reform, which is an economic approach, is used to optimally manage and save water resources and effectively irrigate. Therefore, the review of reform policies shows that the reform of agricultural water pricing in China has achieved significant results in saving water and increasing water use efficiency, which can inspire developing countries in the field of water pricing policy.

Lu et al (2019a); Tang et al (2022); Liu & Yang (2012); Wang (2012); Zhou & Liu (2018); Chen et al (2019) concluded in their studies that, due to water pollution, environmental protection policies, control of polluted water, wastewater and sewage are used to reduce pollution and protect the environment, which can affect sustainable social and economic development. For this reason, in 2005, China's national development strategy prioritized environmental protection over economic growth.

India:

Varma et al (2021) concluded in their studies that, due to water shortages in the summer season and the problems they cause for the livelihoods of the villagers due to their dependence on agriculture, they are forced to migrate. Hence, they are using water-intensive agriculture based on planting water-intensive crops using experiential learning methods, which is a socio-environmental approach, to provide water for irrigation.

Centre for Science and Environment (2023); Rainwater

Harvesting (2023) concluded in their studies that, due to water scarcity, it uses rainwater harvesting, which is a technological approach. Rainwater harvesting involves the collection and storage of rainwater and is a new technology in water policies that can be effective in reducing water consumption by impacting the environment. Harvested rainwater can be used for various applications, including irrigation and non-potable domestic uses.

Mahato et al (2022) concluded in their studies that, given the increasing demand for water in the agricultural sector, the method of promoting sustainable agriculture, which is an environmental approach and includes growing crops that are suitable for the climate, nature-friendly agricultural practices, indigenous and modified varieties, improving soil health, and protecting biodiversity. Farmers should be trained and encouraged to change irrigation (drip irrigation) and other water-efficient technologies; they help reduce water consumption.

Centre for Science and Environment (2023); Rainwater Harvesting (2023); Jena et al (2023) concluded in their studies that using water conservation schemes such as rainwater harvesting involves the collection and storage of rainwater and is a new technology in water policy that can be effective in reducing water consumption by influencing the environment. Harvested rainwater can be used for various applications, including irrigation and non-potable domestic uses. This project has been able to leave positive effects as a technological and successful approach to water balance with regard to the future of groundwater, including: Increasing groundwater through water recharge, minimizing soil erosion through water accumulation. Reduces the likelihood of flooding. Prevents drought. Improves groundwater quality by reducing salinity due to freshwater recharge. In coastal areas, seawater cannot be absorbed into the aquifers. Reduces the load on the stormwater disposal system. Through groundwater recharge, a large amount of water is stored without wasting land. Groundwater storage is environmentally friendly and safe.

Middle Eastern countries (Saudi Arabia and Iraq):

Saudi Arabia:

Christopher Napoli et al (2018) concluded in their studies that, due to population growth and economic development, it is trying to increase domestic production in the agricultural sector without considering the amount of water consumption of the produced product. Therefore, in order to avoid jeopardizing current food security, it can use the replacement of products, including low-water-intensive products, as an economic-environmental approach, and the

elimination of water-intensive products will lead to greater savings in water consumption.

Baig et al (2020); Abubakar & Almulhim (2023) concluded in their studies that, in Saudi Arabia, low annual rainfall with an average of 114 mm and high evapotranspiration rates of 3500-4550 mm, 50 times the global average, exacerbate freshwater scarcity. Water conservation policies are a techno-environmental approach that includes demand management, adoption of water-saving technologies, water reuse and recycling, public awareness and education, and policy and governance frameworks used to meet human needs, reduce consumption, and use water efficiently.

Amin Mir & Waqar Ashraf (2023) concluded in their studies that, Saudi Arabia is facing water scarcity stress due to low rainfall, which affects economic and ecological parameters. Therefore, alternative resource remediation measures, including wastewater treatment, are being used for water sustainability as a technological approach that can help control water supply and demand and provide water for drinking and irrigation.

Iraq:

Morris-Iveson & Day (2021) concluded in their studies that, Iraq has been facing water shortages and reduced water quality due to dams built on the Dejlh and phorat rivers. Therefore, a sustainable water use approach is needed that is suitable even for remote villages and uses the technological approach of solar energy systems, increasing resilience to water scarcity, conservation behaviors and water efficiency. It is also a suitable solution to increase access and reliability to safe water services, reduce installation costs and improve efficiency, reduce maintenance costs, solar energy water systems are more sustainable, reliable and low-carbon, a solution for providing water in areas where access to water is a challenge and in areas where demand has increased, its energy sources are clean and have the potential to reduce the negative effects of greenhouse gases.

Abdul (2024) concluded in their studies that, due to the increasing population and increasing food needs, Iraq is forced to import wheat from arid and semi-arid countries such as Iran, and the exporting country must pay the import cost in proportion to the amount of water. If the economic-technological approach of virtual water trade is used, Iraq can import from humid countries instead of importing from arid countries, which reduces costs. It can also plan to increase its water resources and produce its own products instead of importing them, which helps improve water conservation and decision-making for the priority of the type of exported and imported products.

Muhsin & Al-Mossawi (2014) concluded in their studies that, Iraq, due to the increasing pollution of water and wastewater, needs a coordinated and focused strategy in the agricultural sector, developed by several government agencies, including the ministries of higher education, health, agriculture, industry, and environment, in collaboration with local government organizations. We proposed an approach to address wastewater pollution problems by using wastewater recycling technologies to irrigate crops. This approach has the advantage of preserving freshwater reserves for drinking and reducing

the amount of pollution entering the freshwater system. Wastewater treatment using small-scale units at the main sources of pollution can be implemented in a fast and cost-effective manner.

North America (California):

Ma (2022); Ocean Plan Requirements for Seawater Desalination Facilities [J] (2022); Kurtis Alexander (2022) concluded in their studies that, Californians need water conservation policies that have a technological-environmental approach, as follows:

Reduce water use in agriculture: Establish strict regulations, expand our knowledge of water availability, and use alternative water. One alternative is to increase the implementation of groundwater allocation, which is the largest source of water for agriculture in California during droughts, and new irrigation methods to increase water retention time when irrigating crops.

Development of groundwater facilities: Use of desalination equipment that produces fresh water using less energy.

Using a reservoir to store groundwater: For storing groundwater, which is a quick and cost-effective way to store and protect groundwater, and in addition to a reservoir for groundwater, we can consider reservoirs to store rainwater. These reservoirs can be very effective for drought conditions and in the agricultural sector.

Oceania (Australia):

Australia focused only on water supply during the drought, which caused many negative consequences on the quality of life and the environment. Therefore, they need quick and smart measures to conserve water, and it is necessary to use an approach that affects all social, economic, environmental, and technological dimensions. Therefore, it uses climate resilience policies, which are as follows:

Weinstein Bloome & Guzman (2017) concluded in their studies that, Alternatives to water supply (diversification of water resources): include: rainwater harvesting, wastewater reuse and stormwater absorption projects, desalination facilities, and inter-basin transmission pipelines. Participatory projects: Establish a public campaign to conserve water using water pricing, water restriction projects to limit wasteful use, wastewater reuse and stormwater capture projects, desalination plants, and inter-basin transmission pipelines, and discounts on water-saving equipment and supplies. This project will help to correct supply and demand in light of historical droughts and water shortages.

Norton et al (2015); Weinstein Bloome & Guzman (2017) concluded in their studies that, climate Adaptation Plan to Protect Quality of Life and Ecosystem Services: This plan aims to double the canopy cover of trees to reduce temperatures by approximately 7 degrees, maintain soil moisture at appropriate levels to reduce temperatures through evaporative cooling, recycled water projects, and stormwater harvesting for irrigation.

Grant et al (2013); Weinstein Bloome & Guzman (2017) concluded in their studies that, public behavior programs focusing on water conservation: Public behavior can be controlled through mass media, smart water billing, water

pricing, and decentralized water use such as rainwater harvesting. This plan helps improve efficiency and reduce per capita consumption.

Campisano et al (2017); Imtiaz et al (2012) concluded in their studies that, Australia is facing a growing demand for water, and experts are looking for a sustainable way to meet the increasing demand for water. Rainwater harvesting technology can collect and store water and can be useful for domestic, industrial, and agricultural uses.

Radcliffe & Page (2020) concluded in their studies that, Australia uses the water reclamation policy approach, which is an approach that affects all social, economic, environmental, and technological dimensions and includes water recycling with environmental restrictions and desalination plants, which were, of course neutralized due to high costs. This approach replenishes groundwater and creates a variety of water supplies. From an environmental perspective, restrictions should be created so that sewage effluent does not enter the environment and harm water quality. From a technical perspective, special systems are needed to irrigate plants and trees. From an economic perspective, it is initially calculated as a small cost to attract people to use recycled water, but later it is added to the cost of the water bill. It creates a broader picture for planning for the future, which is important for biodiversity and conservation purposes.

Europe (France):

Gibelin et al (2006); Szczypta et al (2014); Tomas-Bruguera (2022) concluded in their studies that, France Considering the climate change in France, especially in the south of France, and its impact on runoff and soil moisture, we can use two technological approaches: new climate change forecasting systems and predictive plant biomass. Predictive plant biomass means that the evolution of the vegetation throughout the year is linked to the meteorological and soil conditions of that year, not to the imposed climate conditions. This method helps us to create a simulated model of how the cultivated plant will be this year, so that we can develop it for better growth in the face of climate change. This strategy has active vegetation and the ability to adapt to current conditions, and can help the plant to be resistant to climate change and even influence the amount of fertilization.

Gimenez-Maranges et al (2020) concluded in their studies that, in France, in the event of heavy rainfall and storms, considering the underground water transmission lines that transport water in a traditional way, it increases evaporation and transpiration and leads to increased flooding. It is an unsustainable method of water transport, and the creation of floods affects the environment, communities, and the economy. As a result, we need a decentralized nature-based method to manage the volume, speed, and quality of storms. This strategy increases the capacity of the ecosystem to regulate runoff and is less affected by floods, and does this by using evaporation, transpiration, storage, and reuse. It also affects ecosystem services such as pollution control, habitat provision, biodiversity, and overall environmental improvement. It is also important for communities to know and accept this technology to participate in it. For this

reason, it uses a technological-environmental approach to sustainable drainage systems to manage stormwater to prevent flooding.

METHODOLOGY

This research is qualitative research with an applied purpose using library data (literature review). The research framework is based on the DPSIR model:

DPSIR Model: The DPSIR model is a conceptual framework used to analyze and manage environmental and social problems to contribute to sustainability through appropriate responses. The model was developed by the European Environment Agency (EEA) and is divided into five main elements, each of which represents a step in the analysis process:

Driving Force: The main and fundamental factors that lead to environmental change. These factors can include population growth, economic development, increasing energy demand, and changes in consumption patterns. In other words, the driving force is the main cause of the pressures on the environment.

Pressure: The pressures that are placed on the environment due to human activities. These pressures can include the release of pollutants, overuse of natural resources, land use changes, and waste generation. In essence, pressures are the consequences of the driving force that affects the environment.

State: A condition that arises from pressures on ecosystems and natural resources. This state reflects the conditions in the environment and shows what state ecosystems are in; for example, a decrease in water resources or air and water pollution.

Impacts: Changes and effects of ecosystem conditions on human communities and the environment. These effects can be observed in the form of health problems, loss of biodiversity, disruption of water and soil resources, and economic losses.

Response: Actions and solutions taken to improve and sustainably manage the environment. These actions can include policy, new laws and regulations, natural resource restoration programs, and public education. Responses are designed to reduce drivers, control pressures, improve the state of the environment, and mitigate negative impacts.

Results

To design a suitable model for sustainable water resources management in the Lake Urmia basin using the DPSIR framework, we can benefit from the successful experiences of other countries in the field of water resources management. In the following, lessons from these international experiences are presented for each stage of the DPSIR model (driving force, pressure, state, effect, and response) appropriate to the current conditions of the Urmia Lake Basin:

Driving Force:

Lessons from other countries: In many countries, such as China, the main driving force for change is population growth and economic development, which has used the inter-basin water transfer policy to evenly distribute water

in different regions. **Lessons for Urmia Lake:** The inter-basin water transfer policy can be used to restore Urmia Lake and increase the level of water resources for agriculture, as this policy is currently being implemented by transferring water from the Kani Sib Dam in Piran Shahr County and has been very effective.

Lessons from other countries: In Saudi Arabia, the main driving force for population growth was food security, seeking to increase domestic production. To ensure food security in conditions of water shortage, the policy of low-water-intensive crops was used. **Lessons for Urmia Lake:** Given the reduction in water resources, the policy of low-water-intensive crops can be used to prevent the planting of water-intensive crops such as apples and sugar beets and to prevent the increase in irrigation water consumption, as the Agricultural Jihad has currently suggested to farmers to plant pistachios and Pakutah apple.

Pressure:

Lessons from other countries: In many countries, such as China, the main pressure is the increase in water consumption in the agricultural sector and the shortage of water for irrigation. To deal with it, they use a pricing reform policy to balance consumption and value water. **Lesson for Urmia Lake:** Use a pricing reform policy to reduce water consumption in the agricultural sector, so that when irrigating, they have to pay a fee to receive an irrigation turn, and in this way, water is considered an important commodity.

Lessons from other countries: India, considering the main pressure of increasing water demand in the agricultural sector, uses a policy to promote sustainable agriculture, which is an environmental approach and includes growing crops suitable for the climate, nature-friendly agricultural practices, indigenous and modified varieties, improving soil health, and protecting biodiversity. Farmers should be educated and encouraged to change irrigation (drip irrigation) and other water-efficient technologies; they help reduce water consumption and can be effective in reducing water demand. **Lesson for Urmia Lake:** The policy to promote sustainable agriculture can be used to reduce water consumption in agriculture, as the Agricultural Research Department of West Azarbaijan Province provides indigenous and modified seeds to farmers according to the conditions of the region.

Lessons from other countries: Iraq has turned to wastewater control policy due to the main pressure of increasing pollutants in water. **Lesson for Urmia Lake:** Due to the increasing use of pesticides in agriculture, which has caused pollution of water resources, the wastewater control policy is used to control and reduce pollution of water resources, so that farmers are currently advised to use biological methods instead of using pesticides.

State:

Lessons from other countries: Saudi Arabia, temperatures are rising to 50 degrees Celsius, with increased evaporation and transpiration, and reduced rainfall, which is causing water shortages and limited access to fresh water in rivers and groundwater. In such a situation, sustainable water resource conservation policies, which include demand management, adoption of water-saving technologies, water

reuse and recycling, public awareness and education, and policy and governance frameworks, are used to meet human needs, reduce consumption, and use water efficiently, and are useful for Chapin in. **Lesson for Urmia Lake:** When can sustainable water resource conservation policies be used to access water, given the decline in groundwater resources, such that there is no water in wells up to a depth of 12 meters.

Impacts:

Lessons from other countries: California, where the drought crisis has affected 12% of the state of California, has had the following effects: Economic: increased unemployment and poverty, loss of agricultural products, loss of recreational opportunities. Environmental: increased greenhouse gas emissions, habitat destruction. To combat these effects, water conservation policies are used, including: reducing water consumption in agriculture (new irrigation methods to increase water retention during irrigation), developing groundwater facilities (using desalination devices), and using reservoirs to store water (to store groundwater for times of drought). **Lessons for Urmia Lake:** Conducting comprehensive assessments and determining the long-term social and economic impacts of the water situation can help planners and policymakers make better decisions, and one of these policies is the water conservation policy, which includes reducing water consumption in the agricultural sector, developing groundwater facilities, and using reservoirs to store water.

Response:

Lessons from other countries: Australia, which uses the water reclamation policy approach, which is an approach that affects all social, economic, environmental, and technological dimensions, and includes water recycling with environmental restrictions and desalination plants, which were of course neutralized due to high costs. This approach recharges groundwater and creates a variety of water supplies. From an environmental perspective, restrictions should be established so that wastewater does not enter the environment and harm water quality. From a technical perspective, special systems are needed to irrigate plants and trees. From an economic perspective, it is initially calculated as a small cost to attract people to use recycled water, but later it is added to the cost of water bills. It creates a broader picture for planning for the future, which is important for biodiversity and conservation goals. **Lessons for Urmia Lake:** Measures such as reviewing water policies, financial incentives for optimal water use, and increasing local participation can help to sustainably manage and restore Urmia Lake.

Based on the results obtained from lessons learned from other countries, based on the DPSIR model, we were able to design a model to create sustainability for water resources management in the Urmia Lake Basin, which is as follows:

CONCLUSION

Experiences from other countries show that creating sustainability for water resources management at Urmia Lake requires a comprehensive and integrated approach in which social, economic, and environmental factors are

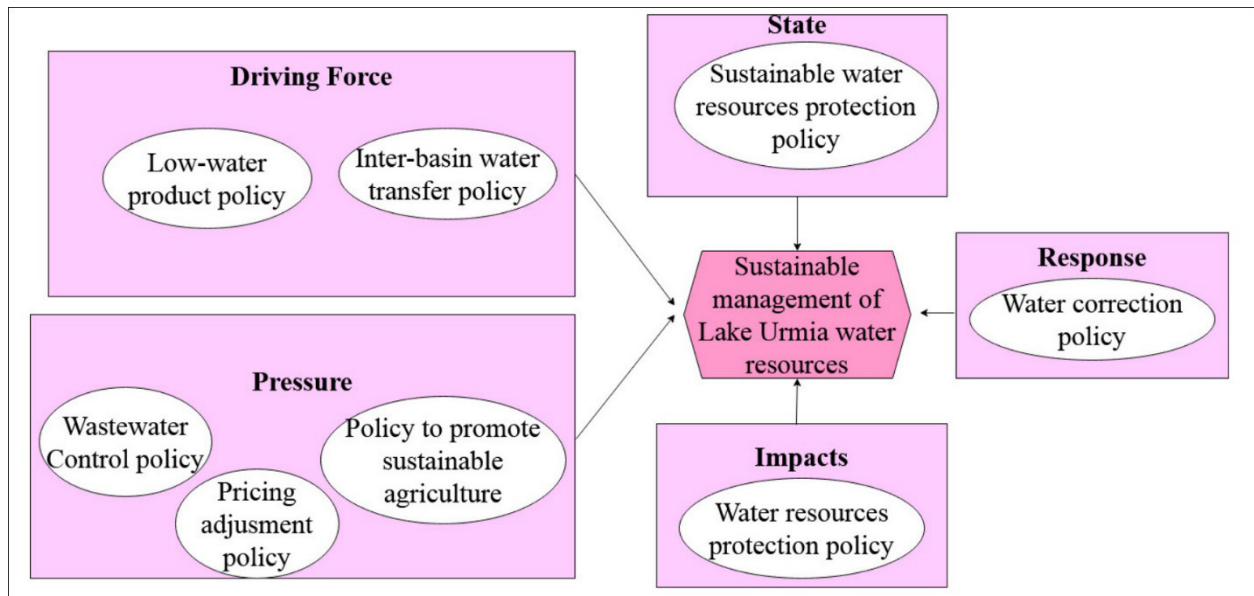


Fig 2. Conceptual model of sustainability for managing Urmia Lake Basin water resources

considered together. For Urmia Lake, utilizing modern tools and long-term policies including: policies for low-water crops, wastewater control, promoting sustainable agriculture (promoting sustainable agriculture, which is an environmental approach and includes growing crops that are suitable for the climate, nature-friendly agricultural practices; indigenous and modified varieties; improving soil health, protecting biodiversity; farmers should be educated and encouraged to change irrigation (drip irrigation) and other water-efficient technologies), pricing reform, inter-basin water transfer, sustainable conservation of water resources, which includes demand management, adoption of water-saving technologies, water reuse and recycling, public awareness and education, and policy and governance frameworks used to meet human needs, reduce consumption, use water efficiently, protect water including: reducing water consumption in agriculture (new irrigation methods to increase water retention during irrigation), developing groundwater facilities (using desalination plants), using reservoirs to store groundwater (to store groundwater for times of drought), water treatment (desalination plants and recycled water), and paying attention to long-term social and economic impacts. It can help promote the sustainability of water resources and restore this valuable ecosystem.

Acknowledgment

I am very grateful for the guidance of all the professors, especially Ms. Dr. Maryam Omidi Najaf Abadi, in writing this article.

Conflict of interest

All authors declare that they have no conflict of interest.

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