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RECEIVED 01 November 2025

REVISED 23 December 2025

ACCEPTED 21 January 2026

PUBLISHED 09 February 2026

CITATION

Haji L and Fallah Haghighi N (2026) Assessing water governance challenges in the lake Urmia Basin, Iran: a DPSIR-based approach. *Front. Environ. Sci.* 14:1737501. doi: 10.3389/fenvs.2026.1737501

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Assessing water governance challenges in the lake Urmia Basin, Iran: a DPSIR-based approach

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The intensifying water crisis in the Lake Urmia Basin, Iran, is driven by climate change and human activities, highlighting the need to examine the economic, social, and management factors affecting water resources. This study analyzes agricultural water governance in the basin, which exemplifies broader governance challenges in Iran. Using the Driver-Pressure-State-Impact-Response framework, the research systematically assesses the current water governance status. The analysis is further enhanced through Partial Least Squares-Structural Equation Modeling (PLS-SEM), providing insights into the interconnections among governance components. A mixed-methods approach, combining quantitative surveys and qualitative semi-structured interviews, offers a comprehensive understanding of the governance landscape. Qualitative results identified 10 “driver” indicators (D) of poor governance, nine “pressure” indicators (P), seven “state” indicators (S), 13 “impact” indicators (I), and 16 “response” indicators (R). Quantitative analysis revealed that drivers significantly contribute to the escalation of the water crisis. Addressing these drivers, mitigating pressures, improving the current undesirable state, and managing the negative impacts of inadequate water governance are strongly influenced by comprehensive responses. This study highlights the complexities of water governance assessment and the dynamic interactions among its components. The findings provide an evidence-based roadmap for designing practical short- and long-term interventions to improve water governance in the Lake Urmia Basin and similar contexts across Iran.

KEYWORDS

climate change, decision-making tools, governance, mixed method, structural equation modeling, water crisis

1 Introduction

Water governance failures have become one of the most important factors exacerbating socio-ecological instability in arid and semi-arid regions of the world. In many countries, institutional fragmentation, sectoral policymaking, and short-term economic and political incentives have led to the persistence of water crises, even despite significant investments (Tortajada, 2010; Goble et al., 2017). Iran is a prominent example of this situation, where extensive groundwater extraction, resource waste, and inefficient agricultural patterns have been consistently reported, and the agricultural sector, as the largest water consumer, has played a decisive role in exacerbating water scarcity (Haji et al., 2024; Sarami-Foroushani et al., 2023; Parsinejad et al., 2022). Meanwhile, Lake Urmia, as one of the largest hypersaline

lakes in the world, is considered to be a symbol of an environmental tragedy in the Middle East (Khazaei et al., 2019). Over the past few decades, the lake has experienced an unprecedented decline in volume (about 96%) and surface area (about 88%), a trend that, according to numerous studies, is mainly due to human activities and the role of climate change has been assessed to be more limited compared to management and institutional factors (Chaudhari et al., 2018; Khazaei et al., 2019). Uncontrolled development of irrigated agriculture in the catchment (Khazaei et al., 2019), extensive damming of the inflowing rivers (Alborzi et al., 2018), construction of the Kalantari bridge that has disrupted the hydrological dynamics of the lake (Marjani and Jamali, 2014), and unsustainable groundwater extraction (Alizade Govarchin Ghale et al., 2018) have significantly reduced the natural water inputs to the lake. The consequences of these trends have included intensification of salt storms, a sharp decline in ecosystem services, and increased pressure on the health and livelihoods of local communities (Balkanlou et al., 2020; Hassani et al., 2020; Mirnezami et al., 2024).

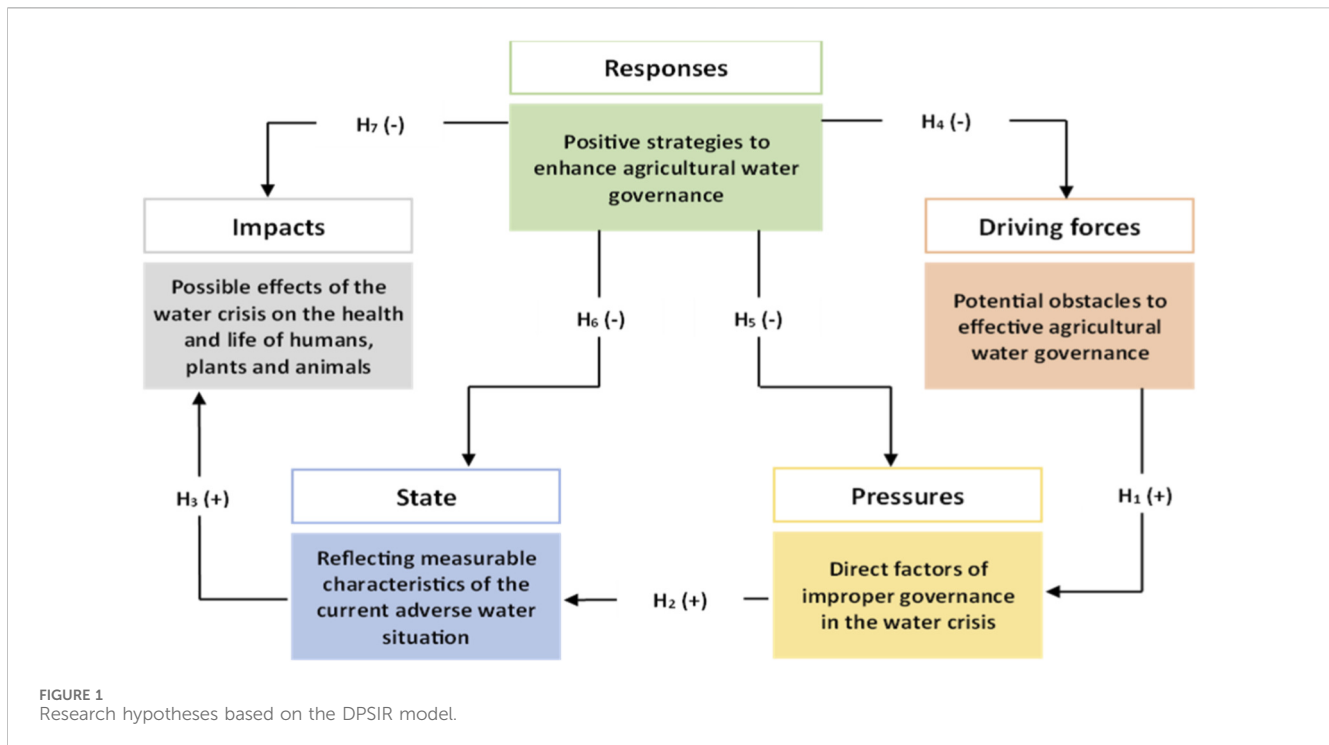
In response to the escalating crisis of Lake Urmia's drying up and increasing concerns at the national and international levels, the Iranian government established the "Lake Urmia Restoration Headquarters" in 2013 as the supreme coordinating body for restoration policies and interventions. In the following years, a series of executive programs and policies aimed at restoring the lake were developed and implemented by this headquarters. However, despite extensive interventions and the allocation of significant financial resources, empirical evidence shows that the lake's condition has not improved significantly and the observed fluctuations have been mostly intermittent and dependent on short-term hydrological conditions (Mirnezami et al., 2024; Esmailzadeh et al., 2025). One of the main reasons for the failure of these efforts is that many restoration interventions have focused on the symptoms of the crisis rather than addressing its structural drivers; For example, improving irrigation efficiency has been pursued without a fundamental overhaul of agricultural policies, local livelihood systems, and water allocation patterns (Ahmadzadeh et al., 2016). The Lake Urmia issue is unique in that it is shaped by a complex interplay of social, economic, political, and environmental factors and is deeply rooted in the geographical, cultural, and ecological context of the region; therefore, unidimensional, technology-based approaches are unable to address its complexities (Esmailzadeh et al., 2025).

Recent research shows that the roots of many of the destructive trends in the Lake Urmia basin can be traced to weak water governance structures, diverse stakeholders, conflict of interest among relevant institutions, and lack of institutional coherence and coordination (Khazaei et al., 2019; Haji et al., 2023; Esmailzadeh et al., 2025). The mandated programs of the Restoration Headquarters, the transfer of water management responsibilities from the regional to the provincial level, and optimistic goals such as setting aside part of the irrigated lands, were not only not realized in practice (Mirnezami et al., 2024), but in some cases led to the opposite results; so that the area of irrigated lands increased, a new sugar factory was built in the basin, and new wells continued to be drilled (Danesh-Yazdi and Ataie-Ashtiani, 2019). In these circumstances, short-term political and financial interests and regional economic priorities prevailed over the long-

term goals of lake restoration (Mirnezami et al., 2024). This experience shows that simplistic approaches to water management, which reduce complex human-nature issues to purely technical problems, often lead to short-term and ineffective solutions and are unable to create sustainable changes in socio-ecological systems (Esmailzadeh et al., 2025).

Despite the rapid growth of the scientific literature on the ecological collapse of Lake Urmia, three fundamental gaps remain. First, although several studies have analyzed governance failures and the political-institutional dimensions of lake restoration (Mirnezami et al., 2024), these socio-political drivers have not yet been integrated into a quantitative causal model that shows how governance factors create hydrological pressures, alter the state of the system, and lead to socio-ecological consequences. Second, existing research has typically examined ecological degradation or policy failures in isolation (Balkanlou et al., 2020), and a systemic synthesis that simultaneously links agricultural governance, water resource pressures, institutional responses, and their resulting consequences is lacking. Third, although the role of agriculture in the lake crisis is widely accepted (Khazaei et al., 2019), agricultural governance mechanisms and their feedbacks on the entire basin water system have not yet been modeled in a structured and quantitative manner. These gaps limit the ability of policymakers to identify leverage points and design effective interventions. In other words, these insights emphasize the need for analytical frameworks that are able to integrate biophysical, institutional, and socio-political processes. Designing successful strategies requires a thorough understanding of the system and its interrelated factors (Wada et al., 2010; Naem et al., 2023). This understanding is essential for grasping the complexities of socio-ecological systems in water management, which necessitates detailed insights into system components and their interactions (Ostrom, 2009). The Driver-Pressure-State-Impact-Response (DPSIR) framework provides a suitable capacity to fill these gaps, as it can integrate biophysical processes with social, economic and institutional drivers and identify causal relationships between them (Scriban et al., 2019; Xu et al., 2024). In the context of water governance, this framework allows for the analysis of how policy incentives, institutional structures, agricultural development and socio-economic trends (D) translate into direct pressures on water resources (P), shape the hydrological and ecological status of the basin (S), generate social and environmental consequences (I), and ultimately trigger management and institutional responses (R). This capability makes DPSIR an efficient framework for analyzing complex and intertwined governance interactions in a basin like Lake Urmia, where policies and institutional structures play an integral role in hydrological outcomes.

Despite the advantages of DPSIR, its application in water governance studies has been mostly descriptive and has rarely been operationalized through rigorous quantitative modeling (Sun et al., 2018). To address this gap, the present study integrates DPSIR with partial least squares structural equation modeling (PLS-SEM) to empirically measure causal pathways among drivers, pressures, status, impacts, and responses. This combined approach has two main advantages: (1) it quantifies and testable the causal relationships governing the governance-environment system, and (2) it assesses the effectiveness of existing institutional responses in reducing drivers, pressures, and



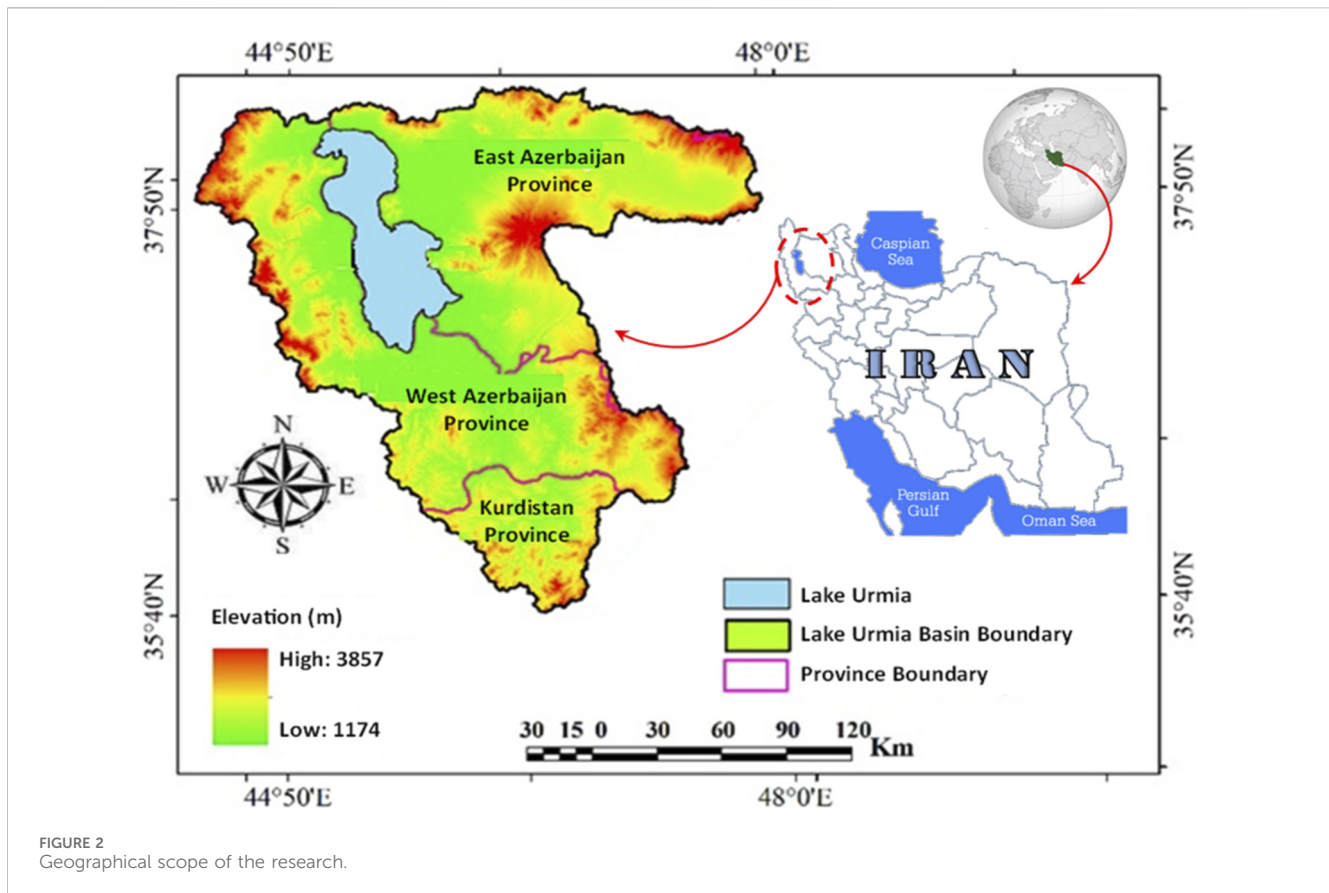
outcomes. To the best of our knowledge, this study is the first comprehensive attempt to construct a quantitative governance model based on DPSIR for the agricultural sector of the Lake Urmia Basin. Accordingly, the aim of this study is to analyze the governance drivers affecting water resource degradation, identify critical pressures, assess the current state of the basin's socio-ecological system, and measure the effectiveness of institutional responses. By combining systems thinking and quantitative modeling, this study provides evidence-based insights to support efficient and coordinated water governance in the Lake Urmia basin.

1.1 DPSIR model

A range of conceptual and analytical models has been employed to examine ecological and socio-environmental systems (Zhang et al., 2021; Talebi and Karimi, 2024). Among these, the DPSIR framework, developed in the late 1990s, has gained broad recognition as a useful tool for elucidating the relationships between human activities and environmental change (Tscherning et al., 2012). The model conceptualizes system dynamics through five interrelated components: Driving forces, Pressures, State, Impacts, and Responses. DPSIR has been widely applied across multiple domains, including ecological risk assessment (Zhang et al., 2021), soil erosion analysis (Talebi and Karimi, 2024), land-use change studies (Obubu et al., 2022), water resources management (Sun et al., 2016), and watershed health assessment (Salehpour Jam et al., 2021). By structuring complex interactions into explicit cause-effect categories, the framework provides a systematic basis for indicator selection and the design of integrated management strategies.

Although DPSIR has traditionally been used as a diagnostic tool for environmental assessment, recent studies emphasize its growing relevance as an analytical framework for governance analysis, particularly in contexts where institutional fragmentation, socio-political incentives, and anthropogenic pressures play a central role in shaping ecological outcomes. In the present study, driving forces encompass the socio-economic, institutional, and environmental conditions that influence water governance in the Lake Urmia Basin. Pressures denote the direct human-induced stressors, such as intensive irrigation practices, excessive groundwater abstraction, and inefficient water allocation, that contribute to accelerated water depletion. The state component captures measurable environmental conditions within the basin, while impacts reflect the ecological and socio-economic consequences arising from governance failures. Finally, responses refer to policy, institutional, and community-level interventions aimed at improving water governance and altering the system's future trajectory. Figure 1 presents the conceptual structure of the DPSIR framework applied in this research. Based on this model, the following hypotheses are proposed:

- H1: "Driving forces" positively influence "pressures".
- H2: "Pressures" positively impact the current adverse "state" of water resources.
- H3: The current "state" positively affects "impacts".
- H4: "Responses" negatively influence "driving forces".
- H5: "Responses" negatively impact "pressures".
- H6: "Responses" negatively affect the current "state".



H7: “Responses” negatively influence “impacts”.

1.2 Study area

The drying up of Lake Urmia has become a major environmental hazard in northwest Iran in recent years (Amini et al., 2019). This situation directly and indirectly impacts the human population of over 13 million in the northwest and west of the country (Amini et al., 2020). Data shows that Lake Urmia’s water level has declined by an average of 40 cm annually over the past 2 decades, resulting in a loss of roughly 30 billion cubic meters in water volume (AminFanak et al., 2022). Demographic changes, human activities, and particularly agricultural water demand in the Lake Urmia catchment area contribute to its drying up. The Lake Urmia Basin (Figure 2), covering 51,876 square kilometers and home to about 6.4 million people, is a crucial agricultural region (Nouri et al., 2023). Experts emphasize that agriculture and excessive water use in this sector play a significant role in this crisis (Valizadeh et al., 2016). In 1979, the cultivated area in the Lake Urmia Basin was 150,000 ha, which increased to 400,000 ha by 2006, nearly tripling in less than 3 decades. Consequently, agricultural water consumption surged from 1.8 billion cubic meters to 5.5 billion cubic meters during this period (Nouri et al., 2023). Historical studies suggest that approximately 70% of the water crisis in the Lake Urmia Basin is attributed to human intervention and poor governance rather than natural factors (Lake Urmia Restoration Program, 2015).

2 Research methods

2.1 Qualitative section

The present study adopts a descriptive-applied research framework, employing a mixed-method approach that integrates both qualitative and quantitative methodologies. The study focuses on the qualitative aspect by conducting in-depth interviews with key stakeholders involved in water management in the Lake Urmia Basin. Thirteen interviews were conducted with a diverse group, including three managers from the Agricultural Jihad Organization, one from the Agricultural and Natural Resources Research and Education Center, two from the Environmental Protection Organization, and two from the Regional Water Organization. Additionally, three representatives from academic institutions and two environmental activists were included to provide a comprehensive understanding of water governance issues in the basin’s agriculture sector. Notably, some of the interviewed stakeholders had a farming background, providing practical, farmer-informed perspectives. Purposive sampling was used to select individuals with relevant expertise and insights into the region’s socio-economic and environmental conditions.

To facilitate the interviews, a structured questionnaire was created, containing critical questions designed to elicit detailed responses. Initially, respondents were asked to define water governance and to 1) assess its appropriateness in the agriculture sector of the Lake Urmia Basin. Following the DPSIR model, they were then asked to 2) identify the drivers of inadequate water

governance in this sector; 3) name the pressures on the basin's water resources; 4) describe the current status of these resources; 5) express the negative impacts of the water crisis on social, economic, and environmental spheres; and 6) suggest solutions to overcome the crisis and achieve effective water governance. Although the DPSIR framework was used to structure the qualitative interviews and subsequent survey design, it was not employed as a closed causal model. Rather, DPSIR served as an analytical scaffold to support respondents in distinguishing between different dimensions of water governance challenges and to stimulate more reflective and detailed response. The in-depth interviews were recorded and noted, and each interview was analyzed line by line, with emerging codes and concepts continuously compared to those from previous interviews. Theoretical saturation was determined when subsequent interviews no longer produced new codes, themes, or indicators, indicating that all relevant perspectives regarding water governance in the agriculture sector had been captured. Furthermore, to ensure the validity of the coding process, the coding scheme was reviewed and discussed with co-authors and a panel of experts, confirming that the codes accurately reflected the concepts expressed by the participants (Guest et al., 2006). Finally, the interview responses were summarized, and concepts related to the DPSIR model were extracted and quantified. While the DPSIR framework guided the interview structure, the allocation of specific indicators to its components resulted from the systematic coding of interview responses rather than from predefined researcher-driven classifications. The findings are presented in Table 1.

2.2 Quantitative section

The quantitative phase of the study involved a structured questionnaire administered in person to a representative sample of farmers from the Lake Urmia Basin, which has a statistical population of 282,061. Using the Krejcie and Morgan (1970) sampling table, a sample size of 384 was determined to ensure robust and representative data. The survey employed a random sampling method with proportional allocation across five counties in three provinces: West Azerbaijan (Naghadeh and Mahabad), East Azerbaijan (Malekan and Bonab), and Kurdistan (Saqqez). One rural district, a rural administrative unit comprising several villages, was randomly selected from each county for the study. The 55-item questionnaire, developed from concepts identified in the qualitative phase, was evaluated for validity by a panel of experts and demonstrated reliability with a Cronbach's alpha above 0.70. Items were rated on a five-point Likert scale (1 = very low to 5 = very high), and the survey was administered by a trained research team, yielding 384 completed questionnaires. After screening for missing data, 368 valid questionnaires were analyzed using SPSS₂₂ and Smart-PLS₃ software.

3 Results

3.1 Qualitative section

A qualitative analysis was conducted to evaluate water governance in the agriculture sector of the Lake Urmia Basin,

gathering insights from various experts and stakeholders. The interview transcripts were systematically analyzed using qualitative content analysis and manually coded to extract relevant indicators for each DPSIR component. The frequency of each indicator was also recorded to identify key patterns and priorities. The assessment revealed a consensus among experts that the current state of water governance in this sector is inadequate. From the qualitative analysis, a total of 55 distinct concepts were identified and systematically categorized according to the DPSIR model: ten concepts related to Drivers, nine to Pressures, seven to the current State, thirteen to Impacts, and sixteen to Response strategies. The frequency of each concept in the respondents' answers was examined, showing that the most frequently mentioned concept appeared 11 times, while the least frequent appeared 3 times (Table 1).

3.2 Quantitative section

3.2.1 Correlation between variables

Before implementing the structural equation model, we examined the correlations among variables in the DPSIR model using Pearson correlation coefficients (Table 2). The results indicated significant negative correlations between the driving force ($r = 0.754$; $p < 0.01$), pressure ($r = 0.604$; $p < 0.01$), state ($r = 0.693$; $p < 0.01$), and impacts ($r = 0.774$; $p < 0.01$) with the responses. This suggests that improved responses to agricultural water governance reduce incentives for poor governance and its associated pressures. Additionally, appropriate solutions can enhance the current adverse state and mitigate the negative impacts of the water crisis.

The analysis also revealed significant positive correlations between the driving forces and the variables of pressure ($r = 0.713$; $p < 0.01$), state ($r = 0.804$; $p < 0.01$), and impacts ($r = 0.967$; $p < 0.01$). This implies that neglecting the potential drivers of inadequate agricultural water governance increases pressure on water resources, worsening the water crisis and adversely affecting humans, plants, and animals. Furthermore, the state variables showed positive correlations with pressures ($r = 0.630$; $p < 0.01$) and impacts ($r = 0.773$; $p < 0.01$), indicating that pressures on water resources lead to their undesirable states. High pressures not only degrade the status of water resources but also have significant negative consequences. Finally, the impacts variable ($r = 0.799$; $p < 0.01$) demonstrated a positive correlation with the adverse state, suggesting that ongoing poor water governance will exacerbate negative effects in the future.

3.2.2 Assessment of DPSIR-PLS results

3.2.2.1 Measurement model

To measure the reflective model, we assessed standard factor loading values, t-values, reliability, convergent validity, and discriminant validity. Factor loadings, determined by the correlations between manifest variables and latent constructs, adhered to a threshold of 0.4 as per Hair et al. (2020). As shown in Figure 3, all standardized factor loadings (λ) exceeded this criterion (>0.4) and were significant at the $p < 0.01$ level, confirming the indices are suitable for measuring the research constructs. Reliability, reflecting the internal consistency

TABLE 1 Concepts extracted from in-depth interviews with experts.

DPSIR	No.	Index	Frequency
Drivers	D ₁	Making temporary and transitory decisions (rapid change of laws)	9
	D ₂	Incorrect implementation of laws and guidelines	9
	D ₃	Reducing people's activism solely to the area of consumption	7
	D ₄	Incompatibility of methods and guidelines with local rules and traditions	6
	D ₅	Social and cultural incompatibility of local people	6
	D ₆	Extreme distance between law and practice	5
	D ₇	Disregard for the position of society's elites in decision-making	5
	D ₈	Paying attention to the short-term interests of specific groups rather than improving the water crisis	5
	D ₉	Lack of internal and external coherence of water management organizations	4
	D ₁₀	Different perceptions of the water crisis among officials	4
Pressures	P ₁	Increasing demand for water and food due to population growth	10
	P ₂	The policy of achieving self-sufficiency	9
	P ₃	Adopting symbolic and showcase development decisions	8
	P ₄	Policy of eradicating poverty	7
	P ₅	Unequal distribution of water resources (water permits)	7
	P ₆	Expansion of dam construction in the lake urchia basin	6
	P ₇	Lack of attention to land use planning	6
	P ₈	Improper development of agricultural activities	5
	P ₉	Water for agriculture being free	4
State	S ₁	Over-extraction of water	10
	S ₂	Decrease in groundwater levels	9
	S ₃	Drying up of rivers and springs	9
	S ₄	Alteration of ecosystems due to inter-basin water transfer	8
	S ₅	Drying up of lake urchia	7
	S ₆	Development of unsustainable irrigated agriculture (cultivating low-quality and rocky lands)	7
	S ₇	Changes in precipitation patterns and their reduction	6
Impacts	I ₁	Migration and population displacement	9
	I ₂	Inter-provincial (ethnic-cultural) tensions	8
	I ₃	Conflict among local people	8
	I ₄	Intensification of drought and desertification	8
	I ₅	Reduction in plant and animal diversity	7
	I ₆	Unstable production (low productivity and decrease in agricultural output)	6
	I ₇	Dependency and food insecurity	5
	I ₈	Low income of rural residents	5
	I ₉	Reduction in job opportunities	4
	I ₁₀	Decline in living standards	4
	I ₁₁	Outflow of currency due to the import of agricultural products	3
	I ₁₂	Occurrence of salt storms	3
	I ₁₃	Land subsidence	3

(Continued on following page)

TABLE 1 (Continued) Concepts extracted from in-depth interviews with experts.

DPSIR	No.	Index	Frequency
Responses	R ₁	Review and develop laws to preserve aquatic, plant, and animal ecosystems	11
	R ₂	Crop pattern reform	10
	R ₃	Controlling the cultivation of water-intensive and secondary crops	9
	R ₄	Raising awareness and promoting a culture of efficient consumption	9
	R ₅	Focusing on dialogue and communication among different stakeholder groups	9
	R ₆	Changing the mindset of managers	8
	R ₇	Blocking unauthorized wells	8
	R ₈	Developing programs based on basin water resources capacity	7
	R ₉	Changing the process of implementing projects to restore lake urmia	6
	R ₁₀	Supporting the non-agricultural economy	6
	R ₁₁	Supporting the modernization of irrigation infrastructure and the use of new methods	5
	R ₁₂	Empowering non-governmental organizations	5
	R ₁₃	Valuing agricultural water (creating a water market)	5
	R ₁₄	Developing information systems to track resource consumption	4
	R ₁₅	Utilizing international programs	4
	R ₁₆	Establishing water police	3

TABLE 2 Mean, standard deviation, and correlation between research variables.

Variable	Mean	SD	R	D	P	S	I
Response (R)	3.93	0.638	1				
Driver (D)	2.19	0.823	-0.754 ^a	1			
Pressures (P)	1.92	0.845	-0.604 ^a	0.713 ^a	1		
State (S)	2.08	0.704	-0.693 ^a	0.804 ^a	0.630 ^a	1	
Impacts (I)	2.19	0.779	-0.774 ^a	0.967 ^a	0.733 ^a	0.799 ^a	1

^aCorrelation is significant at the <0.01 level.
SD, standard deviation.

of constructs (Hair et al., 2020), was evaluated through Cronbach's alpha and composite reliability (CR), both exceeding the recommended threshold of 0.70. The reliability analysis showed satisfactory results, consistent with the criteria outlined in Table 3.

Validity reflects the effectiveness of a research instrument in measuring the desired variable. In PLS, convergent validity indicates the correlation between each construct and its indicators. The average variance extracted (AVE) is used to assess this validity, with a threshold of ≥ 0.5 , though some researchers accept a value of 0.4 or higher (Fornell and Larcker, 1981; Hulland, 1999). The results demonstrate that each indicator effectively measures its corresponding construct (Table 3).

Discriminant validity is established by the lack of correlation between indicators of distinct constructs. To assess this and ensure no collinearity among constructs, the Heterotrait-Monotrait (HTMT) index was utilized, with a threshold value of 0.9

(Henseler et al., 2015). As shown in Table 3, the maximum HTMT value for any construct is 0.9. This indicates both the absence of multicollinearity and adequate discriminant validity among the examined constructs.

3.2.2.2 Structural model

Structural equation modeling was used to examine the relationships between latent variables and assess the study's proposed conceptual framework. The structural model evaluation revealed various indices in Figure 3 and Table 4. While the Bentler and Bonnet Normed Fit Index (NFI) shows an inadequate fit for the proposed model, the model is satisfactory to the data based on other indices. It is important to note that relying solely on the NFI to evaluate the model can be misleading due to its sensitivity to sample size and inherent biases.

The assessment of the DPSIR structural model's fit indices revealed a positive outcome for both collinearity and significance. Specifically, variance inflation factor (VIF) values, which above 3 signify collinearity among predictor constructs (Hair et al., 2021), indicated no such issues as per the findings presented in Table 5. Furthermore, the coefficient of determination (R^2) was calculated within the PLS-SEM framework. With R^2 thresholds of 0.60, 0.33, and 0.19 categorizing explanatory power as appropriate, moderate, and weak respectively (Chin, 1998), the results indicated commendable predictive validity. Specifically, the R^2 values for the driving forces (D), pressures (P), state (S), and impacts (I) constructs were 0.618, 0.542, 0.596, and 0.738, respectively, underscoring the model's robust explanatory capability (Figure 3). The hypothesis tests conducted based on the overall structural model yielded significant results as outlined in Table 5.

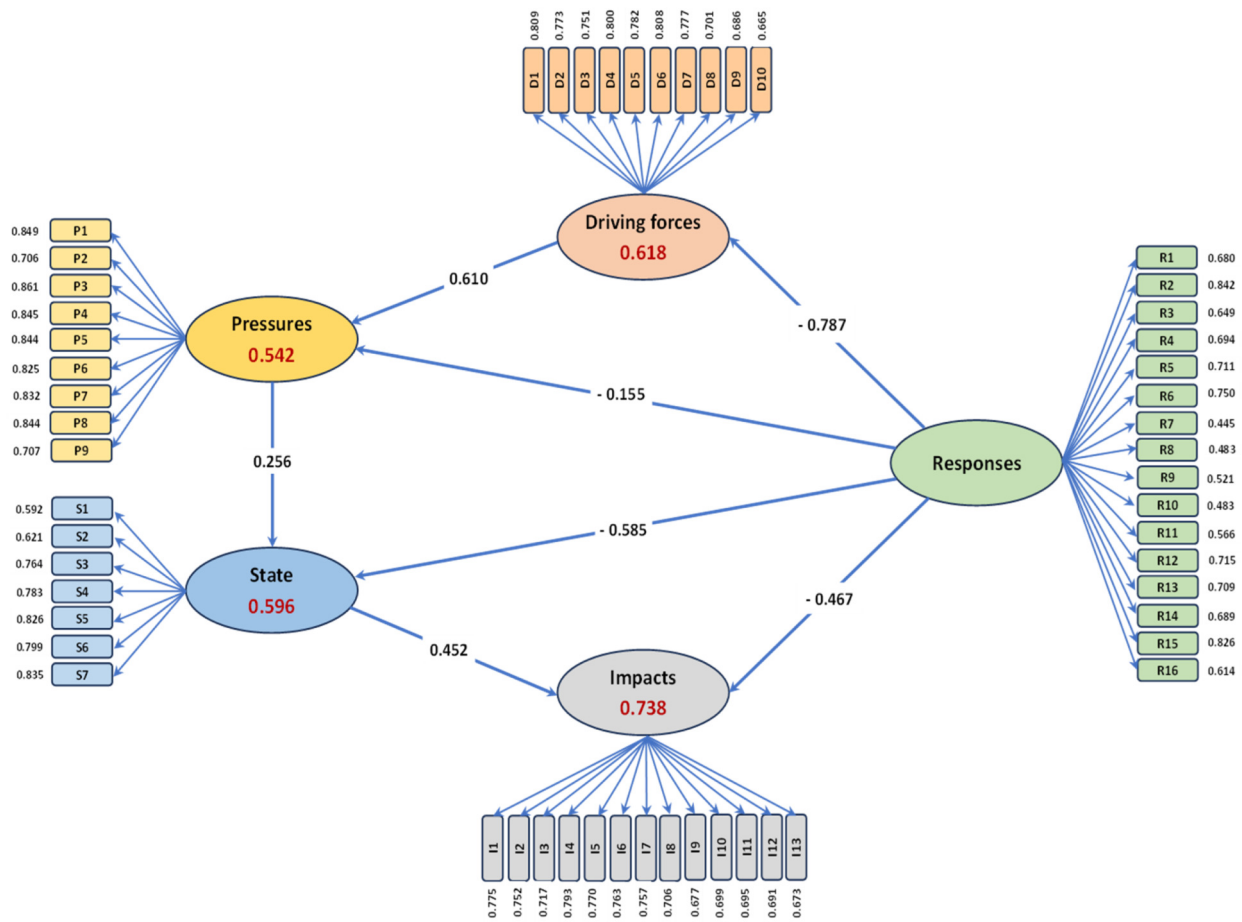


FIGURE 3 Structural model of the research in the form of factor loadings and standardized path coefficients.

TABLE 3 Measurement model statistics.

Variable	CR (≥ 0.7)	α (≥ 0.7)	AVE (≥ 0.5)	Discriminant validity based on the HTMT criteria				
				R	D	P	S	I
Responses (R)	0.92	0.91	0.43	*	0.825	0.655	0.783	0.842
Drivers (D)	0.93	0.91	0.57		*	0.771	0.890	0.900
Pressures (P)	0.94	0.93	0.66			*	0.705	0.83
Satet (S)	0.89	0.86	0.56				*	0.889
Impacts (I)	0.93	0.92	0.53					*

3.2.2.3 Testing hypotheses

To test the research hypotheses, a structural model incorporating latent variables for driving forces (D), pressures (P), state (S), impacts (I), and responses (R) was utilized. The model demonstrates direct path relationships among independent, mediating, and dependent variables (Figure 3). Table 5 presents standardized path coefficients (β), T-values, coefficient of determination (R^2), and significance levels ($p < 0.01$, $p < 0.05$) for each relationship. The standard bootstrapping technique was applied to 368 observations, using

500 samples to evaluate the significance of the path coefficients. Results in Table 5 reveal that inappropriate governance drivers (D) positively and directly affect pressures ($p < 0.01$, $t = 8.495$, $\beta = 0.610$), supporting hypothesis one (H_1). Additionally, pressure on water resources directly affects the adverse state of the water crisis, confirming hypothesis two (H_2) ($p < 0.01$, $t = 4.345$, $\beta = 0.256$). It was also found that as a result of inappropriate water governance, the negative impacts of the water crisis were positively and significantly influenced by the current adverse state of water ($p < 0.01$, $t = 7.763$, $\beta = 0.452$), a

TABLE 4 Model goodness of fit indices.

Indicators	SRMR	NFI	d_ULS	d_G
Minimum cut-off	<0.080	>0.90	p > 0.05	p > 0.05
Estimated parameters	0.069	9.57	14.29	5.03

Normed fit index (NFI), Standardized root mean square residual (SRMR), Squared Euclidean distance (d_ULS), Geodesic distance (d_G).

TABLE 5 Structural model statistics.

Hypothesis	Relationship	VIF	Path coefficients (β)	t-value	p-value	Results
H ₁ +	D→P	2.62	0.610	8.49	0.001	Confirmed
H ₂ +	P→S	1.67	0.256	4.34	0.001	Confirmed
H ₃ +	S→I	2.26	0.452	7.76	0.001	Confirmed
H ₄ -	R→D	1.00	-0.787	36.01	0.001	Confirmed
H ₅ -	R→P	2.62	-0.155	2.12	0.034	Confirmed
H ₆ -	R→S	1.67	-0.585	11.72	0.001	Confirmed
H ₇ -	R→I	2.26	-0.462	7.74	0.001	Confirmed

finding that supports hypothesis three (H₃). Based on the results of the structural analysis, appropriate responses aimed at mitigating the water crisis negatively and significantly affected the inappropriate governance drivers of water ($p < 0.01$, $t = 36.011$, $\beta = -0.787$). This confirms hypothesis four (H₄). According to the results, adopting appropriate responses in the context of reducing suitable governance negatively and significantly affected pressures ($p < 0.03$, $t = 2.125$, $\beta = -0.155$). This result supports hypothesis five (H₅). The current adverse state of agricultural water resources was another construct of the DPSIR model, which was negatively and significantly influenced by appropriate responses regarding water governance ($p < 0.01$, $t = 11.729$, $\beta = -0.585$), supporting hypothesis six (H₆). Finally, hypothesis seven (H₇) regarding the effect of responses on reducing the negative impacts of inappropriate agricultural water governance was confirmed ($p < 0.01$, $t = 7.747$, $\beta = -0.464$). Overall, the p-values for all constructs were less than 0.05. Additionally, the t-values for all direct paths, as presented in Table 5, were above 1.96. The SEM results show that DPSIR linkages are not perceived as equally influential. Certain pathways exert stronger perceived effects than others, highlighting context-specific governance dynamics rather than intrinsic properties of the DPSIR framework.

4 Discussion

The findings indicate that the water crisis in the Lake Urmia Basin is not merely the result of physical water scarcity or climate change; rather, it is rooted in structural failures of water governance. These failures originate at the level of Drivers, intensify through Pressures, lead to a critical deterioration in the State of water resources, and ultimately generate wide-ranging Impacts on socio-economic and environmental systems.

4.1 Drivers

According to the findings, the primary drivers of the crisis in the Lake Urmia Basin are predominantly institutional and political in nature. Short-term and unstable decision-making, improper implementation of laws, a deep gap between legislation and practice, and a lack of coherence among water management organizations indicate that the problem is governance-centered rather than technical. These results are consistent with studies that attribute the failure of the Lake Urmia Restoration Program (ULRP) to weak institutional accountability, inter-organizational conflicts of interest, and short-term political pressures (Salimi and Zarghami, 2025; Mirnezami et al., 2024). Moreover, the reduction of social participation to the level of mere water consumption, the marginalization of local elites, and the misalignment of policies with the socio-cultural context of the region demonstrate that decision-making processes have largely followed a top-down approach. These findings explain why, despite the establishment of formal participatory mechanisms within the ULRP, farmers and local communities neither perceived themselves as genuine stakeholders nor exhibited meaningful changes in water-use behavior (Mirnezami et al., 2024).

4.2 Pressures

Inappropriate governance drivers have translated into a set of structural pressures on water resources. Growing demand for water and food, self-sufficiency policies, extensive dam construction, and neglect of land-use planning reveal that agricultural development has proceeded without regard to the basin's actual carrying capacity. These pressures are consistent

with documented evidence of increased agricultural water consumption, expansion of irrigated lands, and excessive abstraction from surface and groundwater resources (Zarghami and AmirRahmani, 2017; Hassani et al., 2020). The free provision of agricultural water and the inequitable allocation of water abstraction permits constitute some of the most critical pressures, previously identified in the literature as major barriers to demand management. The ULRP experience demonstrated that without reforming economic incentives, technical and regulatory policies, such as improving irrigation efficiency, not only failed to reduce water consumption but, in many cases, led to the expansion of cultivated areas and even the development of related industries (e.g., sugar factories) (Ahmadzadeh et al., 2016; Mirnezami et al., 2024).

4.3 State

The current state of water resources, characterized in the findings by over-abstraction, severe groundwater table decline, river desiccation, and ultimately the drying of Lake Urmia, is a direct consequence of accumulated pressures. Unsustainable agricultural expansion on low-productivity and rocky lands, along with inter-basin water transfers, has not resolved the problem; instead, by disrupting ecological balance, these measures have increased system fragility, a conclusion supported by numerous studies (Mirnezami et al., 2024; Esmailzadeh et al., 2025).

4.4 Impacts

The identified impacts demonstrate that the Lake Urmia crisis is not solely an environmental issue. Migration, inter-provincial and ethnic tensions, declining livelihoods and employment opportunities, food insecurity, and salt storms indicate a direct linkage between the water crisis and the region's social and economic stability. These findings are consistent with the literature on human-induced drought and water bankruptcy in previous studies (Khazaei et al., 2019; Esmailzadeh et al., 2025).

4.5 Rethinking responses

The extracted responses reflect stakeholders' perceptions of potential solutions; however, the ULRP experience shows that many of these measures, such as legal reforms, sealing illegal wells, modifying cropping patterns, and promoting modern irrigation, have already been implemented and have yielded limited effectiveness due to institutional, economic, and political constraints (Mirnezami et al., 2024; Salimi and Zarghami, 2025). Therefore, directly translating these responses into policy recommendations without addressing the reasons for past failures risks reproducing the same patterns of ineffectiveness. Based on the findings of this study and empirical evidence from the performance of the ULRP, the following recommendations are proposed not as immediate solutions but as prerequisites for realistic interventions.

5 Lessons learned and practical recommendations

- Despite the role of the Lake Urmia Restoration Headquarters as the supreme policy-making and coordination body, past experience has shown that it lacks the executive authority necessary to compel ministries, organizations, and provinces to implement basin-wide policies and projects. Divergent perspectives among agencies, local conflicts of interest, and political pressures have rendered long-term decision-making impracticable. Therefore, the establishment of an independent basin authority with a legal mandate and a composition combining technical experts and farmer representatives, serving as the executive arm of the Headquarters, is essential. Such an institution can reduce the gap between decision-making and implementation, prevent the recurrence of short-term and politically driven decisions, set allocation caps, and directly oversee project implementation, thereby complementing and strengthening the Restoration Headquarters' role in operational execution.
- The successful implementation of any management mechanism in the Lake Urmia Basin requires a deep understanding of local geography, power structures, the interests of influential groups, and existing political barriers. Acknowledging that free agricultural water has eliminated economic incentives for conservation, it is recommended that a "market-based capped allocation" model be designed whereby specific water quotas are first defined through agreement among key stakeholders, based on objective criteria and ecological capacity. Subsequently, the creation of a limited and transparent market for quota trading can provide incentives to shift toward higher water-value crops and reduce overall consumption. This market mechanism should be accompanied by targeted support packages, including innovation funds and tax credits, to ensure that consumption reductions are achieved through technological innovation rather than purely coercive measures, thereby enhancing both economic and political sustainability.
- The ULRP experience demonstrated that cropping pattern reform fails without economic incentives and sustained support. It is proposed that a composite index combining the economic value of crops and their water consumption be developed, and that farmers who shift toward low-water, high-value crops such as medicinal plants, saffron, and similar products receive targeted subsidies, facilitated access to inputs, and guaranteed government procurement. This approach reduces farmers' risk, operationalizes cropping pattern change, and significantly decreases water consumption.
- Any policy restricting water abstraction, including sealing illegal wells or reducing cultivated area, must be mandatorily accompanied by livelihood transition packages. One of the main reasons for the failure of past control measures was their implementation without consideration of farmers' livelihood dependence on water, which led to social resistance, local conflicts, and distrust. Linking regulatory policies with multi-year financial support, alternative skill training, and access to low-interest loans for

non-agricultural occupations enables the realistic and sustainable implementation of these policies and prevents the transformation of an environmental crisis into a social one.

- Addressing the knowledge and information failures of the restoration program requires the establishment of a transparent, dual monitoring system. The significant discrepancies between official water-use estimates and independent data indicate serious weaknesses in data analytics and decision-making systems. Integrating smart water abstraction meters with satellite-based monitoring of cultivated areas using remote sensing and artificial intelligence technologies, and publicly disclosing these data, can enhance decision accuracy while enabling social and scientific oversight of both farmers' and implementing agencies' performance. Such transparency prevents the recurrence of decisions based on inaccurate and overly optimistic data.
- Finally, to avoid repeating costly and ineffective interventions, it is essential to institutionalize social impact assessment as a legal requirement prior to the implementation of any major water or agricultural project in the Lake Urmia Basin. Past overreliance on technical and environmental assessments led to the neglect of social consequences, local conflicts, and declining policy legitimacy. Mandating social impact reports and securing approval from local stakeholders can shift decision-making from a top-down process toward a more participatory and equitable pathway, thereby increasing the likelihood of long-term success in restoration policies.

6 Conclusion

The water crisis in Iran, particularly in the Lake Urmia Basin, is primarily due to the mismanagement of water resources. This study reveals that poor governance, especially in agriculture, poses a significant challenge with long-term detrimental effects for the region and beyond. The parable of "water and society" like "the ship and its passengers" is a reminder of the fact that the water crisis and the intensification of the current unfavorable situation can affect vital issues such as food security, social welfare, regional peace, and development, and ultimately endanger human life, wildlife, and plants. Such alarming trends have elicited considerable concern from both researchers and policymakers. Despite extensive studies on water resources governance and management, insufficient efforts have been made to examine the inadequate water governance in the agriculture sector. Therefore, a detailed assessment of the status of water governance to identify existing gaps and problems should be put on the agenda, especially in countries such as Iran where the population and ecosystems dependent on water resources are changing. Access to accurate and current information on the status of water resources is important for various stakeholders, including policymakers, government planners, local communities, and agricultural extension agents, to enhance water resource management and governance. Neglecting this critical issue may result in misguided decisions and exacerbate existing challenges. It is essential to explore various aspects of water governance and its challenges faced by key stakeholders, along with offering practical solutions for decision-making and planning centers.

This study primarily aims to assess water governance in the Lake Urmia Basin. Employing the DPSIR model and the PLS-SEM model, this research presents a comprehensive analysis of governance conditions for the first time. Findings indicate that inappropriate governance of water resources has precipitated severe crises within the agriculture sector. The study underscores the necessity of addressing the interrelated effects of driving forces, pressures, resource states, and impacts arising from governance deficiencies. Furthermore, the examination of causal relationships within the DPSIR model demonstrates that pressures on water resources, coupled with the adverse social, economic, and environmental repercussions of ineffective governance, significantly influence the state of agricultural water resources. This study highlights existing challenges and gaps while proposing actionable measures to improve the situation, underscoring that enhanced water governance is essential for food security, social welfare, and sustainable development in the region. This study demonstrates a notable strength through its mixed-methods approach. Qualitative interviews, followed by comprehensive content analysis, facilitated the identification of indicators about inappropriate governance, associated consequences, and coping strategies. Concurrently, the examination of quantitative relationships among the components of the DPSIR model from the farmers' perspective further enriches the findings. This research, conducted in a region with significant climatic diversity, offers valuable insights relevant to various geographical contexts. As the water crisis is a global issue, the study's findings may enhance management strategies, particularly in developing countries. While the predefined structuring of inquiry around DPSIR may limit alternative framings, this study does not aim to validate the framework itself. Rather, its contribution lies in empirically identifying how stakeholders differentially perceive, prioritize, and weight DPSIR elements and linkages within a specific water governance context. Also, in governance-focused DPSIR applications, the distinction between drivers and pressures is often blurred, as certain policy and demographic factors simultaneously shape systemic conditions and exert direct operational pressure on natural resources. Additionally, this study is based on cross-sectional data and does not capture the temporal evolution of DPSIR variables. Future research could use longitudinal data and trend analysis to examine the dynamics of water governance indicators.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by this study was approved by the Ethics Committee of the Iranian Research Organization for Science and Technology (IROST). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was not obtained from the individual(s), nor

the minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article because no research has been conducted on people under the age of 18.

Author contributions

LH: Conceptualization, Data curation, Formal Analysis, Methodology, Software, Writing – original draft. NF: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – review and editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was supported by the Iran National Science Foundation (INSF) and the Iranian Research Organization for Science and Technology (IROST) (No.4030745).

Acknowledgements

The authors sincerely thank all legal and natural persons, as well as stakeholders, whose invaluable contributions were crucial to the study's success.

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