

Advancing Sustainable Water Governance in Agriculture: Insights from a Delphi Study in Iran's Lake Urmia Basin

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Abstract

Challenges facing water, sustainable agriculture, and food security highlight the need for effective water governance. This study used the Delphi technique to identify practical steps for sustainable water governance in the agricultural basin of Lake Urmia. 17 experts from academic, organizational, and local backgrounds were purposefully selected through snowball sampling. Three Delphi rounds were conducted (17, 17, and 14 participants, respectively), with consensus defined as at least 70% agreement. The study uniquely applies Delphi to the hydro-social context of Lake Urmia basin, combining insights from diverse experts. Consensus was reached on 51 indicators across six components, emphasizing “Integrated and basin-based policy-making”, “Establishing and developing participatory structures”, “Institutional monitoring, transparency, and accountability”, “Innovative sustainability-oriented directions”, “Education, extension, and development of sustainable agricultural practices” and “Justice-centered, rule of law and legal strategies”. Limitations include the small sample size and the potential challenge of generalizing findings beyond the studied basin. These results provide a foundation for future water management decisions and public awareness initiatives.

Keywords: Common good, Convergence of perspectives, Human right to water, Stakeholder participation, Sustainable development.

1. Introduction

Water scarcity has long been one of the most critical challenges in agriculture (Aznar-Sánchez *et al.*, 2019). In recent years, this issue has become more complex due to climate change and increasing food demand (Laurett *et al.*, 2021). Unsustainable water management and the presence of diverse stakeholders with sometimes conflicting interests pose fundamental barriers to achieving sustainable agriculture and food security (Dahimavi *et al.*, 2018; Feola *et al.*, 2015; Gleick, 2014). At the core of these problems lies weak water governance, resulting from complex interactions between human and natural factors (Pavón *et al.*, 2018; Bijani *et al.*, 2020; Haji *et al.*, 2024). Deficiencies in institutional frameworks and management structures further hinder effective responses to these challenges (Nabiafjadi *et al.*, 2025). Generally, there

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32 is a common belief that water problems arise more from poor governance than from absolute
33 scarcity (Badisar *et al.*, 2020).

34 In contrast to this situation, desirable water governance, emphasizing multilateral decision-
35 making and active collaboration among all stakeholders, provides an appropriate platform to
36 resolve conflicts and harmonize competing interests (Tatar *et al.*, 2019; Bell & Scott, 2020;
37 Melnychuk & de Loë, 2020). Water governance is a comprehensive concept that encompasses
38 social, political, economic, and managerial systems aimed at the sustainable development and
39 management of water resources through the participation of formal and informal stakeholders
40 (Pahl-Wostl *et al.*, 2010). This approach mandates cooperation across three dimensions:
41 vertical cooperation coordinates policies across governmental levels; horizontal cooperation
42 ensures interaction between public and private sectors; and territorial cooperation addresses
43 cross-boundary management issues across different regions (Moss & Newig, 2010; Varis *et*
44 *al.*, 2014; Bryson *et al.*, 2015; Lukat *et al.*, 2023; Zhou *et al.*, 2025).

45 Within the governance literature, the design of models to create suitable platforms for effective
46 water governance has been extensively discussed (de Boer *et al.*, 2016; García *et al.*, 2019;
47 Zhou *et al.*, 2025). However, these approaches face multiple practical challenges, including
48 population growth, climate change, and political complications (Uhlendahl *et al.*, 2011; Zhou
49 *et al.*, 2025). Similarly, water governance in Iran, especially at the local level, is not exempt
50 from these challenges due to its unique characteristics (Mirzaei *et al.*, 2017). As uniform
51 solutions for water issues do not exist globally, responses must be tailored to local contexts,
52 particularly in developing countries (OECD, 2015). Despite extensive global literature on water
53 governance, few studies have examined sustainable agricultural water governance in the Urmia
54 Lake Basin, indicating the need for solutions specifically adapted to the local context. Given
55 these challenges, the present study aims to identify appropriate water governance indicators in
56 Iranian agriculture, particularly in the Urmia Lake Basin, to provide evidence-based solutions
57 to water-related problems.

58 59 **1.1 Delphi Method Design**

60 The Delphi approach is a widely used communicative method among experts, especially in
61 environmental sciences like water resources (Assubayeva *et al.*, 2022). It is a structured
62 technique involving multiple rounds of surveys aimed at achieving consensus or identifying
63 disagreements among panel members in the face of high uncertainty and limited information
64 (Avella, 2016; Assubayeva *et al.*, 2022). Studies utilizing the Delphi method strive to develop

65 a shared understanding of complex issues (Belton *et al.*, 2019). By analyzing experts' collective
66 judgments, Delphi contributes to the development of indicators and the validation of specific
67 outcomes (Chan, 2022). The Delphi method is fundamentally qualitative, focusing on the
68 explanation and understanding of complex concepts; however, quantitative applications also
69 exist, aimed at testing and validating findings. For instance, within positivist paradigms, Delphi
70 can assist in testing general theories and hypotheses (Assubayeva, 2021; Avella, 2016).
71 Conversely, interpretive studies employ Delphi to develop frameworks and theories
72 (Assubayeva, 2021). A distinctive feature of the Delphi method compared to conventional
73 surveys is its structured, iterative nature incorporating feedback rounds, which enables
74 refinement and deepening of expert opinions (Dahal *et al.*, 2023).

75 This research has applied the Delphi technique to systematically solicit expert opinion and
76 reach a consensus on sustainable water governance indicators within the complex socio-
77 hydrological context of the Lake Urmia Basin. The Delphi technique is suitably appropriate for
78 fundamental challenges with multiple stakeholders who have limited data. In comparison with
79 other participatory techniques, Delphi offers the advantage of diverse opinion gathering
80 without geographical boundaries, which avoids direct influence among participants and allows
81 several opportunities for iteration and refinement of expert judgment.

82

83 2.1. Study Area

84 The Lake Urmia Basin, covering approximately 52,000 square kilometers, is one of Iran's
85 largest internal basins, spanning East Azerbaijan, West Azerbaijan, and parts of Kurdistan
86 provinces (Figure1). Figure 1 illustrates the geographical extent of the basin, including its
87 hydrological boundaries, elevation ranges, provincial boundaries, and the location of Lake
88 Urmia within the national context. Water resources in the basin consist of rivers, springs, and
89 precipitation, supplying agricultural and drinking water needs for surrounding communities.
90 Over five million people inhabiting more than 36 cities and 3,150 villages directly depend on
91 these water resources (Hamidi *et al.*, 2021). Facing ongoing water challenges, this northwestern
92 Iranian basin exemplifies critical issues related to water scarcity and resource mismanagement.
93 Urmia Lake, with an average depth of 16 meters, a length of 140 kilometers, and a width of
94 about 55 kilometers, is one of the world's largest saline lakes (Zoljoodi & Didevarasl, 2014).
95 Its water level decline has increased salinity to approximately 300 grams per liter, adversely
96 affecting aquatic species (Schulz *et al.*, 2020). Between 2000 and 2020, the lake lost about 45%
97 of its surface area and 85% of its volume due to climate change, excessive water withdrawals,

98 reduced surface inflows, agricultural expansion, and dam construction (Schulz *et al.*, 2020;
99 Sima *et al.*, 2021). High-water-demand crops have quadrupled regional water consumption,
100 with agriculture accounting for 90% of water use in the basin (Research Center of Iran's
101 Parliament, 2021).

102 Recently, exposed salt flats from the lake bed have generated harmful dust storms affecting
103 public health and agricultural productivity (Hamidi *et al.*, 2021). Continued drying threatens
104 severe social, environmental, and ecological consequences for the region (Heydari & Jabbari,
105 2012). One of the most important programs of the Iranian government to address this situation
106 was the Urmia Lake Restoration Program (ULRP). This program was approved in 2013 with
107 an estimated cost of 7 billion US dollars and in cooperation with the Ministry of Energy, the
108 Ministry of Agricultural Jihad, the Ministry of Interior, the Iranian Planning and Budget
109 Organization, and Sharif University of Technology to implement integrated solutions in the
110 field of lake basin management (Hamidi *et al.*, 2021; Sima *et al.*, 2021). Since 2013, the Urmia
111 Lake Restoration National Committee (ULRNC) has been trying to reach ecological levels over
112 a 10-year period through inter-basin water transfers and a 40% reduction in agricultural water
113 consumption (Sima *et al.*, 2021). Despite substantial investment, the Research Center of Iran's
114 Parliament (2021) reported limited progress in resolving the lake's water crisis. One of the
115 primary reasons for the lack of success in water governance projects within the Lake Urmia
116 basin is the absence of prioritization based on project effectiveness and the consequent
117 misallocation of funds. This issue is compounded by inadequate cooperation among
118 responsible organizations, insufficient monitoring and oversight of allocated budgets, and the
119 overall failure to achieve a fundamental change in agricultural and service patterns across the
120 watershed. Furthermore, the projects suffer from a lack of capacity-building tailored to regional
121 needs and unrealistic goal-setting that disregards local and national conditions.

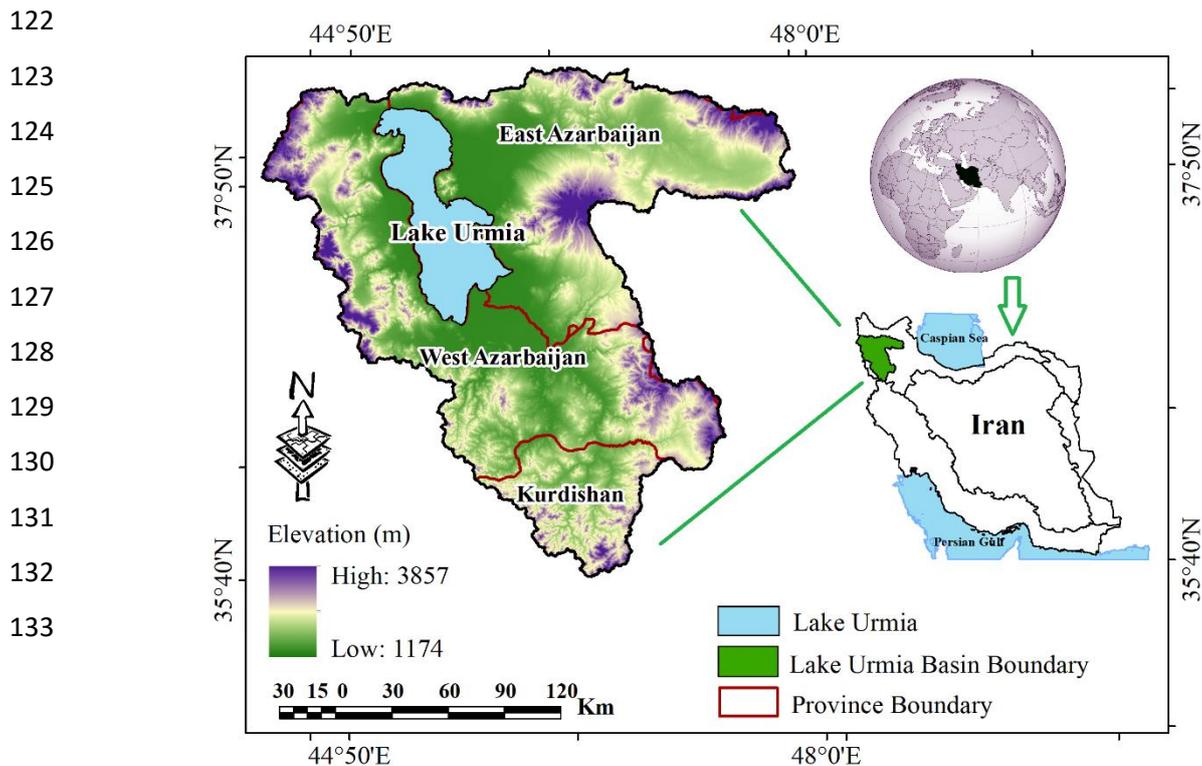


Figure 1. Geographical scope of the research, showing the hydrological boundary of the Lake Urmia Basin, elevation ranges, provincial boundaries, and the location of Lake Urmia within Iran.

134 **2. Research Method**

135 **2.1. Research Design**

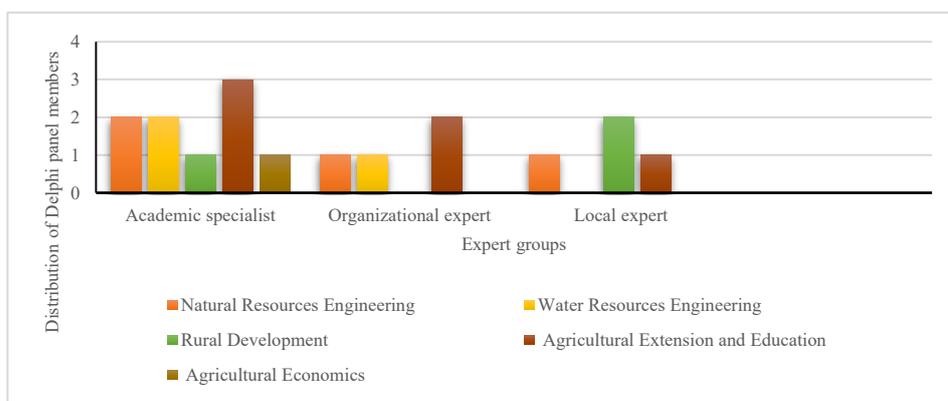
136 This research was designed with a mixed approach (qualitative-quantitative) and following the
137 interpretivist paradigm. Designed with an applied objective, the study examines and analyzes
138 issues related to water governance in the agricultural sector of the Lake Urmia basin. Data
139 collection and analysis conducted using a descriptive-exploratory method, leveraging both
140 qualitative and quantitative techniques to gain a deeper understanding of complex challenges.
141 The results aim to inform improved policymaking and resource management strategies.

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143 **2.2. Determining the Statistical Population and Sampling**

144 Selecting the appropriate participants is a crucial process that requires special attention. The
145 chosen experts should be educated and creatively motivated individuals who are capable of
146 critical thinking and employing strategic approaches, while also respecting diverse perspectives
147 (Toumbourou, 2020). Since the goal is to reduce subjective judgments, group bias, and
148 homogeneity bias (Bonaccorsi *et al.*, 2020), panel members should be representative of the
149 diversity of stakeholders related to the research topic. Therefore, the statistical population of
150 this study includes experts and specialists in various fields such as “Natural Resources

151 Engineering”, “Water Resources Engineering”, “Rural Development”, “Agricultural Extension
 152 and Education”, and “Agricultural Economics”. Inclusion criteria for the study were having
 153 expertise and practical experience in the field of water management and agriculture.
 154 Researchers believe that the reliability of the Delphi method is considered more dependent on
 155 the scientific credibility of participants than on their number; hence, a panel size ranging from
 156 5 to 20 experts is deemed sufficient (Okoli & Pawlowski, 2004; Manoliadis *et al.*, 2009).
 157 Accordingly, participants were selected using a purposive snowball sampling technique based
 158 on expertise. Initially identified experts recommended others within their networks, enabling
 159 the inclusion of individuals with relevant experience and experts related to the research topic.
 160 Ultimately, a sample of 17 experts was assembled, comprising nine academic specialists, four
 161 executive sector experts, and four local experts active in water management. To further ensure
 162 diverse representation and reduce potential homogeneity bias, the initial participants were
 163 carefully selected from different professional backgrounds and geographic regions. Each expert
 164 was then asked to recommend additional participants within their networks, enabling the
 165 inclusion of individuals with varied perspectives and practical experience in water
 166 management. This approach ensured that multiple viewpoints (academic, organizational, and
 167 local) were captured, enhancing the reliability and applicability of the consensus results within
 168 the context of Iran’s water governance. Figure 1 visually illustrates the composition of the
 169 Delphi panel, showing the distribution of experts across academic, organizational, and local
 170 groups, categorized by their fields of specialization in Natural Resources Engineering, Water
 171 Resources Engineering, Rural Development, Agricultural Extension and Education, and
 172 Agricultural Economics.

173



174 **Figure 1.** Distribution of Delphi panel members across academic, organizational, and local
 175 expert groups, categorized by their fields of specialization.

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178 **2.3. Designing the Delphi Questionnaires**

179 The Delphi method implementation in the present study followed a structured process. After
180 identifying panel members, multiple rounds of the Delphi surveys were conducted, with
181 questionnaires distributed and collected accordingly. Three rounds of surveys using the
182 designed Delphi method were carried out from early January to late March 2025. The
183 questionnaires for each round were distributed and gathered both in person and electronically.
184 In the first round, an open-ended question titled “Requirements for Sustainable Water
185 Governance in the Agricultural Sector of the Urmia Lake Basin” was posed to panel members.
186 They were asked to provide their opinions and ideas regarding indicators of sustainable water
187 governance in this basin. As a result, the experts proposed a total of 90 indicators. Following a
188 data screening process that removed duplicates and marginal items, 63 indicators were selected
189 for further analysis (Table 1). The second round involved a closed-ended questionnaire wherein
190 panel members evaluated the importance of the proposed concepts from the first round using a
191 5-point Likert scale (ranging from very high importance to very low importance) (Table 2).
192 This stage aimed to familiarize respondents with each other’s viewpoints and measure the
193 degree of consensus on each item. All panel members participated, and the collected data were
194 analyzed using SPSS software. Central tendency measures (means) and dispersion indices
195 (standard deviations) were employed. Indicators with an average score below 3 were excluded
196 from further analysis due to their low significance (Goodarzi *et al.*, 2017). The third round was
197 designed to achieve consensus. A new questionnaire was developed featuring dichotomous
198 questions (1 = agree, 2 = disagree) based on the concepts from round two. Each participant’s
199 score and the group’s mean score for each specific indicator were provided to respondents,
200 allowing them to compare their views with those of other panel members. This feedback
201 enabled individuals to revise or reaffirm their positions if desired. Finally, to enhance clarity,
202 the sustainable water governance indicators were categorized into broader factors (Table 3).

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204 **2.4. Validity and Reliability**

205 Ensuring validity and reliability in Delphi studies is inherently challenging, as each round may
206 involve different item formats and the method often faces criticism for the lack of strong
207 evidence supporting reliability (Rahmani *et al.*, 2020). Powell (2003) emphasizes that the
208 Delphi method is a structured decision-making process designed to compensate for the absence
209 of definitive data by drawing on expert knowledge and experience; therefore, methodological
210 judgments should not rely solely on traditional statistical indicators. To enhance the rigor of

211 this study, several forms of validity were addressed. Face validity was ensured through expert
212 review of the clarity and relevance of the questionnaires prior to each round. Content validity
213 was strengthened by selecting qualified panel members with expertise in water governance and
214 by refining the indicators iteratively based on their feedback. Additionally, construct validity
215 was supported because the indicators used in the Delphi rounds were originally derived through
216 qualitative content analysis of interview data, ensuring that the extracted items reflected the
217 underlying concepts of water governance rather than predetermined theoretical categories
218 (Abbaszadeh, 2012). For reliability, the internal consistency of the Round 2 questionnaire was
219 examined using Cronbach's alpha. In line with Dalkey (1969), many studies suggest that when
220 the panel size exceeds 13 participants, the average correlation coefficient typically surpasses
221 0.80, indicating acceptable reliability (Harder *et al.*, 2010; Rayfield & Croom, 2010; Goodarzi
222 *et al.*, 2017). However, because classical test-retest procedures are not applicable in Delphi
223 designs, where each round may use different question formats, stability of agreement across
224 rounds was used as an alternative reliability indicator. Round 1 involved open-ended item
225 generation, while Rounds 2 and 3 assessed the same indicators using different response scales.
226 Therefore, temporal stability was evaluated by comparing the consistency of expert judgments
227 between Rounds 2 and 3. Minimal variation in ratings across these rounds indicated stable
228 expert opinions and adequate reliability of the consensus-building process. All participants
229 provided informed consent after receiving written information about the purpose of the study,
230 voluntary participation, and confidentiality procedures. To maintain anonymity and
231 confidentiality, no identifying information was collected in the questionnaires.

232

233 3. Findings

234 3.1. Results of the First Delphi Round

235 In the first round of the Delphi study (n=17), a questionnaire including an open-ended question
236 titled "Requirements for establishing a sustainable water governance system in the agricultural
237 sector of the Lake Urmia Basin" was distributed to the panel members, asking them to
238 document the indicators they considered relevant. In this round, the research team extracted 90
239 indicators through content analysis and open coding. The coding was conducted independently
240 by two researchers, and consistency was assessed through peer comparison, with any
241 disagreements resolved through discussion. Similar indicators were merged based on their
242 conceptual meaning and operational relevance, while marginal or irrelevant items were
243 removed, resulting in a final set of 63 indicators. The frequency of each indicator, reported in

244 Table 1, was calculated based on the number of panel members who mentioned that indicator
 245 or its similar versions. This approach represented expert consensus, and provides a reliable
 246 basis for subsequent rounds of the Delphi study.

247 **Table 1.** Indicators extracted from the first Delphi round.

No.	Indicator	Frequency
1	Raising the awareness of activists regarding the civil rights and duties related to the water crisis	16
2	Linking agricultural policies with water sustainability goals (change in policymaking structure)	16
3	Formulation and revision of comprehensive and expert-based laws	16
4	Basin-level water management instead of provincial-level	15
5	Reforming the cultivation patterns according to available water resources	15
6	Establishment of water councils composed of various stakeholder representatives for long-term governance	15
7	Guiding and encouraging farmers toward sustainable agricultural practices (organic farming, shifting cultivation pattern, etc.)	15
8	Justice-oriented water utilization (organizing water rights)	14
9	Strengthening research and innovation for water and agricultural sustainability	14
10	Development and extension of sustainable and modern agricultural techniques (drought-resistant varieties and new irrigation methods)	14
11	Public access to information and data on the quantity and quality of water resources	14
12	Organizing festivals and local events to raise ecological awareness	13
13	Rehabilitation and creation of appropriate water infrastructure to reduce water losses	13
14	Extension of smart irrigation and precision agriculture through awareness campaigns	13
15	Transparent periodic reporting on the status of water and agricultural resources	13
16	Establishing continuous monitoring and assessment systems to supervise changes and the status of water resources (flow and consumption)	12
17	Accountability of institutions responsible for water and agriculture affairs	12
18	Utilizing smart technologies to control water withdrawal	12
19	Recycling and reusing agricultural wastewater	12
20	Employing advanced models to simulate water resource behavior and predict the effects of climatic and human changes	12
21	Formation of a decision-making committee for Lake Urmia involving local, provincial, and national actors (for urgent and short-term actions)	12
22	Identifying and prioritizing stakeholders with clear definitions of roles and responsibilities	12
23	Strengthening NGOs to advocate for Lake Urmia's water resource protection	12
24	A reasonable view toward self-sufficiency	12
25	Virtual water management	12
26	Planning according to land preparation (agriculture proportional to climate)	12
27	Environmental taxation on excessive water consumption	11
28	Reforming water pricing structure based on actual costs	11
29	Creating educational and extensional content for the public	11
30	Developing legal frameworks and executive guarantees	11
31	Establishing sustainable livelihoods compatible with water resources at the Lake Urmia basin scale (income diversification)	10
32	Preventing unauthorized water harvesting	10
33	Participatory water management models led by farmers (e.g., formation of farmers' associations)	10
34	Utilizing the capacity of elites in decision-making related to water and agriculture	10
35	Planning for adaptation to climate change	10
36	Extension of sustainable consumption behaviors and reduction of excessive water use among the exploitable community	10
37	Consolidation and integration of agricultural lands for sustainability initiatives	10
38	Expansion of financial and credit facilities for farmers	10
39	Enhancing collaboration between universities, research institutions, and user communities	9
40	Encouraging cooperation among basin countries for common resource management	9
41	Reducing cultivation on water-stressed lands	9
42	Developing specific plans for water resource management during drought periods	9

43	Formulating a comprehensive document for water resource management (climatic, social, geological dimensions, etc.)	9
44	Utilizing indigenous knowledge of farming communities in water resource management	9
45	Employing skilled and efficient managers in the water and environmental sectors	8
46	Regulating water use based on real agricultural needs and resource status (demand management)	8
47	Simplifying and effective laws for local communities	8
48	Developing appropriate legal frameworks	8
49	Institutional arrangements for consensus-building in decision-making to reduce conflicts	8
50	Use of unconventional water resources (saline water and urban wastewater)	7
51	Establishing information and data banks for decision-making	7
52	Utilizing GIS and remote sensing for mapping agricultural water resources	7
53	Creating mechanisms for inter-organizational coordination to reduce duplication and conflicts	7
54	Policies justifying shared benefits as incentives for participation	6
55	Establishing specialized consulting centers for farmers	6
56	Developing mechanisms for sharing cultural and scientific information among stakeholders	5
57	Implementing watershed management projects in mountainous areas to preserve surface waters	5
58	Implementation of environmental impact assessment for agricultural and water supply projects	5
59	Strengthening the culture of trust in official institutions	5
60	Measurement of crop yield per cubic meter of water consumed (water productivity)	4
61	Resilience to Changes	4
62	Monoculture farming	4
63	Preservation of plant residues in soil	4

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249 3.2. Results of the Second Delphi Round

250 In this round of the Delphi technique, the remaining indicators from the first phase, along with
 251 the new indicators suggested by the expert panel, were presented in a questionnaire using a
 252 five-point Likert scale, where 1 indicated very low importance and 5 indicated very high
 253 importance. Experts were asked to evaluate the importance of each identified indicator. The
 254 results of this phase are shown in Table 2, where indicators with higher mean scores received
 255 higher ranks. In line with common practice in Delphi studies, the midpoint of the scale was
 256 used as the cut-off point for determining importance. Therefore, a value of 3 was considered
 257 the threshold, as values below this level indicate insufficient expert support for an indicator
 258 (Hsu & Sandford, 2007; Hasson *et al.*, 2000). Given the exploratory nature of the study, using
 259 this threshold helped prevent the premature removal of potentially meaningful indicators while
 260 ensuring that only those with at least a moderate level of agreement were retained for further
 261 analysis. Consistent with previous literature, a mean score of ≥ 3 was applied as the criterion
 262 for keeping indicators (Gajić & Palčić, 2019; Weerawardhana *et al.*, 2022). No indicator fell
 263 exactly at the threshold value. In cases where indicators had the same mean score, the standard
 264 deviation was used as an additional ranking criterion; specifically, indicators with lower
 265 standard deviation received higher ranks. Based on these criteria, indicators with a mean score
 266 below 3 were removed from the list of sustainable water governance indicators in the
 267 agricultural sector. In total, 51 indicators advanced to the third phase (Table 2).

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269 **Table 2.** Ranking of sustainable water governance indicators in the second Delphi round
 270 (number of respondents: 17).

Ranking	Indicator	Mean	Standard Deviation
1	Raising the awareness of activists regarding the civil rights and duties related to the water crisis	4.63	0.500
2	Linking agricultural policies with water sustainability goals (change in policymaking structure)	4.59	0.507
3	Establishment of water councils composed of various stakeholder representatives for long-term governance	4.56	0.512
4	Guiding and encouraging farmers toward sustainable agricultural practices (organic farming, shifting cultivation pattern, etc.)	4.56	0.512
5	Formation of a decision-making committee for Lake Urmia involving local, provincial, and national actors (for urgent and short-term actions)	4.53	0.514
6	Development and extension of sustainable and modern agricultural techniques (drought-resistant varieties and new irrigation methods)	4.53	0.514
7	Basin-level water management instead of provincial-level	4.53	0.514
8	Public access to information and data on the quantity and quality of water resources	4.53	0.624
9	Reforming the cultivation patterns according to available water resources	4.50	0.516
10	Transparent periodic reporting on the status of water and agricultural resources	4.50	0.516
11	Identifying and prioritizing stakeholders with clear definitions of roles and responsibilities	4.50	0.516
12	Strengthening NGOs to advocate for Lake Urmia's water resource protection	4.47	0.514
13	Extension of smart irrigation and precision agriculture through awareness campaigns	4.47	0.514
14	Strengthening research and innovation for water and agricultural sustainability	4.47	0.514
15	Formulation and revision of comprehensive and expert-based laws	4.47	0.514
16	Establishing continuous monitoring and assessment systems to supervise changes and the status of water resources (flow and consumption)	4.47	0.624
17	Justice-oriented water utilization (organizing water rights)	4.44	0.512
18	Rehabilitation and creation of appropriate water infrastructure to reduce water losses	4.44	0.629
19	Organizing festivals and local events to raise ecological awareness	4.41	0.507
20	A reasonable view toward self-sufficiency	4.41	0.507
21	Developing legal frameworks and executive guarantees	4.41	0.507
22	Participatory water management models led by farmers (e.g., formation of farmers' associations)	4.38	0.500
23	Utilizing smart technologies to control water withdrawal	4.35	0.493
24	Virtual water management	4.33	0.488
25	Planning according to land preparation (agriculture proportional to climate)	4.31	0.873
26	Environmental taxation on excessive water consumption	4.24	0.437
27	Reforming water pricing structure based on actual costs	4.24	0.437
28	Accountability of institutions responsible for water and agriculture affairs	4.24	0.664
29	Developing specific plans for water resource management during drought periods	4.24	0.664
30	Planning for adaptation to climate change	4.19	0.544
31	Formulating a comprehensive document for water resource management (climatic, social, geological dimensions, etc.)	4.18	0.393
32	Utilizing the capacity of elites in decision-making related to water and agriculture	4.18	0.529
33	Consolidation and integration of agricultural lands for sustainability initiatives	4.18	0.636
34	Establishing sustainable livelihoods compatible with water resources at the Lake Urmia basin scale (income diversification)	4.12	0.781
35	Recycling and reusing agricultural wastewater	4.12	0.857
36	Establishing information and data banks for decision-making	4.06	0.748
37	Employing advanced models to simulate water resource behavior and predict the effects of climatic and human changes	4.06	0.854
38	Extension of sustainable consumption behaviors and reduction of excessive water use among the exploitable community	4.00	0.791
39	Reducing cultivation on water-stressed lands	4.00	0.816
40	Enhancing collaboration between universities, research institutions, and user communities	4.00	0.845
41	Creating educational and extensional content for the public	3.94	0.827
42	Implementation of environmental impact assessment for agricultural and water supply projects	3.94	0.966
43	Preventing unauthorized water harvesting	3.94	1.088
44	Utilizing indigenous knowledge of farming communities in water resource management	3.88	0.806
45	Expansion of financial and credit facilities for farmers	3.88	0.857
46	Regulating water use based on real agricultural needs and resource status (demand management)	3.82	0.728
47	Encouraging cooperation among basin countries for common resource management	3.76	0.752
48	Employing skilled and efficient managers in the water and environmental sectors	3.75	0.697
49	Simplifying and effective laws for local communities	3.71	0.683
50	Utilizing GIS and remote sensing for mapping agricultural water resources	3.53	0.772
51	Institutional arrangements for consensus-building in decision-making to reduce conflicts	3.23	0.895

272 **3.3. Results of the Third Delphi Round**

273 In the third round of the Delphi technique, the primary objective was to resolve disagreements
274 and establish final consensus among the expert panel regarding the indicators. Unlike the
275 second round, where a five-point Likert scale was used to assess the degree of importance of
276 each indicator, the third round employed dichotomous response options, “agree” or “disagree”,
277 to obtain definitive expert judgments. Consensus in this round was defined as at least 70%
278 agreement among respondents for a given item. The expert panel consisted of 14 members;
279 however, in cases where one or more experts left an item unanswered, the agreement
280 percentage was calculated based on the number of respondents to that specific item rather than
281 the total panel size. Each participant was shown both their individual scores and the average
282 scores from the previous round, allowing them to recognize divergences and reconsider their
283 positions if desired. Indicators that consistently received high agreement and maintained their
284 ranking were recognized as consensus indicators, while changes in rankings reflected
285 adjustments toward collective viewpoints. Given that the establishment of consensus criteria
286 in Delphi studies remains a debated topic with no universal standard (Barrios *et al.*, 2021), and
287 considering that the Delphi literature reports consensus thresholds ranging from 51% to 80%
288 (Toumbourou, 2020), this study adopted a 70% agreement threshold as a balanced and justified
289 criterion (Goodarzi *et al.*, 2017). This level was appropriate given the diversity of the expert
290 panel and the exploratory nature of the research, helping to ensure a realistic representation of
291 expert perspectives while avoiding the unnecessary exclusion of potentially important
292 indicators. Table 3 presents all indicators that met this consensus threshold, demonstrating their
293 applicability for future studies and reflecting broad agreement among the panel experts.

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305 **Table 3.** Percentage of agreement on sustainable water governance indicators in the third
 306 Delphi round (number of respondents: 14).

Component	Ranking	Indicator	Agreement
Establishment and development of participatory structures	1	Establishment of water councils composed of various stakeholder representatives for long-term governance	100
	2	Formation of a decision-making committee for Lake Urmia involving local, provincial, and national actors (for urgent and short-term actions)	92.9
	3	Identifying and prioritizing stakeholders with clear definitions of roles and responsibilities	85.7
	4	Strengthening NGOs to advocate for Lake Urmia's water resource protection	84.6
	5	Participatory water management models led by farmers (e.g., formation of farmers' associations)	78.6
	6	Utilizing the capacity of elites in decision-making related to water and agriculture	78.6
	7	Enhancing collaboration between universities, research institutions, and user communities	76.9
	8	Encouraging cooperation among basin countries for common resource management	71.4
	9	Institutional arrangements for consensus-building in decision-making to reduce conflicts	71.4
Education, extension, and development of sustainable agricultural practices	1	Raising the awareness of activists regarding the civil rights and duties related to the water crisis	100
	2	Guiding and encouraging farmers toward sustainable agricultural practices (organic farming, shifting cultivation pattern, etc.)	92.3
	3	Extension of smart irrigation and precision agriculture through awareness campaigns	85.7
	4	Organizing festivals and local events to raise ecological awareness	78.6
	5	Creating educational and extensional content for the public	71.4
	6	Extension of sustainable consumption behaviors and reduction of excessive water use among the exploitable community	71.4
Innovative sustainability-oriented directions	1	Development and extension of sustainable and modern agricultural techniques (drought-resistant varieties and new irrigation methods)	100
	2	Utilizing smart technologies to control water withdrawal	92.9
	3	Strengthening research and innovation for water and agricultural sustainability	85.7
	4	Rehabilitation and creation of appropriate water infrastructure to reduce water losses	84.6
	5	Recycling and reusing agricultural wastewater	78.6
	6	Employing advanced models to simulate water resource behavior and predict the effects of climatic and human changes	76.9
	7	Reducing cultivation on water-stressed lands	71.4
Institutional monitoring, transparency, and accountability	1	Public access to information and data on the quantity and quality of water resources	100
	2	Transparent periodic reporting on the status of water and agricultural resources	100
	3	Establishing continuous monitoring and assessment systems to supervise changes and the status of water resources (flow and consumption)	92.9
	4	Accountability of institutions responsible for water and agriculture affairs	85.7
	5	Developing specific plans for water resource management during drought periods	78.6
	6	Formulating a comprehensive document for water resource management (climatic, social, geological dimensions, etc.)	78.6
	7	Establishing information and data banks for decision-making	78.6
	8	Utilizing GIS and remote sensing for mapping agricultural water resources	76.9
	9	Implementation of environmental impact assessment for agricultural and water supply projects	76.9
Integrated basin-based policymaking	1	Linking agricultural policies with water sustainability goals (change in policymaking structure)	100
	2	Basin-level water management instead of provincial-level	100
	3	Reforming the cultivation patterns according to available water resources	100
	4	A reasonable view toward self-sufficiency	92.9
	5	Virtual water management	92.9
	6	Planning according to land preparation (agriculture proportional to climate)	92.3
	7	Environmental taxation on excessive water consumption	85.7
	8	Reforming water pricing structure based on actual costs	85.7
	9	Planning for adaptation to climate change	85.7
	10	Consolidation and integration of agricultural lands for sustainability initiatives	84.6
	11	Establishing sustainable livelihoods compatible with water resources at the Lake Urmia basin scale (income diversification)	78.6
	12	Preventing unauthorized water harvesting	78.6
	13	Utilizing indigenous knowledge of farming communities in water resource management	78.6
	14	Employing skilled and efficient managers in the water and environmental sectors	71.4
	15	Regulating water use based on real agricultural needs and resource status (demand management)	71.4
Justice-centered, rule of law and legal strategies	1	Formulation and revision of comprehensive and expert-based laws	100
	2	Justice-oriented water utilization (organizing water rights)	85.7
	3	Developing legal frameworks and executive guarantees	85.7
	4	Expansion of financial and credit facilities for farmers	76.9
	5	Simplifying and effective laws for local communities	76.9

307
 308 For clearer and more practical presentation of results, indicators with over 70% agreement were
 309 categorized into six overarching factors with similar characteristics. These factors include
 310 “establishment and development of participatory structures,” “education, extension, and

311 development of sustainable agricultural practices,” “innovative sustainability-oriented
 312 directions,” “institutional monitoring, transparency, and accountability,” “integrated basin-
 313 based policymaking,” and an emphasis on “justice-centered, rule of law and legal strategies”.
 314 This structured categorization not only organizes the indicators but also enables more detailed
 315 analysis, identification of relationships among the indicators, and practical application for
 316 enhancing sustainable water governance in the agricultural sector of the Lake Urmia basin
 317 (Table 3 and Figure 2).

318



319

320 **Figure 2.** Ranking of sustainable water governance factors based on average
 321 underlying indicators.

322 4. Discussion

323 The findings of this study, which identify six key factors for sustainable water governance in
 324 the Lake Urmia basin, provide a clear and structured framework for understanding governance
 325 challenges in the region and facilitate meaningful comparison with other studies. International
 326 experiences also support these findings. For example, in Australia’s Murray–Darling Basin,
 327 polycentric governance, stakeholder participation, environmental water allocation, and water-
 328 use reduction policies have helped balance agricultural needs with ecological sustainability
 329 (Marshall *et al.*, 2013; Bischoff-Mattson & Lynch, 2017; Samnakay *et al.*, 2024). Key elements
 330 such as integrated water management, efficient irrigation, localized governance, and flexible
 331 legal frameworks have also contributed to successful outcomes. Similarly, in the California’s
 332 Sacramento-San Joaquin system (USA), integrated water management, flood control,

333 groundwater regulation, water pricing, adaptive legal mechanisms, and long-term storage
334 strategies are used to address water scarcity and competing sectoral demands (Laćan & Resh,
335 2016; Lund, 2016; Andrew & Sauquet, 2017; Rudnick *et al.*, 2025). These international
336 experiences provide valuable practical benchmarks and guidance for strengthening water
337 governance in the Lake Urmia basin, particularly within the framework of the Urmia Lake
338 Restoration Program (ULRP). In interpreting these findings, it is important to note that the
339 identified indicators stem from expert consensus derived through the Delphi method.
340 Accordingly, they should be understood as prioritized expert judgments rather than empirically
341 validated causal determinants of governance effectiveness.

342 Sustainable water governance in the agricultural sector of the Lake Urmia basin requires an
343 “integrated basin-oriented policymaking” approach. Expert consensus in this study identifies
344 key governance indicators whose coordinated reform can support more effective water
345 management, enhance resilience, and protect local livelihoods. Central to this process is
346 aligning agricultural policies with water sustainability objectives and moving from fragmented,
347 provincial-based management toward watershed-based governance. Longstanding challenges,
348 such as misaligned development priorities, self-sufficiency pressures, and market-driven
349 cropping decisions, underscore the need for revising cropping patterns based on actual water
350 availability, climate conditions, virtual water considerations, and land-use planning tools.
351 Complementary measures such as establishing fair water pricing mechanisms, enforcing
352 environmental taxes on overconsumption, and addressing illegal water extraction are essential
353 to promote responsible practices. Socioeconomic pressures on farmers require targeted support
354 programs that stabilize livelihoods and reduce reliance on unauthorized wells. Additional
355 priorities include land consolidation, diversification of income sources at the basin scale, and
356 strengthening managerial capacity within water and environmental institutions.
357 Implementation, however, may face institutional inertia, political resistance, and budgetary
358 limitations. Addressing these challenges will require phased planning, incentive-based
359 mechanisms, and enhanced inter-agency coordination.

360 “Establishment and development of participatory structures” emphasize the importance of
361 inclusive and coordinated decision-making structures across the Lake Urmia basin.
362 Establishing a representative water council consisting of stakeholders from local, provincial,
363 and national levels can improve transparency, reconcile competing interests, and support more
364 accountable policy processes. A formally institutionalized council with clearly defined
365 mandates can provide long-term continuity for stakeholder engagement. Complementary

366 structures, such as a multi-level decision-making committee dedicated to Lake Urmia, can
367 ensure timely action on urgent issues while maintaining policy coherence across administrative
368 levels. Accurate stakeholder identification and clear role distribution further minimize
369 institutional overlap and potential conflicts. Supporting NGOs through capacity building,
370 resource provision, and dedicated dialogue platforms strengthens community oversight and
371 encourages civil society participation in governance. Farmer-led associations also play a
372 critical role by integrating indigenous knowledge and enhancing local ownership of water
373 management initiatives. Knowledge exchange through university–community partnerships and
374 international cooperation projects enriches the governance process by linking scientific
375 research with practical expertise. Nevertheless, political and institutional barriers may
376 undermine participation efforts; therefore, formalizing participation frameworks, ensuring
377 legal clarity, and providing stable funding remain essential to strengthen participatory
378 structures.

379 “Institutional monitoring, transparency, and accountability” form another critical dimension of
380 sustainable water governance in the Lake Urmia basin. Public access to reliable water data and
381 consistent reporting builds the foundation for informed decision-making and trust among
382 stakeholders. Developing integrated monitoring systems, such as basin-wide data dashboards,
383 groundwater audits based on remote sensing, and annual state of the basin reports, enhances
384 oversight and reduces inefficiencies. Technological tools, including GIS and remote sensing,
385 can significantly improve the accuracy of monitoring water extraction and allocation.
386 Furthermore, drought management strategies must transition from reactive measures to
387 proactive planning based on climate scenarios and risk assessments. Strengthening
388 accountability mechanisms through clear institutional responsibilities and comprehensive
389 management plans helps reduce conflicts and ensures more consistent policy implementation.
390 Environmental impact assessments also play a key role in aligning agricultural development
391 with ecological preservation. However, challenges persist, including limited data-sharing
392 between agencies and administrative fragmentation. These issues highlight the need for
393 standardized data-governance protocols, inter-organizational agreements, and stronger
394 regulatory oversight to ensure cohesive implementation.

395 “Innovative sustainability-oriented directions” strategies provide additional opportunities for
396 optimizing water use in agriculture within the Lake Urmia basin. Experts emphasize the
397 importance of adopting modern agricultural technologies, such as advanced irrigation systems,
398 drought-resistant crop varieties, and smart monitoring technologies, to enhance water-use

399 **efficiency**. The use of simulation models enables policymakers to better predict climate impacts
400 and evaluate the consequences of different water management scenarios. Infrastructure
401 rehabilitation, including repairing irrigation canals and updating aging water-delivery systems,
402 can reduce conveyance losses. Similarly, promoting wastewater recycling and reuse in
403 agriculture contributes to resource diversification and reduces pressure on freshwater supplies.
404 Reducing cultivation in highly stressed areas is also essential to ensure long-term ecosystem
405 stability. Practical strategies for implementation include farmer training programs, investment
406 in the development of smart water technologies, strengthening applied research institutions,
407 prioritizing infrastructure rehabilitation based on hydrological assessments, and creating
408 incentives for treated wastewater use. **Yet, high investment costs, limited adoption among
409 farmers, and technical capacity gaps pose implementation challenges. Addressing these
410 barriers requires phased financing, demonstration farms, and incentive-based adoption
411 mechanisms.**

412 “Education, extension, and the development of sustainable agricultural practices” constitute
413 another essential pillar of water governance in the Lake Urmia basin. Effective governance
414 requires improving the knowledge, attitudes, and behaviors of farmers and other stakeholders
415 regarding sustainable water use. Beyond increasing technical capacity, educational initiatives
416 should incorporate cultural and social dimensions to foster long-lasting behavioral change.
417 Training programs focusing on precision agriculture, smart irrigation, and environmentally
418 responsible farming practices can significantly reduce water withdrawals. Culturally relevant
419 communication efforts, such as local events, festivals, and multimedia content adapted to
420 regional dialects, strengthen the sense of community responsibility toward water resources.
421 Encouraging sustainable consumption patterns further supports water conservation goals.
422 **However, limited institutional capacity, insufficient long-term funding, and resistance to
423 change may hinder educational efforts. Mitigation strategies include involving community
424 leaders, forming local facilitation teams, and ensuring stable financial support for outreach
425 programs.**

426 “Justice-centered, rule of law and legal strategies” are fundamental for ensuring equitable and
427 sustainable water governance in the Lake Urmia basin. Revising and strengthening water-
428 related legislation to reflect regional environmental and socio-economic realities provides the
429 foundation for effective governance. Equitable water allocation safeguards the rights of
430 vulnerable farmers while promoting efficient use across agricultural systems. Achieving this
431 requires clear legal frameworks, transparent enforcement procedures, and mechanisms to

432 prevent overextraction. Financial and credit facilities targeted at smallholder farmers help
433 reduce economic barriers to adopting water-saving technologies. Simplifying legal procedures
434 and communicating them effectively can enhance compliance and promote broader
435 participation. Key actions include establishing expert legal working groups to review and
436 reform existing legislation, launching awareness campaigns to emphasize justice in water
437 distribution, improving water rights registration systems, and developing flexible financing
438 mechanisms tailored to farmers' needs. Persistent barriers, such as weak enforcement capacity,
439 bureaucratic delays, and low trust, highlight the need for stronger local enforcement
440 institutions, alternative dispute-resolution mechanisms, and farmer-government liaison units to
441 support implementation.

442

443 5. Conclusions

444 This study shows the importance of a fundamental review of existing structures and approaches
445 to agricultural water governance in the Lake Urmia basin. The key identified components,
446 including “establishment and development of participatory structures,” “education, extension,
447 and development of sustainable agricultural practices,” “innovative sustainability-oriented
448 directions,” “institutional monitoring, transparency, and accountability,” “integrated basin-
449 based policymaking,” and an emphasis on “justice-centered, rule of law and legal strategies,”
450 provide a comprehensive framework for designing an effective governance system. These
451 components, as a multidimensional and complex foundation, indicate that water governance is
452 not merely a technical issue but requires a holistic and integrative perspective encompassing
453 social, political, and environmental dimensions. Moreover, this research, utilizing the Delphi
454 technique and converging expert views, elucidates the complex governance challenges within
455 the geographic scope of the study and clarifies its fundamental obstacles. These challenges
456 include the translational and imitative approach to water resource management models
457 incompatible with local conditions, the exacerbating impact of populist policies on the water
458 crisis, the limited role of the public in the decision-making process, and the misalignment of
459 development patterns with the region's hydrological realities. These issues further emphasize
460 the necessity of a comprehensive approach that engages all stakeholders, pays particular
461 attention to localizing solutions, and enhances the interaction between government and civil
462 society. Accordingly, success in integrated water resources management in the Lake Urmia
463 basin requires policy alignment with the region's environmental and social characteristics and
464 the strengthening of institutional and human capacities, which can constitute an effective step

465 toward addressing water crises and ensuring the sustainability of the region's sensitive
466 ecosystems. The findings can guide the implementation of policies and governance reforms in
467 the basin and can be integrated into regional planning processes to ensure coordinated and
468 practical actions. Accordingly, the identified indicators should be pilot tested under real water
469 management conditions to assess their applicability.

470 5.1. Limitations and Future Directions

471 This study faced several limitations that could shed light on the direction of future research.
472 First, the relatively limited size of the Delphi panel may have reduced the diversity of
473 perspectives and the complete coverage of the basin's stakeholders; therefore, expanding the
474 panel and utilizing more diverse groups in future studies is recommended. Second, relying
475 solely on subjective judgments of experts could potentially affect the objectivity of the results,
476 so the use of secondary data and organizational documentation is necessary to strengthen the
477 validity of the findings. Third, the extracted indicators have not been empirically tested;
478 therefore, field evaluation and piloting of the indicators in real water management conditions
479 can clarify their applicability. Finally, the limitation of the research to the Lake Urmia basin
480 limits the generalizability of the results, and conducting similar studies in other basins can help
481 identify common or specific indicators.

482

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489

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678 **پیشبرد حکمرانی پایدار آب در کشاورزی: بینش‌هایی از یک مطالعه دلفی در حوضه دریاچه ارومیه**
679 **ایران**

680 **لطیف حاجی، و نگین فلاح حقیقی**

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چکیده

683 چالش‌های پیش روی آب، کشاورزی پایدار و امنیت غذایی، نیاز به حکمرانی مؤثر آب را برجسته می‌کند. این مطالعه از
684 تکنیک دلفی برای شناسایی گام‌های عملی برای حکمرانی پایدار آب در حوزه کشاورزی دریاچه ارومیه استفاده کرد. 17
685 متخصص با پیشینه‌های دانشگاهی، سازمانی و محلی به صورت هدفمند از طریق نمونه‌گیری گلوله برفی انتخاب شدند.
686 سه دور دلفی انجام شد (به ترتیب 17، 17 و 14 شرکت‌کننده) که اجماع به عنوان حداقل 70٪ توافق تعریف شده است.
687 این مطالعه به طور منحصر به فرد دلفی را در زمینه آبی-اجتماعی حوزه دریاچه ارومیه به کار می‌برد و بینش‌های
688 متخصصان مختلف را ترکیب می‌کند. در مورد 51 شاخص در شش مؤلفه، با تأکید بر «سیاست‌گذاری یکپارچه و مبتنی
689 بر حوزه»، «ایجاد و توسعه ساختارهای مشارکتی»، «نظارت نهادی، شفافیت و پاسخگویی»، «جهت‌گیری‌های نوآورانه
690 مبتنی بر پایداری»، «آموزش، ترویج و توسعه شیوه‌های کشاورزی پایدار» و «استراتژی‌های عدالت‌محور، حاکمیت
691 قانون و حقوقی»، اجماع حاصل شد. محدودیت‌ها شامل حجم نمونه کوچک و چالش بالقوه تعمیم یافته‌ها به فراتر از حوزه
692 مورد مطالعه است. این نتایج، پایه و اساسی برای تصمیمات آتی در مورد مدیریت آب و ابتکارات آگاهی‌بخشی عمومی
693 فراهم می‌کند.
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