



## Assessment of Ilam Dam water quality using TLI, TSI, TSIM, and IRWQI indices

Ehsan Fathi<sup>1</sup>, Mohammadreza Ekhtesasi<sup>2</sup>, Ali Talebi<sup>2</sup>, and Jamal Mosaffaie<sup>3</sup><sup>1</sup>Faculty of Natural Resources and Desert Studies, Yazd University, Yazd, Iran<sup>2</sup>Department of Water Science and Engineering, College of Agriculture, Isfahan University of Technology, Isfahan, Iran<sup>3</sup>Soil Conservation and Watershed Management Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran

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### ABSTRACT

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**Corresponding author:**

E. Fathi

✉ [mr\\_fkhtesasi@yazd.ac.ir](mailto:mr_fkhtesasi@yazd.ac.ir)

The prevention of water resource degradation and the monitoring of pollution are of particular importance. This study examined the water quality of the Ilam Dam, situated in Ilam Province, using the TLI, TSI, TSIM, and IRWQI indices, and analyzes the impact of various factors on its quality. Water quality parameters, including BOD, DO, pH, EC, nitrate, COD, ammonium, phosphate, turbidity, total hardness, total phosphorus, total nitrogen, Secchi disk depth, and chlorophyll a, were measured at 4 stations over 6 months from April to September 2023. Based on the obtained results, the IRWQI values ranged from 47.1 to 65.4, indicating water quality from moderate to relatively good. Additionally, the TSI values ranged from 54.2 to 61.27, and the TLI values were between 4.33 and 4.9, with both indices indicating eutrophic water conditions. Furthermore, the TSI<sub>M</sub> index, with values ranging from 43.9 to 54.67, indicated a status ranging from mesotrophic to eutrophic. The inflow of pollutants into the reservoir poses a threat to the water quality. Accurate monitoring, increasing the number of sampling stations, waste and wastewater management, and watershed management can improve the water quality. Continuous monitoring and stricter regulations to control pollution and reduce nutrient inputs are essential for preserving ecosystem health. The findings of this study provide a foundation for developing water resource protection programs and improving water quality.

**Highlights**

- Comprehensive water quality assessment using TLI, TSI, TSIM, and IRWQI indices.
- Results indicated moderate to relatively good quality, with signs of eutrophication.
- Nutrient enrichment and pollution inputs identified as main threats.
- Emphasis on continuous monitoring, watershed management, and stricter regulations for protection.

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### 1. Introduction

Eutrophication is a process that occurs due to the excessive input of nutrients such as phosphates and nitrates into natural waters, including lakes, rivers, wetlands, and coastal areas. This phenomenon not only affects the environment but can also have adverse impacts on the economy and public wellbeing. Excessive nutrients may accelerate algal growth, which in turn reduces oxygen levels in the water, decreases water quality, and leads to the death of fish and other aquatic organisms (Escobar et al., 2023). Moreover, drinking water derived from contaminated sources may cause gastrointestinal, respiratory, or other health problems (US EPA, 2023). Water

quality plays a crucial role in determining the ecological environment and public health (Lu et al., 2015; Shi et al., 2017). Fresh, clean, and safe water is a key resource for economic and social development (Perez-Gutierrez et al., 2017). The deterioration of water quality caused by point and non-point sources of pollution is a global environmental challenge (Zielinski et al., 2016; Shoemaker et al., 2017). Nowadays, due to the large volume of pollutants discharged into the environment and the continuous growth of the world's population, water has emerged as a global crisis (Mahrooyan et al., 2021). In today's society, not only the quantity of water but also its quality is of great concern (Amini & Hesami,

2017). Research has demonstrated that many diseases are associated with poor water quality. Consequently, considerable expenditures are allocated to the provision of safe water, which, given its role in improving public health, is regarded as a sound investment with substantial benefits (Ebrahimpour & Mohammadzadeh, 2014; Ababakr, et al. 2023). Natural processes such as precipitation, erosion, and weathering of materials, atmospheric chemistry, geology, vegetation cover, and the dissolution of organic matter (Yidana et al., 2008), along with anthropogenic activities such as urban, industrial, and agricultural practices (Papatheodorou et al., 2006), influence water quality. Since surface waters are more vulnerable than groundwater due to their easier accessibility for wastewater disposal, regular analysis of their quality data allows for both their utilization in various sectors and the implementation of proper and effective management strategies (Nosrati et al., 2011). One of the simplest methods for assessing water quality is the use of water quality indices. These indices are valuable tools in water quality management and can play an effective role in managerial decision-making (Avvannavar & Shrihari, 2008; Fathi & Ahmadifard, 2020). Moreover, by applying water quality indices, a large volume of sampling data is converted into a single, dimensionless value that conveys an interpretable qualitative meaning (Mohseni-Bandpey et al., 2014; Abedini et al., 2021).

On the other hand, by simplifying raw data, these indices not only express water quality but also examine its variations over time and space, while identifying and managing areas that are more exposed to pollution. Various indices have been employed to evaluate and determine the quality conditions of rivers, dams, wetlands, and lakes, among which Trophic level index, Trophic State Index, Improving Carlson's TSI and IRan Water Quality Index for Surface Water Resources-Conventional Parameters can be mentioned. Due to their simplicity and wide applicability, these indices hold significant importance (House, 1989; Avvannavar & Shrihari, 2008). These indices have been widely applied for monitoring water quality parameters (Chu & He, 2023). In this study, the TLI, TSI, TSIM, and IRWQIsc indices will be used to assess the water quality of the Ilam Dam. These indices are of great importance due to their simplicity in calculation and their ability to interpret the trophic status and overall water quality. The TLI, TSI, and TSIM indices determine the trophic status of the reservoir and allow for the assessment of water quality variations over time. On the other hand, the IRWQIsc index, which is a native index for Iran's water resources, evaluates the overall water quality of the dam from various perspectives and is used as a management tool in decision-making related to monitoring and improving water quality. The use of these indices enables the comparison of water quality across different time periods and contributes to a better understanding of qualitative change trends and the impacts of environmental and anthropogenic factors.

Considering the importance of this issue, numerous studies have been conducted to assess the quality of water resources, and a few of them are mentioned here. El-Serehy et al. (2018) assessed the water quality and classified the trophic status of Lake Timsah using the TSI, TLI, and Water Quality Index (WQI). The results showed that Lake Timsah had a TSI of 60 and a TLI of 2.5, both of which reflect the eutrophic condition

of the lake's water. In addition, the WQI value, with an average of 49, indicated that the water of Lake Timsah was poor and unsuitable for primary uses. Bilgin (2020) investigated the trophic status of the Borçka Dam reservoir in Turkey using the Trophic State Index (TSI) and the Trophic Level Index (TLI), and accordingly classified the reservoir conditions as mesotrophic based on these two indices. Feyzi et al. (2023) employed the TLI, TSI, and WQINSF indices to assess the water quality of Zarivar Lake in Kurdistan Province. The results indicated that, according to the TLI, Zarivar Lake, with a numerical value of 25.6, fell into the hypertrophic category, while based on the TSI, with a value of 64.06, it was classified as eutrophic. Also, based on the NSFQI index, Zarivar Lake, with a value of 55.7, was classified as being in a moderate condition. Khalili et al. (2020) used three indices NSFQI, RPI, and WAWQI to assess the water quality of the Germarud River. For the calculation of the indices, the following parameters were used: DO, temperature, BOD, fecal coliform, turbidity, TS, pH, ammonium nitrogen, nitrate phosphate, chloride, total hardness, sulfate, magnesium, and calcium. The results showed that the value of the NSFQI index ranged from 50.26 to 75.6, the value of the RPI index ranged from 2.25 to 5.5, and the value of the WAWQI index ranged from 33.92 to 48.55. The results of all three indices indicated relatively good quality at station No. 1 and poor quality at stations No. 2 and 3. Gençer & Basaran (2024), with the aim of examining the water quality of the Akarçay River in Turkey for drinking and irrigation purposes, used the Water Quality Index (WQI) and the indices of Sodium Adsorption Ratio, Residual Sodium Carbonate, and Magnesium Hazard. The results showed that, due to the high levels of certain parameters such as salinity, iron, and manganese, the river water is unsuitable for irrigation and drinking purposes. A review of various studies on the assessment of trophic status and water quality indicates that these indices are effective tools for monitoring and managing water resources. Research has shown that the application of these indices in different parts of the world has contributed to accurately identifying the trophic status and water quality and has provided reliable results. These reviews highlight the importance of using a combination of multiple quality indices to achieve a more accurate and comprehensive assessment and emphasize that continuous monitoring and data analysis can contribute to the improvement of water resource management and protection. The high quality of surface waters and rivers is of great significance for human health as well as economic and social development (Ghamarnia et al., 2022). Given the increasing demand for the utilization of surface water resources, protecting these resources against pollution is of particular importance. In this regard, examining the trophic status and water quality of dam reservoirs is considered one of the fundamental approaches in water resources management. The Ilam Dam, which plays an important role in supplying drinking water, irrigation, agriculture, and flood control, faces serious challenges in terms of water quality due to the inflow of pollutants such as wastewater from upstream villages, livestock waste, and agricultural drainage. This issue can negatively affect the sustainability of water resources, public

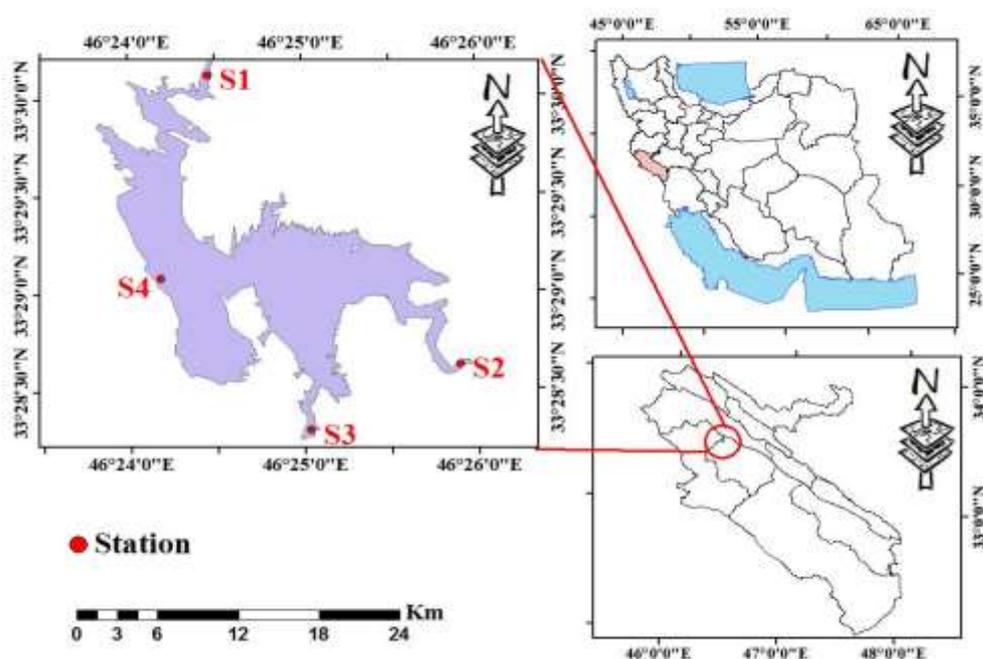
health, and the productivity of the agricultural sector. Therefore, monitoring and assessing the trophic status of the dam and examining changes in its water quality are not only essential for identifying pollution sources and determining the trend of qualitative changes but can also contribute to developing effective management strategies to improve water quality, reduce environmental risks, and increase the efficiency of water resources. For this reason, in the present study, the water quality of the Ilam Dam is evaluated using the TLI, TSI, TSIM, and IRWQIsc indices, and depending on the degree of water quality at different sampling stations, the potential pollution source will be identified.

## 2. Materials and Methods

### 2.1 Study area

The Ilam (Cham-Gerdalan) reservoir dam, with a capacity of 64 million cubic meters, is located 22 km southeast of Ilam city within the Ilam Dam watershed, at the geographical coordinates of 46°15'50" to 46°38'56" E longitude and 33°23'24" to 33°38'56" N latitude. This dam was constructed to supply drinking water to Ilam city, control floods, and

**Fig. 1** Location map of sampling stations at Ilam Dam



### 2.2 Research method

In order to evaluate the water quality of the Ilam Dam, all experiments were repeated at least three times to minimize laboratory error. After sampling, the samples were transported to the laboratory in the presence of ice at a temperature of 4°C and stored in a refrigerator until the analysis process began. The analysis of the samples was carried out immediately after transfer. All procedures for sterilizing sampling containers, transportation, and storage in the laboratory were conducted in accordance with the guidelines provided in the Standard Methods, 2017 edition. The parameters of EC, pH, and DO were measured in the field using the HQ30d Portable device manufactured by HACH, and turbidity was measured using the Aqualytic turbidity meter. The remaining parameters were transferred to the laboratory for further analysis.

irrigating agricultural lands in the region, at the confluence of the three rivers of Golgol, Emma, and Chaviz, which ultimately form the Konjan Cham River. The average annual precipitation in this watershed during the statistical period of 2011–2021 is about 560 mm, while the mean maximum and minimum temperatures are 23.25 °C and 11.06 °C, respectively. Given the limitation of groundwater resources around Ilam city, the construction of the mentioned dam for water storage, as the most important source of drinking water (amounting to 16.8 million cubic meters per year) and the closest water source to the provincial center, can have significant socio-economic importance. To obtain the necessary information for examining the status and quality of Ilam Dam water, sampling was conducted from April to September 2023 at four stations, with measurements of physical and biochemical parameters. The selection of sampling points was made by considering the dam's inflow and outflow points as well as areas prone to pollutant accumulation. The location of the study area and the sampling stations is shown in Fig. 1.

### 2.3 Iranian water quality index

Iranian water quality index (IRWQI) is based on the most common parameters of surface water quality in Iran and has been introduced by the Department of Environment of Iran. The IRWQI is obtained from Eq.1 (Hashemi et al., 2011).

$$IRWQI = \left[ \prod_{i=1}^N I_i^{w_i} \right]^{\frac{1}{y}} \quad ; \quad y = \sum w_i \quad (1)$$

where,  $W_i$  represents the weight of the  $i$ -th parameter,  $N$  denotes the number of parameters, and  $I_i$  indicates the index value for the  $i$ -th parameter. Table 1 presents the parameters of this index along with the relative weight of each parameter. Table 2 shows the classification of water quality according to this index (Hashemi et al., 2011).

**Table 1** Weight values of each parameter in the IRWQIsc Index

Parameters	Weight
Fecal coliform	0.140
BOD <sub>5</sub>	0.117
Nitrates	0.108
Dissolved oxygen	0.097
Electrical conductivity	0.096
COD	0.093
Ammonia	0.090
Phosphates	0.087
Turbidity	0.062
Hardness	0.059
pH	0.051
Total	1

**Table 2** Water quality classification based on the IRWQIsc Index (Hashemi et al., 2011)

WQI value	>85	70.1–85	55.1– 70	45 – 55	30 – 44.9	15 - 29.9	15>
Status	Excellent	Good	Fairly good	Moderate	Fairly bad	Bad	Very bad

**2.3 Eutrophication assessment indices**

**2.3.1 Trophic state index**

The Trophic State Index (TSI) is calculated using the logarithmic transformation (Ln) based on the parameters of chlorophyll-a concentration (Chl. a) (Eq. 2), Secchi disk depth (SD) (Equation 3), and total phosphorus (TP) (Equation 4). The final TSI value is obtained according to Equation 5 (Carlson, 1977). Table 3 presents the classification of lakes based on the TSI.

$$TSI_{(Chl)} = 9.81 \ln (Chl-a) + 30.6 \tag{2}$$

$$TSI_{(SD)} = 60 - 14.41 \ln(SD) \tag{3}$$

$$TSI_{(TP)} = 14.42 \ln(TP) + 4.15 (\mu g/l) \tag{4}$$

$$Total_{(TSI)} = \frac{TSI_{(Chl)} + TSI_{(SD)} + TSI_{(TP)}}{3} \tag{5}$$

Where, Chl a is expressed in  $\mu g/l$ , Secchi disk depth (SD) in meters, and TP in  $\mu g/l$ .

Table 3 Classification of lakes based on trophic status using the TSI Index (Lee & Lin 2000; Agency 2000)

TSI	trophic status	SD(m)	Chl. a( $\mu g/l$ )	TP( $\mu g/l$ )
40 >	Oligotrophic	4<	>2.6	12>
40 -50	Mesotrophic	2-4	2.6-7.2	12-24
50 -70	Eutrophic	0.2-0.5	7.6-55.5	24-70
70 <	Hypereutrophic	0.5>	>55.5	96<

**2.3.2 Trophic level index**

Burns et al. (2005) modified the Trophic Level Index (TLI) developed by Carlson (1977) into the TLI (Trophic Level Index). Both indices (TSI and TLI) use the values of chlorophyll a concentration (Chl. a), Secchi disk depth (SD), and total phosphorus (TP). However, the TLI also includes total nitrogen (TN). The numerical values of the TLI for assessing trophic status are calculated using Equation 6 for chlorophyll-a concentration (Chl. a), Equation 7 for Secchi disk depth (SD), Equation 8 for total phosphorus (TP,  $\mu g/l$ ), Equation 9 for total nitrogen (TN), and Equation 10 for the final TLI (Burns et al., 2005). Each of these parameters alone

is also indicative of the trophic state. The values of the TLI and its variables are presented in Table 4.

$$TL_{(Chl)} = 2.22 + 2.54 \log (Chl) \tag{6}$$

$$TL_{(SD)} = 5.10 + 2.60 \log (1/SD - 1/40) \tag{7}$$

$$TL_{(TP)} = 0.218 + 2.92 \log (TP) \tag{8}$$

$$TL(TN) = -3.61 + 3.01 \log (TN) \tag{9}$$

$$TLI = \frac{TLI (TP) + TLI (TN) + TLI (CA) + TLI (SD)}{4} \tag{10}$$

where, Chl a is expressed in  $\mu g/l$ , Secchi disk depth (SD) in meters, and both TP and TN are expressed in  $\mu g/l$ .

Table 4 TLI index values and corresponding trophic categories (Bryers & Bowman 2000)

trophic status	Nutrient Enrichment	TLI	Chl. a( $\mu g/l$ )	SD(m)	TP( $\mu g/l$ )	TN( $\mu g/l$ )
Ultramicrotroph	Absolutely Pure	0-1	0.33>	25<	1.8>	34>
Microtroph	Very Low	1-2	0.33-0.82	15-25	1.8-4.1	34-73
Oligotrophic	Low	2-3	0.82-2	7-15	4.1-9	73-157
Mesotrophic	Moderate	3-4	2-5	2.8-7	9-20	157-337
Eutrophic	High	4-5	5-12	1.1-2.8	20-43	337-725
Supertrophy	Very High	5-6	12-31	0.4-1.1	43-96	725-1558
Hypereutrophic	Saturated	6<	31<	0.4>	96<	1558<

### 2.3.3 Modified trophic state index

To overcome the limitations of Carlson’s Modified Trophic State Index (TSIM), a new method called the Modified Trophic State Index (TSIM) was proposed (Aizaki et al., 1981; Torres-Franco et al., 2018; Wen et al., 2019).

In this index, the parameters of chlorophyll-a TSIM (Chl-a), Secchi disk depth TSIM (SD), and total phosphorus TSIM

$$TSI_M = 0.54 \times TSI_M(\text{Chl-a}) + 0.297 \times TSI_M(\text{SD}) + 0.163 \times TSI_M(\text{TP}) \tag{14}$$

where, SD in meters (m), TP concentration in micrograms per liter (µg/l), and chl-a concentration in micrograms per liter (µg/l). According to the TSIM index, the trophic status of lakes is classified into three categories. Lakes with a TSIM value less than or equal to 30 are considered oligotrophic, which indicates low nutrient levels and high-water transparency. Values between 30 and 50 indicate a mesotrophic state, representing moderate conditions in terms of nutrients and biological productivity. Finally, when the TSIM value exceeds 50, the lake is classified as eutrophic, which reflects high nutrient enrichment, increased algal growth, and a decline in water quality.

## 3. Results and Discussion

### 3.1 Analysis of physicochemical water parameters

(TP) are calculated according to Equations 11, 12, and 13, respectively. The final TSIM value is obtained from Eq. 14.

$$TSI_{M(\text{chl-a})} = 10 \times \left( 2.46 + \frac{\ln \text{chl-a}}{\ln 2.5} \right) \tag{11}$$

$$TSI_{M(\text{SD})} = 10 \times \left( 2.46 + \frac{3.69 - 1.53 \ln \text{SD}}{\ln 2.5} \right) \tag{12}$$

$$TSI_{M(\text{TP})} = 10 \times \left( 2.46 + \frac{6.7 + 1.15 \ln \text{TP}}{\ln 2.5} \right) \tag{13}$$

Continuous monitoring and evaluation of water quality is a key issue for protection and sustainable management. Reservoirs and lakes are often exposed to sudden environmental changes caused by various human activities (industrial, agricultural, water supply, recreational, etc.) and tourism. Therefore, it is necessary to identify ecological approaches for protecting the valuable water resources of lakes and reservoirs. The results obtained from measuring the trophic indices TSI, TSIM, TLI, and IRWQI indicate the water quality status of the Ilam Dam during different months from April to September 2023. Table 5 presents the minimum, maximum, mean, and standard deviation values of the measured physicochemical parameters, along with the trophic state index (TSI), trophic level index (TLI), TSIM, and water quality index (IRWQI) in the Ilam Dam.

**Table 5** Minimum, maximum, mean, and standard deviation of measured physicochemical parameters

Parameter	Unit	Minimum	Maximum	Average	Standard deviation
DO	mg/l	5.2	10.5	7.20	1.31
BOD	mg/l	1.3	3.9	2.83	0.81
COD	mg/l	5.9	11.7	8.44	1.61
PH	-	6.8	9.1	8.16	0.51
Nitrate	mg/l	5.6	13	8.96	2.21
Ammonium	mg/l	0.01	0.21	0.08	0.07
Turbidity	NTU	1.8	16	9.52	4.53
Phosphate	mg/l	0.015	0.144	0.07	0.04
TH	mg/l	180	270	220.75	28.38
EC	µs/cm	353	1782	654.25	329.61
chl-a	µg/l	1.1	8.3	4.11	3.27
SD	m	1.4	3.8	2.48	0.98
TP	µg/l	230	310	274.16	32.15
TN	µg/l	1910	2450	2161.66	208.53

Table 6 presents the values and trophic status of Ilam Dam based on the Trophic State Index (TSI), the Trophic Level Index (TLI), and TSIM, as well as the water quality status

of Ilam Dam according to the mean value of the Iranian Surface Water Quality Index (IRWQI) during the six months under study.

**Table 6** Values and water quality status of the Ilam Dam based on TLI, TSI, TSIM indices, and the average IRWQI

Indices month	TSI		TSI <sub>M</sub>		TLI		IRWQI	
	Amount	status	Amount	status	Amount	status	Amount	status
April	54.2	Eutrophic	43.9	Mesotrophic	4.33	Eutrophic	57.57	Fairly good
May	56.63	Eutrophic	45.47	Mesotrophic	4.51	Eutrophic	61.42	Fairly good
June	58.42	Eutrophic	47.88	Mesotrophic	4.53	Eutrophic	58.65	Fairly good
July	61.27	Eutrophic	53.43	Eutrophic	4.9	Eutrophic	55.75	Fairly good
August	57.99	Eutrophic	53.33	Eutrophic	4.59	Eutrophic	57.17	Fairly good
September	59.92	Eutrophic	54.67	Eutrophic	4.7	Eutrophic	60.72	Fairly good

### 3.2 Trophic state assessment indices

The TSI index in all months falls within the eutrophic range, indicating a high level of trophic status and the presence of excessive nutrients in the water. This condition can lead to excessive algal growth, resulting in reduced water quality and environmental problems. The highest TSI value was observed in July (61.27), reflecting a more severe eutrophic state during this month. This increase may be attributed to higher temperatures, increased evaporation, and reduced surface inflows, which lead to greater nutrient concentration in the water. Prasad et al. (2024) employed the TSI index in their study to assess Beira Lake in Sri Lanka, which has been heavily influenced by human activities. The results indicated that Beira Lake is in eutrophic to hypereutrophic conditions. Opiyo et al. (2019), in their assessment of water quality in Lake Simbi, demonstrated that seasonal nutrient inputs from agricultural and urban sources exacerbate the eutrophic condition. According to Table 3, the results of the trophic status assessment using monthly data showed that from April to June, chlorophyll-a remained within the oligotrophic range, while Secchi disk depth corresponded to the mesotrophic level. In contrast, total phosphorus reached the hypereutrophic level, indicating excessive nutrient availability. From July onward, chlorophyll-a increased and reached the eutrophic level, reflecting intensified algal growth, whereas Secchi disk depth remained at the mesotrophic level. Total phosphorus consistently remained at the hypereutrophic level across all months, suggesting nutrient enrichment and the potential for ecological problems caused by algal blooms and reduced water transparency. This increase may be attributed to higher temperatures, increased evaporation, and reduced surface inflows, which result in greater nutrient concentration in the water.

The TSIM index in April, May, and June falls within the mesotrophic range, while in July, August, and September it shifts to the eutrophic range. This change reflects the increase in algal growth and nutrient enrichment during the second half of the study period (summer season). The highest TSIM values were recorded in July (53.43), August (53.33), and September (54.67), indicating more critical water conditions during these months. The TLI index remained within the eutrophic range throughout all months, which, similar to the TSI, indicates a high trophic state of the water. This situation requires serious attention and the implementation of targeted management strategies to limit nutrient inputs into aquatic resources. By adopting measures such as optimal land-use management,

controlling wastewater discharges, and improving treatment processes, it is possible to prevent the intensification of eutrophication and its negative impacts on water quality and ecosystem balance. The assessment of the trophic state in the reservoir, based on Table 4, indicates that the lake exhibits a combination of mesotrophic to hypertrophic conditions across different months. Chlorophyll-a concentrations and Secchi disk depth are predominantly within the mesotrophic to eutrophic range, whereas total phosphorus and total nitrogen mostly fall into the supereutrophic and hypertrophic categories.

These conditions reflect the presence of excessive nutrients in the water, excessive algal growth, and reduced water transparency, which can lead to ecological problems and deteriorated water quality. In general, the lake experiences nutrient enrichment and variations in trophic indices across different months, necessitating careful management and monitoring to preserve the aquatic ecosystem. Wu et al. (2010) reported that the discharge of domestic wastewater particularly detergents, industrial effluents, and runoff from chemical fertilizers into water bodies leads to increased phosphate concentrations. Moreover, elevated phosphate levels may indicate the continuous presence of pollution originating from human activities. Jamshidi and Naderi (2023), in their study, demonstrated that agricultural activities, including irrigation and land-use changes in upstream areas, are the main sources of nitrogen and phosphorus pollution in the wetland. Researchers have suggested that over the course of a decade, a 50% reduction in the use of chemical fertilizers, livestock manure, and irrigation water could decrease nitrogen pollution by up to 85% and phosphorus pollution by up to 25% (Zamani-Ahmadmoodi et al., 2025). Lenard and Solis (2009), in their research, examined the eutrophication status of three lakes Piaseczno, Rogozno, and Krasne in Poland. Their findings indicated variations in the values of different Carlson index models as a result of increased nitrogen and phosphate concentrations.

### 3.3 Iranian water quality index

The average IRWQI across all months indicates a relatively good status. Although this condition reflects an acceptable water quality, there remains a need for improvement. The highest average IRWQI was observed in May (61.42), while the lowest average was recorded in July (55.75).

**Table 7** Comparison of water quality evaluation indices for the Ilam Dam with various studies

Dam or River	TLI	TSI	TSIm	IRWQI	Reference
Ilam Dam	4.9 – 4.33	61.27 – 54.2	54.67 – 43.9	65.4 – 47.1	present study
Chitgar Lake	-	50 - 29	-	-	Abedini et al. (2021)
Alavian Dam	4.8	53.5	-	-	Aghajanloo (2022)
Malayer Dam	-	-	-	74.4 – 59.1	Merrikhpour et al. (2021)
Babolroud River	-	-	-	73 - 57	Shaker Donyavi et al. (2023)
Służewiecki Stream (Warsaw)	6.5	87 - 83	-	-	Wojtkowska, & Bojanowski, (2021)
Erhai Lake	-	56 - 40	55 - 29	-	Lin et al. (2020)
Zarivar	-	52.2-60.17	-	63.2-72.9	Zamani-Ahmadmoodi et al. (2025)

This fluctuation illustrates variations in water quality during the study period. Such changes may be influenced by various factors, including flow fluctuations, pollutant inflows, and seasonal variations in rainfall and air temperature. The IRWQI values at the studied stations also show that the best water quality, according to this index, occurred at Station 4 in May with a value of 65.4, while the lowest quality was recorded at Station 1 in July with a value of 47.1, indicating a moderate water quality status. Human activities and hydrological conditions have played a role in water quality differences across the studied area. Aghajanloo et al. (2022), using the IRWQI and WAWQI indices and by measuring various physical, chemical, and biological parameters of water, assessed the water quality of the Karun River at two stations, Mollasani and Ahvaz. The results showed that, according to the WAWQI index, the water quality at Mollasani and Ahvaz stations was classified as poor and very poor, respectively, while based on the IRWQI index, it was placed in the relatively poor category. In addition, due to the high values of fecal coliform, TDS and turbidity at both stations, the river water was unsuitable for drinking, agricultural use, and aquatic ecosystem preservation. Table 7 provides a comparison of the TLI, TSI, TSIM, and IRWQI indices in the Ilam Dam with surface water resources in different regions of the world.

#### 4. Conclusion

This study was conducted to assess the water quality of the Ilam Dam using the indices TLI, TSI, TSIM, and IRWQI as analytical methods. The findings indicate that:

1. The trophic level in the reservoir, based on the TLI, TSI, and TSIM indices, is relatively high, reflecting unstable conditions in water quality.
2. The IRWQI assessment revealed that the reservoir water quality, in terms of standard benchmarks, requires improvement, with potential risks arising from surface water pollution and agricultural inflows.
3. The main factors contributing to the decline in water quality include agricultural runoff, wastewater discharge, and excessive use of chemical fertilizers.

To improve water quality and manage water resources, it is recommended to implement sustainable agricultural management programs such as efficient irrigation practices, organic farming, and reducing the use of chemical fertilizers. In addition, the development of advanced wastewater treatment technologies, the establishment of monitoring networks for continuous water quality assessment, and raising public awareness hold particular importance for enhancing water resource management. The practical implications of this research include strengthening the attention and supervision of authorities on watershed and dam management to reduce nutrient loads in water resources, improving the environmental conditions of aquatic ecosystems, and lowering the costs of drinking water treatment. Furthermore, it is suggested that future research focus on the impact of supportive policies in reducing the use of chemical fertilizers, the effectiveness of advanced wastewater treatment methods in nutrient reduction,

and modeling water quality changes considering climate variability and eutrophication trends.

#### Statements and Declarations

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##### Data availability

The data used in this research are provided in the text of the article.

##### Conflicts of interest

The authors of this paper declared no conflict of interest regarding the authorship or publication of this paper.

##### Author contribution

E. Fathi: Writing, Preparing the main draft, Performing calculations and software, Editing the article; M.R. Ekhtesasi: Analyzing and reviewing data, Supervising the research process; A Talebi: Analyzing and reviewing data, Supervising the research process; J Mosaffaie: Analyzing and reviewing data, and Supervising the research process.

##### AI Use Declaration

This study did not incorporate artificial intelligence techniques; instead, all analyses and optimizations were conducted using conventional and widely accepted analytical methods.

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