

Temporal and spatial distribution of physicochemical parameters and water quality indices in an oligotrophic dam lake: A case of Maksutlu Dam Lake, Sivas, Türkiye

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Abstract: This study was conducted at three selected stations in Maksutlu Dam Lake (Şarkışla, Sivas), covering both the dry season (August 2023) and the rainy season (May 2024). Water samples were collected from the lake and a total of 18 physicochemical parameters were analyzed. The eutrophication index (*EI*), organic pollution index (*OPI*) and nutrient pollution index (*NPI*) values were calculated for both seasons based on the physicochemical parameters of the lake water. Additionally, a Geographic Information System (GIS) was used to show the seasonal variation in index values. Bray–Curtis and Pearson correlation analyses were applied to the physicochemical parameters of the water. As a result, it was found that both the physicochemical parameters and water quality indices of the lake exhibited seasonal variation. Phosphate pollution was detected in the lake and it was found that the lake may be oligotrophic in terms of NO_3 and Mg values. Several suggestions were also made for the sustainable management of the dam lake.

Keywords: geographic information system; reservoir; organic pollution index.

INTRODUCTION

Dam lakes are aquatic ecosystems formed by the accumulation of water in large areas behind embankments, created by building a dike across a river valley, typically at its narrowest point. While dam lakes were once the primary sources of drinking water and agricultural irrigation, they now play a significant role in activities such as energy production, transportation, industry and tourism. Dam lakes are also crucial structures for flood protection. Acidification, eutrophication, and various changes in hydrology and geomorphology are the primary pressures affecting the integrity of these lakes.²

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33 The excessive input of plant nutrients, particularly nitrogen and phosphorus,
34 into lakes promotes the growth of organic matter, algae, periphyton and macro-
35 phytes, leading to eutrophication. This growth results in changes to aquatic org-
36 anisms and water quality.³ As a consequence of eutrophication, decreases in dis-
37 solved oxygen levels can lead to hypoxia and toxic algal blooms.³

38 Human activities, including domestic and industrial wastewater discharge and
39 agricultural runoff, contribute to the physical, chemical, and biological pollution
40 of freshwater resources, leading to the deterioration of water quality. This situation
41 also limits the use of freshwater resources for various purposes.⁴ Additionally,
42 intensive and excessive use of these resources can harm both the environment and
43 the organisms that depend on them.

44 Sivas Province is located in the central part of the Anatolian Peninsula, in the
45 Upper Kızılırmak section of the Central Anatolia Region. The province, with an
46 average altitude of over 1,000 m, exhibits continental climate characteristics. Sum-
47 mers are very hot, dry and short, while winters are cold, long and snowy. There are
48 15 dam lakes in Sivas Province, used for irrigation, energy production and drinking
49 water. In the Şarkışla district, there are three dam lakes: Maksutlu, Yapıaltı and
50 Kanak. Kanak Dam was built to meet the drinking and utility water needs in Şar-
51 kışla and to irrigate agricultural lands. Maksutlu and Yapıaltı dams are primarily
52 used for irrigation. Recreation and picnic areas are located around Maksutlu Dam
53 Lake, which is situated close to the Şarkışla district center.⁵

54 There are few studies on the dam lakes in Şarkışla.^{6,7} One study evaluated
55 both the physicochemical data and benthic macroinvertebrates of Kanak Dam Lake
56 by sampling water and benthos monthly for one year.⁶ Another study compared
57 the filling rates of Maksutlu Dam Lake between 2010 and 2019.⁷ It emphasized
58 that there were decreases in the filling rates of the dam due to drought and that the
59 dam lake should be used rationally. The study also reported that necessary meas-
60 ures should be taken to address the water crisis that may occur during dry periods
61 and that a water management plan should be prepared for Maksutlu Dam Lake.

62 This study examined certain physicochemical parameters during both the dry
63 and rainy periods of Maksutlu Dam Lake, which has not been studied in detail
64 before. First, water quality values were determined according to various criteria.^{8,9}
65 Second, three different water quality indices were applied to the physicochemical
66 parameters. Third, the spatial distribution of the index values across the dam lake
67 was mapped using the IDW interpolation method. Fourth, the relationships between
68 the physicochemical data were investigated using various statistical methods. Fin-
69 ally, several recommendations were made for the sustainable use of the dam lake.

70 EXPERIMENTAL

71 Details related to the sampling locations are given in the Supplementary material to this
72 paper.

73 The research was conducted through both field and laboratory work. During the fieldwork,
 74 water temperature was measured using a simple thermometer (°C), electrical conductivity (EC)
 75 was measured with a conductivity meter ($\mu\text{S cm}^{-1}$), pH was determined using a pH meter and
 76 total dissolved solids (TDS) were measured with a portable device (ppm). For the measurement
 77 of other physicochemical parameters (DO , BOD_5 , COD , Cl, salinity, Ca, Mg, total hardness
 78 (TH), NO_3^- , NO_2^- , NH_4^+ -N, SO_4^{2-} , PO_4^{3-}), water samples were collected using a Ruttner water
 79 sampler and transferred to the laboratory in 2-L dark glass bottles.

80 The water samples brought to the laboratory were prepared for analysis without delay.
 81 Classical titrimetric and spectrophotometric methods were used for this purpose.¹⁰ The quality
 82 of the water samples was determined according to specific criteria.^{8,9}

83 All statistical data were analyzed using Microsoft Office Excel 20 (LogBase10) and SPSS
 84 9.0 software to reveal the similarity between stations and physicochemical parameters.¹¹ The
 85 relationship between physicochemical parameters was examined using Pearson correlation ana-
 86 lysis conducted in IBM SPSS Statistics, version 27.¹²

87 Water quality indices

88 The EI is used to evaluate the trophic conditions of the surface water body. COD , dissolved
 89 inorganic nitrogen (DIN / mg L^{-1}), and dissolved inorganic phosphorus (DIP / mg L^{-1}) are used
 90 to calculate the EI values, which are computed using the formula below. An EI value less than
 91 1 indicates the absence of eutrophication, while a value of 1 or greater indicates the presence of
 92 eutrophication.^{3,13}

$$93 \quad EI = 10^6 \frac{COD \times DIN \times DIP}{4500} \quad (1)$$

94 OPI is used to assess the organic pollution status of surface water resources. COD , DIN ,
 95 DIP , DO and their standard concentration values are used to calculate the OPI . The standard
 96 concentration values of COD_S , DIN_S , DIP_S and DO_S were taken from the references in the
 97 previous study.^{8,13} The value obtained from the formula was evaluated as follows. <0: Excellent
 98 water quality, 0–1: good water quality, 1–2: water starting to be polluted, 2–3: lightly polluted
 99 water, 3–4: moderately polluted water, >4: heavily polluted water.^{13,14} OPI values were cal-
 100 culated using the following formula:

$$101 \quad OPI = \frac{COD}{COD_S} + \frac{DIN}{DIN_S} + \frac{DIP}{DIP_S} + \frac{DO}{DO_S} \quad (2)$$

102 The NPI values of the dam lake were calculated using the NO_3^- and PO_4^{3-} parameters in
 103 surface water sources. These values were calculated using the following formula. The obtained
 104 value categorizes the pollution levels as follows. <1: no pollution, 1–3: moderately polluted, 3–6:
 105 significantly polluted, >6: very high pollution.^{13,15} The NO_3^- -N maximum limit (mg L^{-1}) is
 106 referred to as MAC_N , and the PO_4^{3-} -P maximum limit (mg L^{-1}) is referred to as MAC_P , with values
 107 taken from the criteria:¹³

$$108 \quad NPI = \frac{C_N}{MAC_N} + \frac{C_P}{MAC_P} \quad (3)$$

109 The IDW interpolation technique was used to show the spatial distribution of index values
 110 on the dam. In IDW interpolation, the distances between the data points are first calculated for
 111 estimation. Then, weight values are determined based on the distance of each data point. Finally,
 112 the predicted value at a specific location is calculated by taking the weighted average of the
 113 points with known locations.¹⁶ In the formula, $Z(x)$ represents the predicted value; $Z(x_i)$ represents

114 the values of known points in the environment; w_i is the weight of each point; and N represents
 115 the number of points in the environment:

$$116 \quad Z(x) = \frac{\sum_{i=1}^N w_i Z(x_i)}{\sum_{i=1}^N Z w_i} \quad (4)$$

117 **RESULTS AND DISCUSSION**

118 The water quality classes, based on physicochemical data and the average
 119 values obtained from sampling in Maksutlu Dam Lake during the dry and rainy
 120 seasons, are given in Table I.^{8,9}

121 TABLE I. Water parameters and mean values of Maksutlu Dam Lake in dry and rainy seasons.
 122 Min: Minimum; Max: Maximum; Ave: Average; *WT*: water temperature; *EC*: electrical
 123 conductivity; *DO*: dissolved oxygen; *BOD*₅: biological oxygen demand; *COD*: chemical oxy-
 124 gen demand; *TDS*: total dissolved solids; *TSS*: total suspend solid; Cl: chloride; Ca: Calcium;
 125 Mg: magnesium; *TH*: total hardness; *NO*₃: nitrate nitrogen; *NO*₂: nitrite nitrogen; *NH*₄-N:
 126 ammonium nitrogen; *PO*₄: phosphate; *SO*₄: sulfate

Parameter	Unit	Dry season			Rainy season			Min-Max	Ave	Class
		1	2	3	1	2	3			
<i>WT</i>	°C	32.5	32.2	34	19.3	18.3	18	18–34	25.7	I
<i>EC</i>		384	268	344	573	495	513	268–573	429.5	I and II
pH		8.23	8.56	7.86	8.01	8.31	7.91	7.86–8.56	8.15	II
<i>DO</i>	mg L ⁻¹	4.37	4.76	3.04	7.23	7.80	6.66	3.04–7.80	5.64	III
<i>BOD</i> ₅	mg L ⁻¹	32.3	25.4	42.3	10.2	15.01	9.78	9.78–42.3	22.5	III
<i>COD</i>	mg L ⁻¹	54.8	35.5	55.2	14.5	18	14.2	14.2–55.2	32.03	I and II
<i>TSS</i>	mg L ⁻¹	120	360	210	105	318	165	105–360	213	
<i>TDS</i>	ppm	176	268	167	286	247	256	167–286	233.3	I
Cl	mg L ⁻¹	38.98	41.98	39.98	29.99	26.99	31.99	26.99–41.98	34.99	I and II
Salinity	‰	0.02	0.01	0.03	0.02	0.03	0.03	0.01–0.03	0.02	
Ca	mg L ⁻¹	26.45	24.08	20.04	101	48	70	20.04–101	48.26	
Mg	mg L ⁻¹	3.41	2.69	2.38	2.96	1.33	1.99	1.33–3.41	2.46	
TS	FS °	12.4	13	10.6	0.8	1	1.2	1–12.4	6.50	
<i>NO</i> ₃	mg L ⁻¹	16.50	21.27	16.50	44	47.90	53.51	16.50–53.5	33.28	I and II
<i>NO</i> ₂	mg L ⁻¹	0	0	0.023	0.02	0.02	0	0–0.023	0.01	I
<i>NH</i> ₄ -N	mg L ⁻¹	0.013	0.019	0.017	0.044	0.012	0.008	0.008–0.04	0.02	I
<i>PO</i> ₄	mg L ⁻¹	0.19	0.32	1.56	1.245	0.023	1.305	0.023–1.56	0.77	
<i>SO</i> ₄	mg L ⁻¹	5.57	11.56	5.95	9.89	10.33	10.39	5.57–11.56	8.95	I

127 Water temperature is a highly effective factor on biotic components in aquatic
 128 ecosystems. It plays an important role in reproduction, nutrition, and metabolic
 129 activities. Increase in temperature increases the rate of biological activity and de-
 130 creases oxygen saturation.¹⁷ It was observed that the water temperature values of
 131 the dam lake vary seasonally. During the dry season sampling, an increase in both

132 air and water temperatures was noted. The average water temperature placed the
133 lake in class I water quality.

134 The *EC* value is an indicator of the total amount of dissolved substances in
135 water. *EC* values vary depending on the geological structure and the amount of
136 precipitation. It was found that the *EI* values of the lake water were higher in the
137 rainy season (Table I). The primary reason for this is the significant outflow into
138 the lake during the rainy season. During this period, a large amount of material
139 from outside the lake is transported into it by rain or snowmelt. The average *EI*
140 values were found to range between Class I and Class II water quality.⁸ The pH
141 value is an indicator of water acidity.¹⁸ When the average pH value of the dam
142 lake was analyzed, it was determined that the water quality was Class II.⁸ It can be
143 concluded that the lake water exhibits basic properties.

144 The solubility of oxygen in water is inversely proportional to temperature.
145 Additionally, a wavy lake surface and high moisture content increase the solubility
146 of oxygen. As the salt concentration in the water increases, the amount of dissolved
147 oxygen decreases.¹⁹ It was observed that the *DO* values of the lake varied signif-
148 icantly between the dry and rainy periods. During the dry season, the water tem-
149 perature increased due to heat, and the lake water evaporated. As a result, the *DO*
150 values were found to be quite low in the dry season. However, during the rainy
151 season, the water level of the lake increased due to rainfall, which in turn increased
152 the *DO*. In terms of *DO*, it was determined that the lake water fell under Class III
153 water quality. *BOD*₅ is defined as the amount of oxygen required by bacteria to
154 break down organic matter under aerobic conditions.²⁰ Based on the average
155 *BOD*₅, the dam lake was classified as Class III water quality. *COD* is the amount
156 of oxygen required for the breakdown of chemical compounds. The *COD* value is
157 inversely proportional to the *DO*. *COD* values are generally higher than *BOD*₅
158 values because *COD* measures the total organic matter present in a water sample,
159 while *BOD*₅ only indicates the amount of biodegradable organic matter.²¹ In this
160 study, *COD* values were higher than *BOD*₅ values, supporting the findings in the
161 literature. It was determined that the lake waters were classified as between Class
162 I and Class II water quality based on the average *COD*.

163 Knowing the total amount of soluble substances or minerals in natural waters
164 is an important parameter for defining the chemical composition of water. It also
165 provides general information about the bottom structure, which contributes to the
166 productivity of the water.²⁰ The *TDS* originate from agricultural runoff, industrial
167 wastewater, natural sources, and domestic activities. The main ions that contribute
168 to the *TDS* include bicarbonates, carbonates, sulfates, chlorides, nitrates, mag-
169 nesium, sodium, potassium, calcium and others. In addition, silt, clay, small org-
170 anic particles, inorganic substances, soluble organic compounds, plankton and
171 other microscopic organisms also contribute to the *TDS*.

172 The Cl is an important component of all natural waters and is generally found
173 in low concentrations. High concentrations indicate that salinity and *EC* values are
174 also high.²² Based on the average Cl values, the lake water was found to fall
175 between Class I and Class II water quality.

176 The Ca is one of the most abundant elements in natural waters.^{23,24} The source
177 of Ca ions in water comes from calcium carbonate and calcium sulfate minerals.
178 Therefore, Ca can be found in waters at varying concentrations. The Ca is the most
179 important ion contributing to water hardness.²⁵ According to some researchers,
180 water is classified as soft if Ca is less than 10 mg L^{-1} , moderately hard if it ranges
181 from $20\text{--}25 \text{ mg L}^{-1}$, and hard if it exceeds 25 mg L^{-1} .²⁰ In this study, the average
182 value was found to be 48.26 mg L^{-1} . Since the lithological structure of the study
183 area consists of volcanic formations, the concentration of Ca ions may be high.
184 This elevated value indicates that the lake has very hard water.

185 The Mg is one of the ions that contribute to the hardness of water. Since Mg
186 is present in the composition of chlorophyll, it is vital for chlorophyllous plants. It
187 also regulates phosphorus metabolism in algae, fungi and bacteria. Low Mg levels
188 in lakes significantly affect phytoplankton productivity, resulting in the lake acquiring
189 oligotrophic characteristics.²⁶ Mg concentrations in natural waters typically range
190 between $10\text{--}50 \text{ mg L}^{-1}$.¹⁷ The average Mg value in this study was found to be 2.46 mg L^{-1} .

191 The nitrates are the most common mineral form of nitrogen in oxygen-rich
192 waters and is an important factor that can either limit or promote algal growth. It
193 is found in trace amounts in surface waters. The amount of nitrogen is low in oli-
194 gotrophic waters and quite high in eutrophic waters. $\text{NO}_3\text{-N}$, an essential element
195 for the intensive development of phytoplankton, is typically found in waters at
196 concentrations between $1\text{--}10 \text{ mg L}^{-1}$. It was determined that the lake water falls
197 between Class I and Class II water quality in terms of the average $\text{NO}_3\text{-N}$ value.
198 The NO_2 is an intermediate product in the biological oxidation of ammonium to
199 nitrate. The concentration of NO_2 is generally low in natural waters but can reach
200 high levels in areas with organic pollution and low oxygen levels.²⁶ In this study,
201 it was found that the average $\text{NO}_2\text{-N}$ values of the lake were classified as Class I
202 water quality. In clean and oxygenated waters, NH_4 compounds are found at very
203 low levels. NH_4 is a waste product of aquatic organisms and is reabsorbed by other
204 organisms.¹⁹ Many algae and higher plants can directly take up NH_4 . Generally,
205 NH_4 levels should be 1 mg L^{-1} or less. Based on this parameter, the water quality
206 was considered Class I.¹²

207 It has been reported that productivity is high in waters with PO_4 content
208 between 0.15 and 0.30 mg L^{-1} , but when the PO_4 content exceeds 0.30 mg L^{-1} , the
209 water is considered polluted. When the phosphate level exceeds 0.50 mg L^{-1} , the
210 water shows excessive pollution and causes eutrophication.²³ Waters with a total
211 phosphorus concentration of $20 \mu\text{g L}^{-1}$ or higher are considered eutrophic.²⁷

213 The SO_4 is an ion that must be present in natural waters to enhance biological
 214 efficiency. If its concentration is insufficient, phytoplankton development is inhib-
 215 ited and plant growth slows down. SO_4 values in natural lakes typically range from
 216 3 to 30 mg L⁻¹.²⁸ An increase in SO_4 concentrations in aquatic environments,
 217 caused by various industrial wastes, agricultural runoff, and domestic effluents, is
 218 an indicator of pollution. SO_4 levels greater than 250 mg L⁻¹ signify serious con-
 219 tamination.²³ It was found that the lake had Class I water quality based on the
 220 average SO_4 concentration.

221 Pearson correlation analysis was applied to the physicochemical parameters
 222 of lake water that show a normal distribution. According to the Pearson correlation
 223 analysis with *WT*, very strong positive correlations were observed between *BOD*₅,
 224 *COD* and chloride Cl. A positive correlation was found between *TDS* and NO_3 and
 225 sulfate SO_4 . Since NO_3 and SO_4 are ions that form part of salts, the of *TDS* in
 226 water increases as they dissolve. A negative correlation was found between *BOD*₅
 227 and *TDS* and SO_4 in relation to *WT* and NO_3 . Additionally, a general relationship
 228 was observed between SO_4 , *WT*, *BOD*₅ and *COD*. The correlation coefficients
 229 from the Pearson correlation analysis are presented in Table II.

230 TABLE II. Pearson correlation analysis and correlation coefficients. *WT*: water temperature;
 231 *BOD*₅: biological oxygen demand; *COD*: chemical oxygen demand; *TDS*: total dissolved solids;
 232 Cl: chloride; SO_4 : sulphate; NO_3 : nitrate; *: correlation is significant at 0.01 level ($p < 0.01$);
 233 **: correlation is significant at 0.01 level (2-tailed). -: indicating that no statistically significant
 234 correlation was detected

	<i>WT</i>	<i>BOD</i> ₅	<i>COD</i>	<i>TDS</i>	Cl	SO_4	NO_3
<i>WT</i>	1						
<i>BOD</i> ₅	0.923**	1					
<i>COD</i>	0.941**	0.962**	1				
<i>TDS</i>	-0.676	-0.835*	-0.878*	1			
Cl	0.943**	0.777	0.813*	-0.498	1		
SO_4	-0.582	-0.768	-0.808	0.927**	-0.390	1	
NO_3	-0.988**	-0.930**	-0.948**	0.682	-0.895*	0.627	1

235 The *EI*, *OPI* and *NPI* index values of the dam lake were calculated (Table III)
 236 using the formulas provided above. When evaluating the *EI* values in terms of
 237 stations, they were ranked as 1 < 2 < 3 during the dry season and 2 < 1 < 3 during
 238 the rainy season. The *OPI* values were also ranked as 1 < 2 < 3 in the dry season
 239 and 2 < 1 < 3 in the rainy season. For the *NPI* values, the ranking was 2 < 1 < 3 in
 240 both the dry and rainy seasons. The lowest *EI* value was observed at station 2
 241 during the rainy season (326), while the highest *EI* value was recorded at station 3
 242 during the dry season (23122). The lowest *OPI* value was found at station 2 during
 243 the rainy season (3.29), while the highest value was observed at station 3 during
 244 the dry season (13.16). The lowest *NPI* value was recorded at station 1 during the

245 dry season, while the highest value was found at station 3 during the rainy season.
 246 Water quality index values are presented in Table III.

247 TABLE IV. Water quality index values (*EI*, *OPI* and *NPI*) of stations in the dry and rainy seasons

Station	Dry season			Rainy season		
	<i>EI</i>	<i>OPI</i>	<i>NPI</i>	<i>EI</i>	<i>OPI</i>	<i>NPI</i>
1	2835	4.05	2.48	1311	3.62	11.42
2	3981	4.41	1.70	326	3.29	3.75
3	23122	13.16	12.63	16307	12.03	12.53

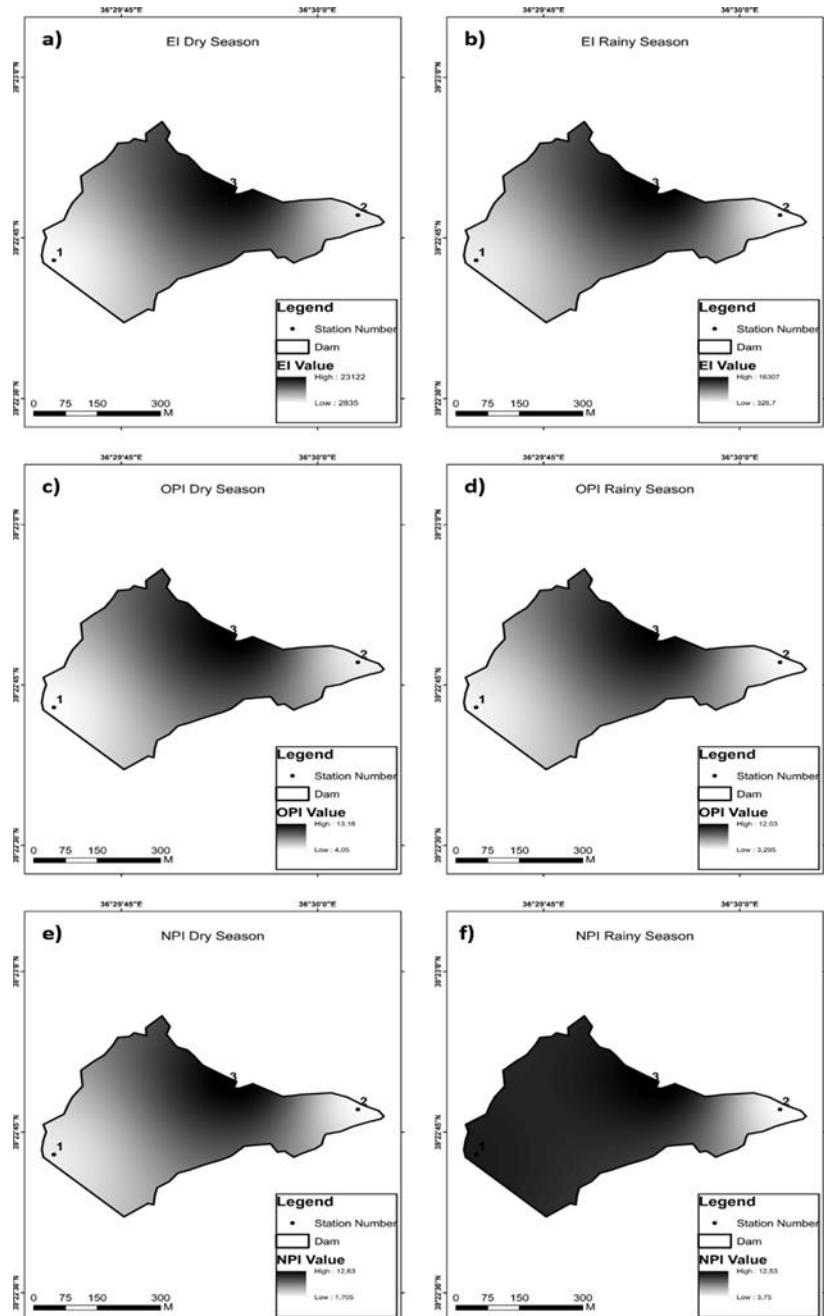
248 The Bray–Curtis similarity dendrogram for the stations is presented in Fig. 2.
 249 This dendrogram summarizes the similarity of physicochemical data between the
 250 stations based on Bray–Curtis similarity analysis. The first and third stations
 251 showed the highest similarity (91.60 %), while the second station had a lower sim-
 252 ilarity to the other two stations (82.35 %).



0 50 100 Fig. 2. Bray–Curtis Similarity dendrogram of stations.

253 Remote sensing methods, which have significantly increased in use in recent
 254 years, can be employed to determine both water quality and pollution levels.^{28,29}
 255 In this study, maps showing the distribution of index values across stations were
 256 created using a Geographic Information System (GIS). The index values for the
 257 stations were generated using GIS, and the corresponding maps are presented in
 258 Fig. 3. The spatial distribution of *EI*, *OPI* and *NPI* index values in dry and wet
 259 seasons using the IDW method is also presented in Fig. 3.

260 In the dry season, *EI* values ranged from 2835 (low) to 23122 (high). Lower
 261 values were observed in the western and southwestern parts of the map, particu-
 262 larly near the 1st station, while higher values were concentrated around the center
 263 and 3rd station. This was due to a significant decrease in the lake's water level
 264 caused by evaporation from warming air, which resulted in high eutrophication
 265 index values due to increased NO_3 and PO_4 concentrations. These elevated values
 266 in the central regions may indicate the accumulation of nutrient loads, which could
 267 contribute to eutrophication (Fig. 3a). During the rainy season, *EI* values decreased
 268 significantly, ranging from 326 (low) to 16307 (high). Although there was a gen-
 269 eral decrease in *EI* values, high values were still observed around the 3rd station.
 270 This could be due to the dilution of nutrient enrichment caused by increased precip-
 271 itation (Fig. 3b).



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274

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Fig. 3. a) Spatial distribution of *EI* in dry season. b) Spatial distribution of *EI* in rainy season.
 c) Spatial distribution of *OPI* in dry season. d) Spatial distribution of *OPI* in rainy season.
 e) Spatial distribution of *NPI* in dry season. f) Spatial distribution of *NPI* in rainy season.

276 In the dry season, *OPI* values ranged from 4.05 (low) to 13.16 (high). During
 277 the rainy season, *OPI* values ranged from 3.29 (low) to 12.03 (high). While *OPI*
 278 values generally decreased slightly compared to the dry season, the organic load
 279 remained high in the central regions and around the 3rd station (Fig. 3d). This
 280 suggests that organic pollution persists even during wetter conditions, particularly
 281 near the 3rd station.

282 In the dry season, *NPI* values ranged from 1.705 (low) to 12.63 (high). High
 283 *NPI* values were observed around the 3rd station and some central areas, while the
 284 region around the 1st station exhibited low values (Fig. 3e). This indicates mod-
 285 erate to high levels of pollution in the central areas, particularly near the 3rd station.
 286 In the rainy season, *NPI* values varied between 3.75 (low) and 12.53 (high). The
 287 *NPI* index generally increased across all areas during the rainy season (Fig. 3f),
 288 possibly due to the dilution of pollutants and the introduction of additional runoff
 289 from surrounding regions.

290 During the rainy season, *OPI* the values range from 3.29 (low) to 12.03 (high).
 291 Although the *OPI* values generally decreased slightly during the rainy season, the
 292 organic load remains high in the center and 3rd station (Fig. 3d). In the dry season,
 293 the *NPI* index ranges from 1.705 (low) to 12.63 (high). The area around 3rd station
 294 and some parts of the center show high *NPI* values in the dry season. The area
 295 around 1st station shows low values (Fig. 3e). In the rainy season, the index varies
 296 between 3.75 (low) and 12.53 (high). Accordingly, the *NPI* seems to have gener-
 297 ally increased in all areas during the rainy season (Fig. 3f). In addition, 3rd station
 298 has high values for all three indices, which is an indication that this area is a serious
 299 impact zone. In summary, the effect of seasonal variations is evident at all stations.

300 In this study, seasonal changes in the physicochemical parameters of Maksutlu
 301 Dam Lake were analyzed, and the application of pollution indices such as *EI*, *OPI*,
 302 and *NPI* revealed varying levels of eutrophication, organic pollution, and nutrient
 303 pollution across different seasons. As a result, while our study shows similarities
 304 with some studies, it also reveals differences. Anthropogenic activities occurring
 305 in water bodies lead to an increase in nutrient levels, reduce water quality and limit
 306 its intended uses. Excessive nutrient input causes the overgrowth of aquatic plants,
 307 which leads to algal blooms and a decrease in the oxygen content of the water.

308 CONCLUSION

309 In the present study, some physicochemical parameters of Maksutlu Dam
 310 Lake were evaluated during both dry and rainy periods. According to the results,
 311 the average values of *WT*, *TDS*, *NO₂-N*, *NH₄-N*, and *SO₄* were classified as Class
 312 I water quality; the average values of *EC*, *COD*, *Cl* and *NO₃-N* were found to fall
 313 between Class I and Class II water quality; the average pH value was classified as
 314 Class II water quality; and the average values of *DO* and *BOD₅* were classified as
 315 Class III water quality. The *EI*, *OPI*, and *NPI* index values were also evaluated for

316 both seasons in the study. These index values were analyzed using GIS. In conclusion,
317 the $\text{NO}_3\text{-N}$ and Mg parameters, along with the water quality index values,
318 indicate that the lake may be oligotrophic. The findings obtained from the study
319 show that the dam lake is suitable for irrigation. It was also found that the lake is
320 under the influence of eutrophication, organic pollution and nutrient pollution. To
321 ensure the sustainability of the dam lake, two suggestions can be made below.

322 1) These and similar studies should be conducted periodically, and the phys-
323 icochemical, pesticide and toxicological content of the lake, as well as benthic
324 macroinvertebrates, should be examined and monitored comprehensively.

325 2) Satellite data and GIS should be utilized for large-scale monitoring of nut-
326 rient levels and eutrophication trends in water bodies. Monitoring water quality
327 with satellite data and GIS has been proven to secure the long-term biodiversity
328 and sustainability of water resources, as well as maintain ecosystem health.

329 SUPPLEMENTARY MATERIAL

330 Additional data and information are available electronically at the pages of journal web-
331 site: <https://www.shd-pub.org.rs/index.php/JSCS/article/view/13203>, or from the correspond-
332 ing author on request.

333 ИЗВОД

334 ВРЕМЕНСКА И ПРОСТОРНА ДИСТРИБУЦИЈА ФИЗИЧКО-ХЕМИЈСКИХ ПАРАМЕТАРА
335 И ИНДЕКСА КВАЛИТЕТА ВОДЕ У ОЛИГОТРОФНОМ ВЕШТАЧКОМ ЈЕЗЕРУ:
336 СЛУЧАЈ ЈЕЗЕРА МАКСУТЛУ, СИВАС, ТУРСКА

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340 Sivas, Türkiye

341 Ова студија је спроведена на три одабране станице у језеру Максутлу Дам (Шарки-
342 сла, Сивас), покривајући сушну сезону (август 2023. год.), као и кишну сезону (мај 2024.
343 год.). Из језера су прикупљени узорци воде, а анализирано је укупно 18 физичко-хемијских
344 параметара. Вредности индексаeutрофикације (EI), индекса органског загађења (OPI) и
345 индекса загађења нутријентима (NPI), израчунате су за обе сезоне на основу физичко-
346 -хемијских параметара језерске воде. Поред тога, коришћен је Географски информациони
347 систем (GIS) за приказ сезонских варијација у вредностима индекса. На физичко-хемијске
348 параметре воде примењене су Bray-Curtis и Pearson корелационе анализе. Као резултат
349 тога, утврђено је да и физичко-хемијски параметри и индекси квалитета језерске воде
350 показују сезонске варијације. У језеру је детектовано фосфатно загађење и установљено
351 је да језеро може бити олиготрофно у погледу садржаја NO_3 и Mg. Дато је и неколико
352 предлога за одрживо управљање вештачким језером које је настало изградњом бране.

353 (Примљено 7. јануара, ревидирано 6. фебруара, прихваћено 11. априла 2025)

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SUPPLEMENTARY MATERIAL TO

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**Temporal and spatial distribution of physicochemical
415 parameters and water quality indices in an oligotrophic
416 dam lake: A case of Maksutlu Dam Lake, Sivas, Türkiye**

417

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Maksutlu Dam Lake was constructed for irrigation purposes on the Maksutlu Stream, upstream of Maksutlu village in the Şarkışla district of Sivas Province. The dam, which is of the clay-core homogeneous fill type, serves irrigation needs. The dam lake has a volume of 2,950,000 m³ and irrigates an area of 400 hectares. The dam's height from the riverbed is 19 m. At the normal water level, the lake's volume is 2.95 hm³ and its surface area is 0.42 km².¹ Three stations that best represent the characteristics of the dam lake were selected for this study. Information about these stations and their characteristics is presented in Table S-I.

429

TABLE S-I. Coordinates and Characteristics of the Stations

Stations	Coordinates	Characteristics of Stations
1	39° 22' 42" N 36° 29' 39" E	It is just behind the dam embankment.
2	39° 22' 48" N 36° 30' 04" E	This station is located opposite the dam embankment, very close to agricultural areas.
3	39° 22' 50" N 36° 29' 54" E	It was selected from a part of the dam lake close to the picnic areas.

430

The map of the study area and sampling locations is given in Fig. S-1.

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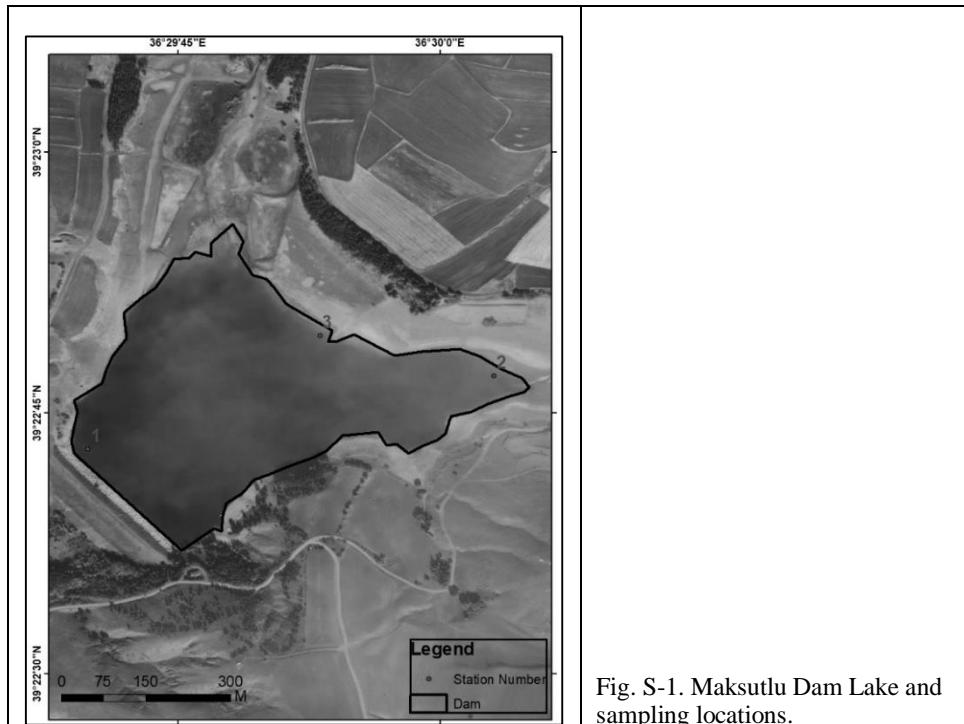


Fig. S-1. Maksutlu Dam Lake and sampling locations.

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