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TEMPERATURE AND DISSOLVED OXYGEN STRATIFICATION IN ALMUS DAM LAKE ON YEŞILIRMAK RIVER (TURKEY) AND ITS GIS MAPS

ABSTRACT

The temperature and dissolved oxygen parameters of Almus Dam Lake located in the district Almus of province Tokat were seasonally determined at nine stations located along the lake. The water quality class of Almus Dam Lake was determined by comparing the results of our measured parameters with the values of Intercontinental Water Sources Quality Classification. The spatial and seasonal variations in physical parameters were analyzed with the Two-Way ANOVA, the relationships among these parameters. According to Intercontinental Water Sources Quality Classification, Almus Dam Lake has Class I water quality when considering parameters of temperature (14.30±7.44C°), dissolved oxygen (10.15±2.67mg/L. With the examination of seasonal temperature-depth profile, it was observed that winter stagnation and spring and fall vertical mixing occurred during the January and March and spring May and November, respectively. Temperature stratification was clearly observed during the July and September. Epilimnion, metalimnion (thermocline) and hypolimnion were well clearly visible at the first 10 meters, between 10-20 meters, and below 20 meters, respectively. GIS maps with spatial and seasonal values were created for temperature and dissolved oxygen variables.

Keywords: Temperature, Dissolved Oxygen, Stratification, Almus Dam Lake, Yeşilırmak River

YEŞİLIRMAK NEHRİ (TÜRKİYE) ÜZERİNDE BULUNAN ALMUS BARAJ GÖLÜ'NDE SICAKLIK VE ÇÖZÜNMÜŞ OKSİJEN TABAKALAŞMASI VE CBS HARİTALARI

ÖZ

Yeşilırmak Nehri üzerinde bulunan Almus Baraj Gölü'nde belirlenen 9 istasyonda sıcaklık ve çözünmüş oksijen parametreleri mevsimsel ve alansal olarak tespit edilmiştir. Çalışmada fiziksel parametrelere ait bulgular "Kıta İçi Su kaynakları Kalite Sınıflandırılması" değerleri ile karşılaştırılarak, Almus Baraj Gölü'nün ölçülen parametreler (sıcaklık ve çözünmüş oksijen) açısından su kalite sınıfları tespit edilmiştir. İlgili parametrelerde meydana gelen mevsimsel ve alansal değişimleri tespit etmek için; iki yönlü varyans analizi (ANOVA) testi kullanılmıştır. Kıta İçi Su kaynakları Kalite Sınıflandırılmasına göre Almus Baraj Gölü sıcaklık (14.30±7.44C°), çözünmüş oksijen (10.15±2.67mg/L) açısından I. sınıf su kalitesine sahiptir. Sıcaklık değerlerinin derinliğe göre değişimi incelendiğinde, Almus Baraj Gölü'nde Ocak ve Mart aylarında kış stangasyonu, Mayıs ve Kasım aylarında ilkbahar ve sonbahar karışımı, Temmuz ve Eylül aylarında ilk 10m'de epilimnion, 10 ile 20m arasında termoklin, 20m'den aşağı derinliklerde ise hipolimnion tabakası tespit edilmiştir. Sıcaklık ve çözünmüş oksijen değişkenleri için mekânsal ve mevsimsel değerlere sahip CBS haritaları oluşturulmuştur.

Anahtar Kelimeler: Sıcaklık, Çözünmüş oksijen, Tabakalaşma, Almus Baraj Gölü, Yeşilırmak Nehri

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1. INTRODUCTION

Dams and reservoirs have mainly been built for the purposes of drinking and irrigation water supply, electric power generation and flood protection [1]. Monitoring the water quality of a lake is very critical [2]. Lake hydrology forms a basis for water quality. Mixing and circulation formation influence nutrient retention and the development of hypoxia. Hydrological factors includes retention time, stratification and mixing, circulation, water level fluctuation and drawn down. Lake basin morphology influences lake hydrodynamics and lake responses to pollution [3]. Thermal regime in water quality models is important in two senses. Firstly, temperature has a direct effect on the chemical reaction rate. Secondly, thermal equilibrium has a great effect on mixing in fresh water systems [4]. Rising water temperatures, reduced lake mixing, and increased biotic consumption of dissolved oxygen reduce water quality [5]. Dissolved oxygen concentration is both an indicator and driver of water quality in lakes. Decreases in oxygen concentration leads to altered ecosystem function as well as harmful consequences for aquatic biota, such as fishes. The responses of oxygen dynamics in lakes to climate-related, such as temperature and wind speed, are well documented for lake surface waters [6].

The thermal stratification in the lakes controls seasonal water movements. There are seasonal changes in water quality as well as seasonal temperature changes in water mass. Especially the thermal grading is very apparent in the summer phase. In the winter calm period, it is less visible. With the mixture of spring and autumn, these gradients are removed. Water quality is almost the same in all depths. As the temperature difference between the surface and the bottom decreases in the spring and autumn, the stratification is ineffective and with the smallest wind movement it is enough to mix the water with the daily temperature changes. For this reason, the quality of the water is deteriorated to a considerable extent and algae explosion can occur [7]. Yeşilırmak River is one of the most important rivers in Turkey and is increasingly threatened by pollution. The waters of Almus Dam Lake poured to Yeşilırmak River. In the study, the temperature and dissolved oxygen changes of the lake were examined in detail and it was planned to create spatial maps using not only depth maps or stratification but also GIS techniques.

2. RESEARCH SIGNIFICANCE

Almus Dam Lake is built on Yeşilırmak River. These shallow waters pour into the Yeşilırmak River. For this reason, it is important to investigate the lake water temperature and dissolved oxygen values. There are many cage fisheries on the Almus Dam Lake. In addition, many fish species such as carp, spring fish are hunted by the fishery cooperative. Sudden temperature and dissolved oxygen strata affect these activities in the lake. For this reason, depth maps of the lake have been produced. In the other phase of the study, the lake spatial database (GIS maps) for temperature and dissolved oxygen was created using ARCGIS 9.1 Geographic Information Systems software. With GIS maps, measurements were made at a certain number of stations defining the lake and the results were extrapolated to the entire lake area where no measurements were taken. Thus, it is aimed to have information about the entire lake. The GIS maps created for measured parameters allowed us to estimate the water quality of the lake areas that were not sampled.

3. EXPERIMENTAL METHOD-PROCESS

3.1. Study Area

The location of Almus Dam Lake and the sampling stations are shown in Figure 1. The coordinates of sampling stations are given Table 1. The lake was built on Yeşilırmak River and located in the Tokat where located near such as Kazova and Kelkit basins of the most important in Turkey. The lake basin has a water potential of 950.00hm^3/yr. Almus Dam Lake covers an area of 31.30km^2 and irrigation water area of 21350hm^3. The area and depth of the lake change with years and seasons.

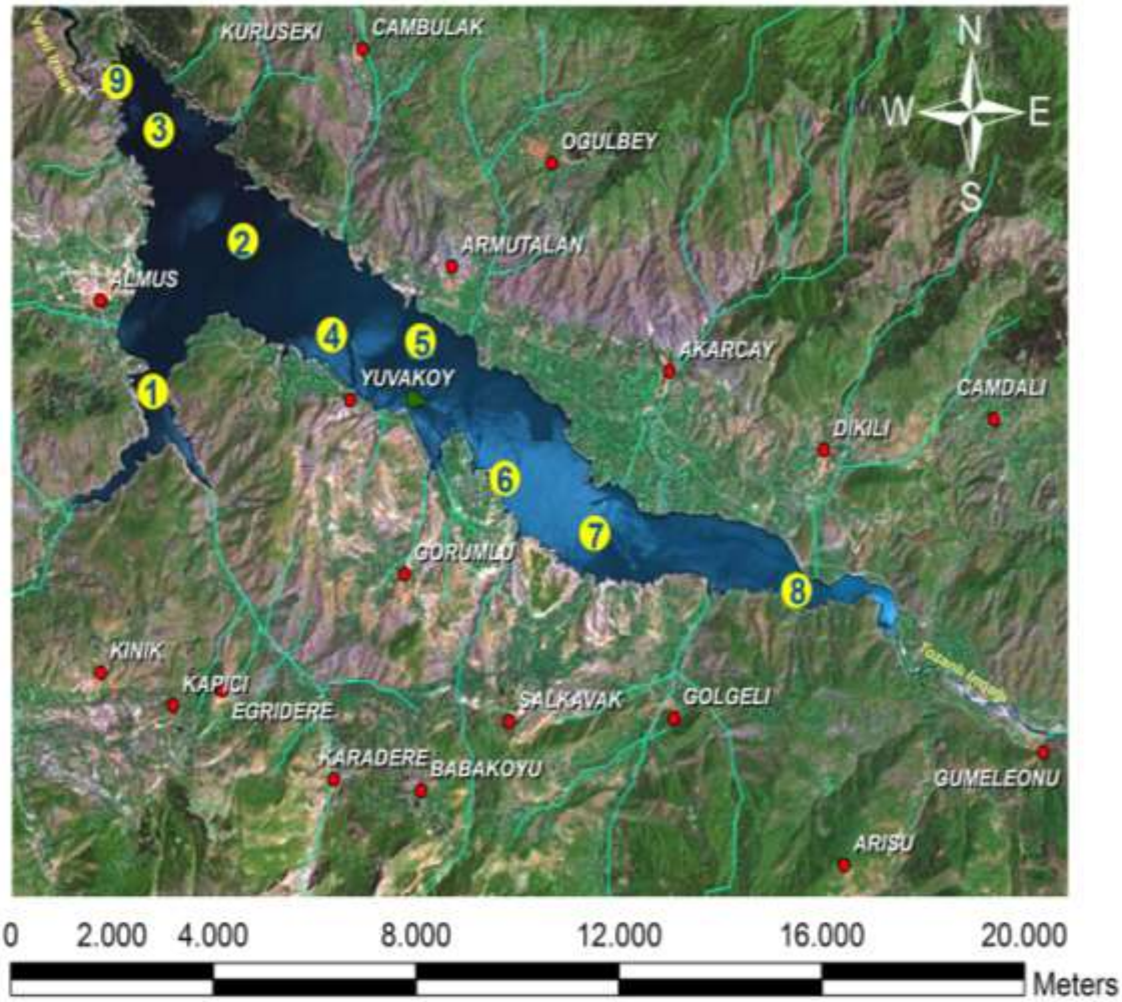


Figure 1. Sampling stations in Almus Dam Lake
(Şekil 1. Almus Baraj Gölü'nde örnekleme istasyonları)

The villages of Tokat and urban areas are found on near of where 1st, 4, 5, 6, 7th stations located. 2nd and 3th stations are the most of depth in stations on the lake. The Tozanlı Stream where station 8th located is the most water contributor to the lake. The waters of Almus Dam Lake poured to Yeşilırmak River where station 9th located.

Table 1. Coordinates of sampling stations in Almus Dam Lake
(Tablo 1. Almus Baraj Gölü'ndeki örnekleme istasyonlarının koordinatları)

1 st: 40° 21′ 59″ latitude	36° 55′ 00″ longitude
2 nd: 40° 23′ 00″ latitude	36° 56′ 22″ longitude
3 th: 40° 24′ 00″ latitude	36° 55′ 02″ longitude
4 th: 40° 22′ 16″ latitude	36° 57′ 48″ longitude
5 th: 40° 21′ 40″ latitude	37° 00′ 38″ longitude
6 th: 40° 20′ 88″ latitude	36° 59′ 93″ longitude
7 th: 40° 20′ 38″ latitude	37° 01′ 64″ longitude
8 th: 40° 21′ 59″ latitude	36° 55′ 00″ longitude
9 th: 40° 23′ 41″ latitude	36° 42′ 20″ longitude

3.2. Analysis of Water Samples

This study was carried out annually by sampling every two months was carried out as in-situ in surface and different depth. For temperature and dissolved oxygen measurements; portable oxygen meter of YSI 85D model which can measure the depths between -5°C and +45°C with a sensitivity of 1°C and a dissolved oxygen value between 0mg/L and 15mg/L with a sensitivity of 0.2mg/L was used. Temperature and dissolved oxygen values were measured at depths of 2, 4, 8, 10, 20, 30m and bottom (sediment depth) starting from the surface at each station.

3.3. Creating Depth Maps

Temperature and dissolved oxygen depth maps were generated using the obtained data. Epilimnion, metalimnion (thermocline) and hypolimnion layers were identified.

3.4. Creating Raster Maps with GIS

In the other phase of the study, the lake spatial database for temperature and dissolved oxygen was created using ArcGIS 9.1 Geographic Information Systems software. Geographic Information System (GIS) maps were created using only surface and bottom waters. The creation of the lake spatial database is the conversion of the water data obtained from the field studies to the XYZ database into the spatial distribution maps, or in other words, to the map of the grid (raster or grid). The data of the water variables in the XYZ database we have obtained are interpolated at 30m resolution in ArcGIS 9.1 using the Kriging method (spherical semivariogram). Thus, raster maps with spatial and seasonal values for temperature and dissolved oxygen variables were created. In each map, the blue colors changed their low concentration values, while the red colors indicated high concentration values; they changed in direct proportion to the intensity values of the color. The results obtained by correlation and other statistical analyses were overlapped with the results of GIS maps.

3.5. Statistical Procedures

The difference between temperature and dissolved oxygen values by depth (surface and deep water) was determined by T-Test. The spatial and seasonal variations at temperature and dissolved oxygen were analyzed with the Two-Way ANOVA the relationships among these parameters were evaluated using Pearson Correlation Analysis. According to the variance analysis, The SNK test was applied if the difference was statistically significant (Student Newman-Keul). The According to this test, the difference between the months and stations indicated by different letters is statistically significant ($p<0.05$).

Results of statistical analyses (T-Test) were compared with the GIS maps.

4. FINDINGS AND DISCUSSIONS

The annual mean, minimum, maximum values and standard deviations of Dam are given in Table 2 and the results of T-Test according to depth (surface and deep water) are given in Table 3.

Table 2. Almus Dam Lake surface and bottom water annual mean
(Tablo 2. Almus Baraj Gölü yüzey ve dip suyu yıllık ortalamaları)

Variable	N	N*	Mean	Mean*	Min.	Min.*	Max.	Max.*	Standard Deviation	Standard* Deviation
Temperature (˚C)	55	55	14.30	10.26	2.1	2.10	24.3	22.3	7.44	5.47
Dissolved Oxygen (mg/L)	55	55	10.15	9.04	7.6	3.00	13.4	16.19	1.59	2.67

Table 3. T-Test results of surface and depth dependent
(Tablo 3. Yüzey ve derinlik bağımlı T-test sonuçları)

Variable	T-Değeri	P-Değeri
Temperature (˚C)	6.18	0.000
Dissolved oxygen (mg/L)	4.58	0.000

According to Table 3, temperature and dissolved oxygen, variables were statistically different in surface and deep water ($p<0.05$). Temperature, dissolved oxygen values showed, normal and homogeneous distribution with respect to seasonally and spatially. The SNK (Student Newmans Kouls) test results are also given in Table 4 and Table 5. The spatially and seasonal changes of temperature and dissolved oxygen are also in Figure 2 and Figure 3.

Table 4. The SNK (Student Newmans Kouls) test results according to seasonally
(Tablo 4. Mevsimlere göre SNK test sonuçları)

Months	January	March	May	July	September	November
Parameter						
Temperature (˚C)	3.86^{f}	5.82^{e}	18.18^{c}	22.82^{a}	21.48^{b}	13.61^{d}
Dissolved Oxygen (mg/L)	12.00^{a}	11.83^{a}	9.95^{b}	8.38^{c}	8.36^{c}	10.36^{b}

The months to be marked with a like letters don't difference statistical

Table 5. The SNK test results according to sampling stations
(Tablo 5. Örnekleme istasyonlarına göre SNK test sonuçları)

Parameter	Stations								
	1	2	3	4	5	6	7	8	9
Temperature (˚C)	14.40 ab	14.12^{a} b	14.07^{a} b	14.58^{a} b	14.48^{a} b	14.80^{a}	14.67^{a} b	14.57^{ab}	12.98 b
Dissolved oxygen (mg/L)	9.87^{b}	10.21^{a} b	10.17^{a} b	9.83^{b}	9.87^{b}	$10.^{ab}$	10.1^{ab}	10.21^{ab}	11.00 a

The stations to be marked with a like letters don't difference statistical

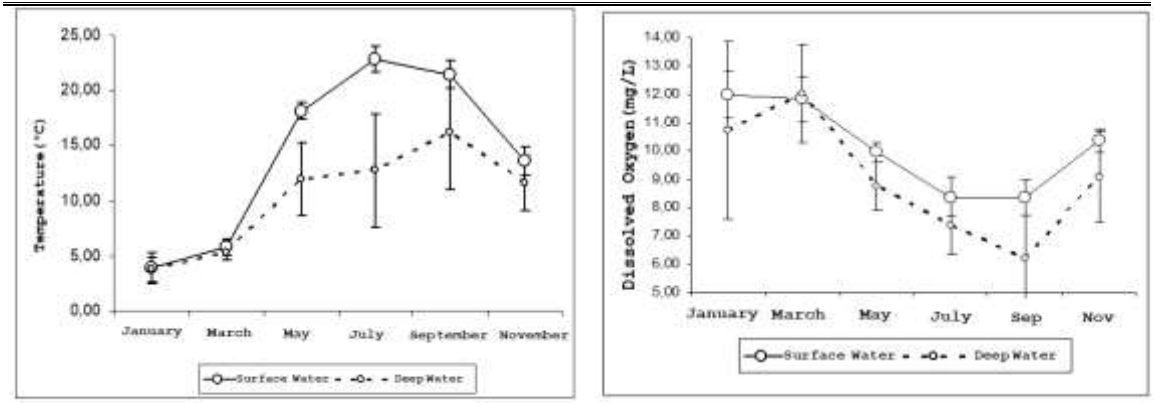


Figure 2. Measured temperature and dissolved oxygen seasonal changes in Almus Dam Lake
(Şekil 2. Almus Baraj Gölü'nde ölçülen sıcaklık ve çözünmüş oksijendeki mevsimsel değişmeler)

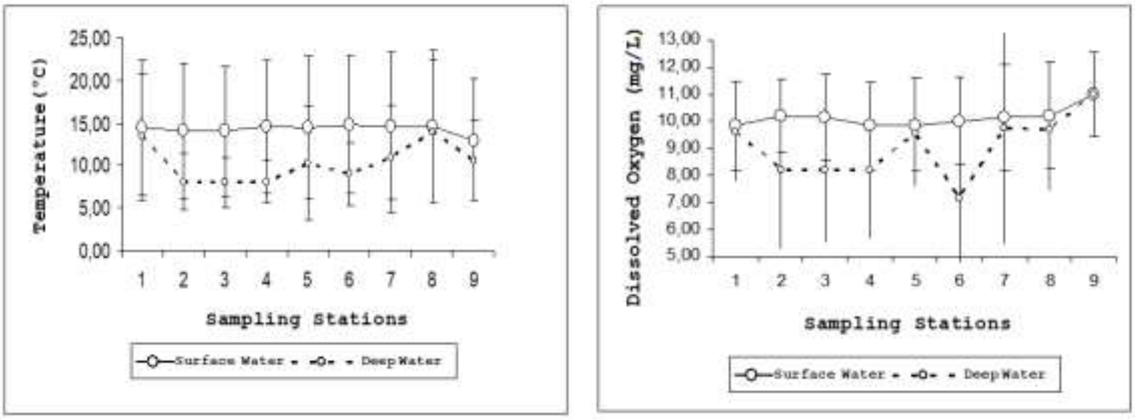


Figure 3. Spatial variations in temperature and dissolved oxygen in Almus Dam Lake
(Şekil 3. Almus Baraj Gölü'nde sıcaklık ve çözünmüş oksijendeki alansal değişmeler)

Almus Dam Lake annuall average surface water temperature value is 14.30°C (Table 2). Dam Lake is first class water quality according to the values of Intercontinental Water Sources Quality Classification. Average surface water temperature peaked in highest mean value in July and down to lowest values in January. Average deep water temperature peaked in highest mean value in September and down to lowest values in January (Figure 2). SNK test results indicated that the temperature values were significantly different in all seasonal ($F_{5,40}$=691.32; p=0.0001, Table 4). The temperature values also weren't significantly different according to spatial lack 6 and 8th stations ($F_{8,40}$=2.16; p=0.0525, Figure 3, Table 5).

With the examination of seasonal temperature-depth profile, it was observed that winter stagnation and spring and fall vertical mixing occurred during the January, March and May, November, respectively. Temperature stratification was clearly observed during the July and September. Epilimnion, Metalimnion (thermocline) and hypolimnion were respectively well clearly visible at the first 10 meters, between 10-20 meters, below 20 meters (Figure 4).

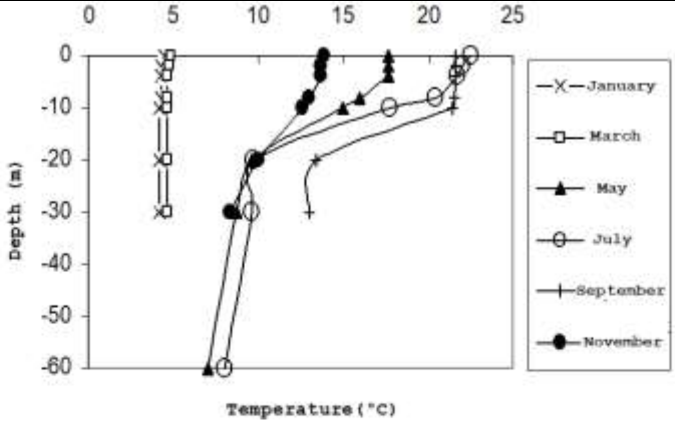


Figure 4. The water temperature value seasonal variation acorrding to depth
(Şekil 4. Derinliğe göre su sıcaklığındaki mevsimsel değişmeler)

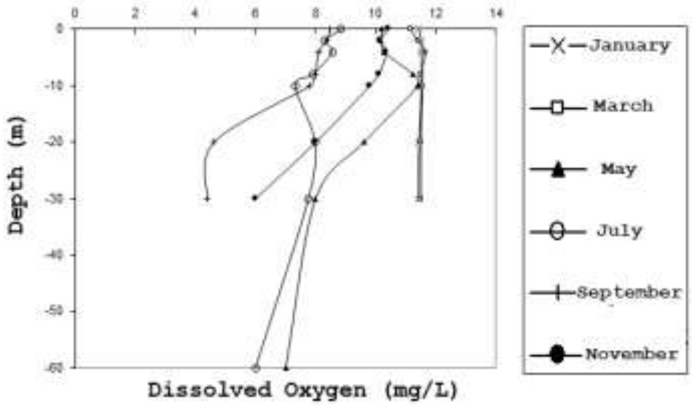
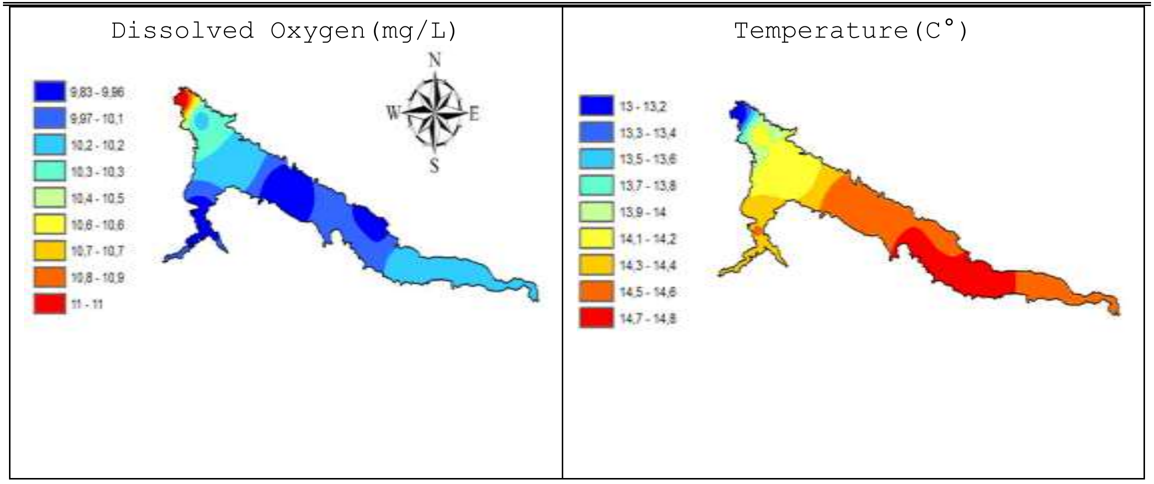


Figure 5. Dissolved Oxygen value seasonal variation acorrding to depth
(Şekil 5. Derinliğe göre çözünmüş oksijen değerindeki mevsimsel değişmeler)

Almus Dam Lake annually average surface water dissolved oxygen value is 10.15mg/L (Table 2). Dam Lake has first class water quality according to the values of Intercontinental Water Sources Quality Classification for dissolved oxygen. According to water depth the dissolved oxygen value seasonal variation was shown in Figure 5. Dissolved oxygen values were in parallel with the temperature dependent stratification. The dissolved oxygen level in January and March remained constant up to 30m. The dissolved oxygen in the first 10 m in May decreased, then increased and again decreased. In July, dissolved oxygen showed a slight increase on water surface, but dissolved oxygen decreased in value as depth increased. Dissolved oxygen has the lowest value in September. In November, there was a steady decrease from the surface to a depth of 30m. According to the Person Correlation Analysis, a high correlation was found high negative relationship between temperature, dissolved oxygen (-0.930). In the study performed, the correlations between the parameters; it has been found that the maps produced by the GIS method can be presented without statistical analysis. The maps (temperature, dissolved oxygen) are shown in Figure 6, taking into account the annual rate of change. In maps, blue colors vary in low concentration values, while red colors indicate high concentration values the intensity of color varies with the concentration value.

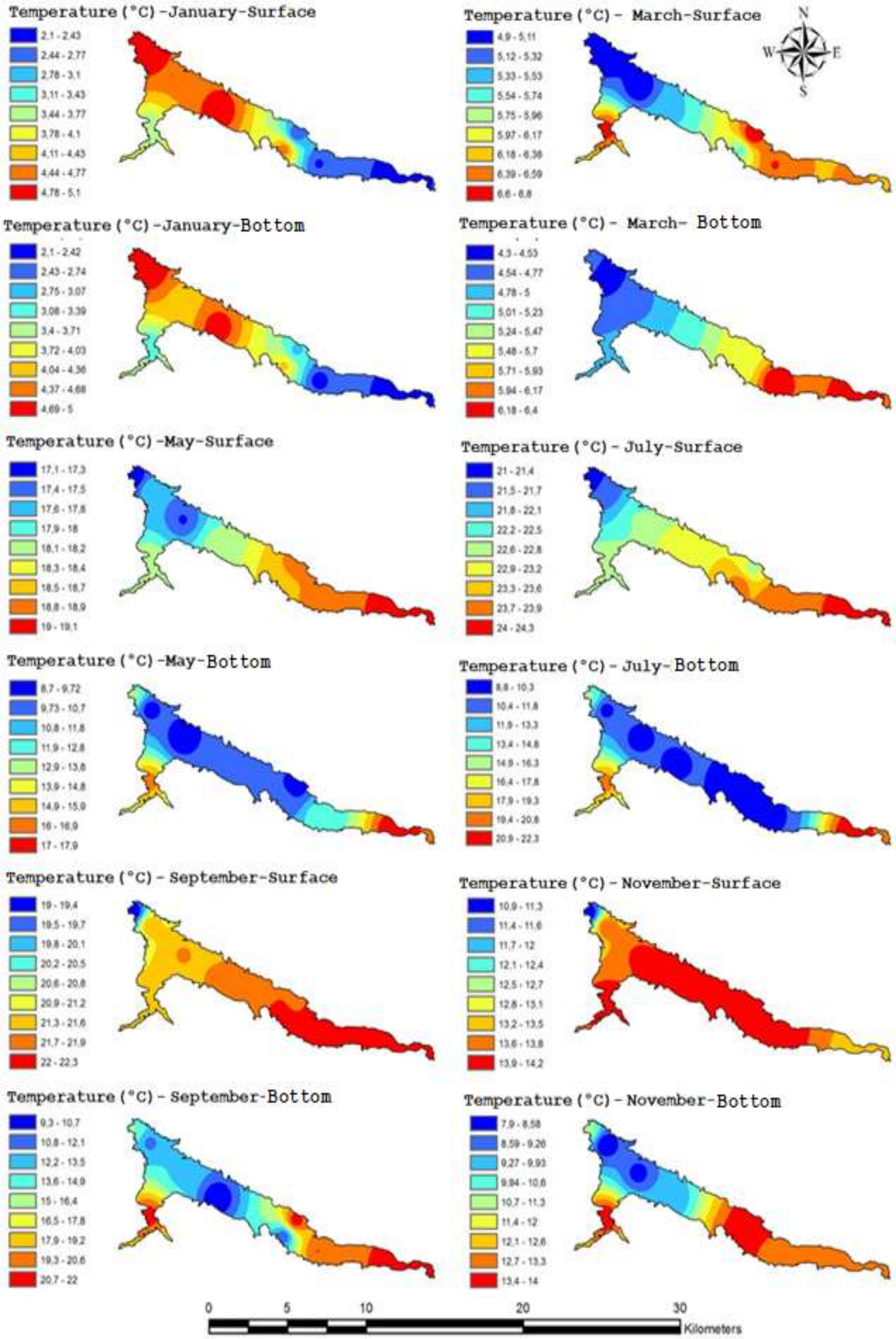


*For each map, the minimum value is expressed in dark blue and the maximum value in red

Figure 6. Relations between temperature and dissolved oxygen
(Şekil 6. Sıcaklık ve çözünmüş oksijen arasındaki ilişkiler)

Geographical Information System (GIS) maps based on temperature values; shows the spatial distribution of temperature values in January, March, May, July, September and November (Figure 6). In order to make a comparison, a map showing research stations (Figure 1) is given. The January surface water temperature has a minimum value of 2.1˚C at 8th station (the part indicated by dark blue on the relevant map). 5.1°C at the 9th station (shown in red on the relevant map) has the maximum value. Temperature values for January and March did not show a change from surface and bottom depth.

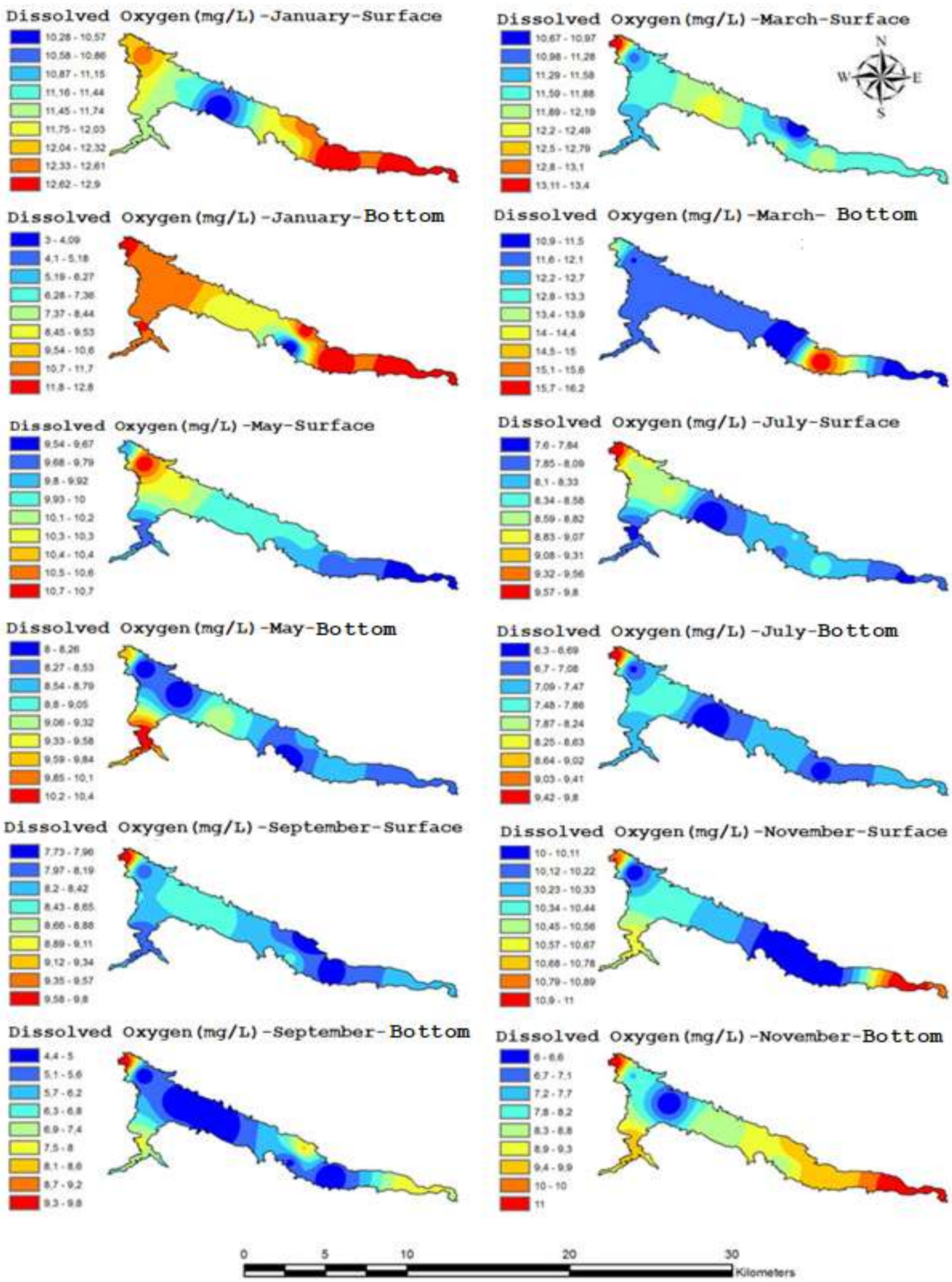
The July surface water temperature reached its minimum value at 8°C (indicated by dark blue) at 21°C. At 24.3˚C, the 9th station (indicated by red) has the maximum value (Figure 7). At July bottom water temperature was the minimum value of 8.8–10.3˚C (indicated by dark blue) in the other regions, except for the regions where the depths of the rivers and streams were mixed with the lake (stations 2 and 8). In September and November, surface water temperatures of the stations on the ground were evenly distributed across almost all stations. The minimum surface water temperature in September was measured as 19°C (the part shown in dark blue) and the maximum temperature was 22.3°C (the part shown in red on the map). In November the surface water temperature reached a maximum value of 14.2°C (Figure 7).



*For each map, the minimum value is expressed in dark blue and the maximum value in red

Figure 7. Spatial database of Almus Dam Lake temperature variable
(Şekil 7. Almus Baraj Gölü sıcaklık değişkenine ait uzaysal veri tabanı)

The spatial database of the dissolved oxygen variable of Almus Dam Lake is given in Figure 8. GIS maps have proven to be useful for generating spatial maps in dissolved oxygen parameters such as temperature.



*For each map, the minimum value is expressed in dark blue and the maximum value in red

Figure 8. Spatial database of Almus Dam Lake temperature variable (Şekil 8. Almus Baraj Gölü çözünmüş oksijen değişkenine ait uzaysal veri tabanı)

According to Figure 4, the temperature did not change in January and March, but remained constant at 4°C-5°C. This condition is found in the temperate zone waters and is named as winter stagnation by Cirik et al. [8]. In May, when the air began to warm up, sudden temperature drops started to occur at about 4-5m. Sudden temperature drops were noticeable in the July and September months when the air was heavily heated. According to Figure 3, the thermocline layer between the first 10m and 20m in July and September was clearly observed. As stated in Wetzel (1975), epilimnion, metalimnion and hypolimnion layers were calculated from the temperature profiles [9]. Thermal stratification is one of the most prominent features used to characterize a lake or dam lake. Basically, geological, morphometric and hydrological characterization of the lake is determined by thermal stratification [10]. According to Yu and Culver (2000), thermal stratification is the most important feature for characterizing a lake or dam. When thermal stratification occurs, oxygen stratification is also common at the same time [11]. At the first 10 m deep (epilimnion) in July when the tile was best observed, dissolved oxygen was reduced. Dissolved oxygen between 10m and 20m (thermocline) increased with the sudden decrease in temperature, whereas in hypolimnion dissolved oxygen began to fall.

Talling, in his 2003 study, found that small temperature changes in lakes change water density rapidly, and that temperature stratification in this case creates greater effects than predicted in the distribution of living things such as fish, diatoms [12]. The water layer for passing or absorbing light through can indirectly affect stratification biological processes according to temperature, as plankton's distribution in various regions of water changes its abundance [13 and 14]. At Almus Dam Lake, stratification began to disappear in November. Nahimana et al [15] conducted a study on Lake Tanganyika in 2008, the same situation was observed in November when the air began to cool down. This situation is named as autumn mixture as Cirik et al. [8]. The results show similarities and differences in the seasons of winter stagnation, stratification and water mixture in Almus Dam Lake. This result clearly shows the effect of temperature and dissolved oxygen on water quality of Almus Dam Lake.

Geographical information systems (GIS) and remote sensing (RS) techniques have been widely used in science circles in recent years, with continuous monitoring of pollution in the water [8]. The annual temperature values of surface water were not statistically different in the stations other than the 9th station according to the SNK test results (Table 5). The same situation was found to be consistent with the CBS temperature map given in Figure 7. According to the correlation analysis; Temperature-Dissolved Oxygen (-0.930) correlation is available. The same correlations (associations) have also appeared in the GIS maps given in Figure 6. This leads to the conclusion that relations between physicochemical parameters can be easily examined without applying a statistical process with the help of GIS maps. The GIS maps derived for each physical and chemical parameter in this phase of the study made it possible to estimate the water quality of even untested points in the lake. The information and relationships obtained by correlation analysis or other statistical analyzes could easily be explained by GIS maps. A number of studies have been conducted that describe the water quality of lakes using GIS and RS(remote sensing). Some examples of these studies; Cocker et al. [16], Wang et al. [17], Dwiwediet al. [18], Lathrop [19], Tran et al. [20]. In the U.S.A. Georgia, under the Atlanta Geological Research Service, the "Western European Environmental Program" was developed. GIS software was used in the study. As a result, an environmental program of Western European countries has been developed [16]. Our study, detailed maps for Almus Dam Lake was produced using GIS, relations between physical and chemical parameters were investigated and the results were compared with GIS maps. Statistically meaningful relations were found. Thus, a scientific study has been carried out as an example to other dam lakes in Turkey.

5. CONCLUSION AND RECOMMENDATIONS

As a result, it has been reported that Almus Dam Lake has first class water quality in terms of temperature and dissolved oxygen according to Inland Water Resources. Winter stagnation at +5°C in January and March, thermoklin in September and July, Autumn mixture in November. Also in the study Almum Dam Lake, first 10m epilimnion, 10 to 20m metalinyonion, 20m to 30m hypolimnion layer was first seen. Using the study, detailed maps for Almus Dam Lake were produced by using GIS, relations between temperature and chemical parameters were investigated and the results were compared with GIS maps. The study found that GIS maps could be successfully used even in the case of unpredictable spots of surface water sources such as lakes and rivers. As a result, a scientific study has been carried out as an example of other dam lakes in Turkey. According to the results of the study, the areas where the trout farming on the Almus Dam Lake to be built on Yeşilırmak River can be planned according to the temperature and dissolved oxygen parameters. All parameters affecting the temperature and dissolved oxygen and water quality in terms of the future of Yeşilırmak River and Almus Dam Reservoir should be monitored in the coming years using GIS.

NOTICE

This study was presented as an oral presentation at the I. International Scientific and Vocational Studies Congress (BILMES 2017) in Nevşehir/Ürgüp between 5-8 October 2017.

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