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Evaluation of Temperature, DO and BOD in Mosul Dam Lake Using Geographical Information System

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Abstract

The aim of this study is to evaluate the seasonal variations of Mosul dam lake by measuring the temperature, dissolved oxygen (DO) and biochemical oxygen demand (BOD) during the period from July 2018 to April 2019. Twenty two sites were selected within the studied lake. The obtained results were integrated with the geographical information system (GIS) using spatial images to create maps utilizing Arc map software. These maps were used to demonstrate the concentrations of the investigated parameters during the study period. The results show that all parameters were within the accepted levels, indicating the good status of the lake.

Keywords: Iraq, Limnology, Mosul dam lake, Remote sensing.

تقييم درجات الحرارة, الاوكسجين المذاب والمتطلب الاحيائي للاوكسجين في بحيرة سد الموصل باستخدام نظام المعلومات الجغرافية (GIS)

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الخلاصة

تهدف هذه الدراسة إلى تقييم التباين الموسمي لبحيرة سد الموصل عن طريق قياس درجة الحرارة, الأوكسجين المذاب والمتطلب الاحيائي للأوكسجين خلال الفترة من تموز 2018 إلى نيسان 2019. اختير 22 موقعاً داخل البحيرة و كومت النتائج التي تم الحصول عليها مع نظام المعلومات الجغرافية (GIS) عن طريق استخدام الصور المكانية لإنشاء خرائط باستخدام برنامج Arc map, استخدمت الخرائط لتوزيع تراكيز المحددات المذكورة خلال فترة الدراسة. أظهرت النتائج أن جميع المحددات كانت ضمن المستويات المقبولة والتي تشير إلى الحالة الجيدة للبحيرة.

Introduction

Lakes are key inclusions of the earth's landscape. They are remarkably important environments that provide a range of products and administrations to mankind. However, anthropogenic pressures on lakes have expanded quickly in recent decades[1].

Geographic information systems is a computer-based tool that is utilized to analyse, store, control and visualize geographic data, ordinarily within the frame of an outline. GIS applications allow clients to form and analyse spatial data, adjust information in maps, and display the outcomes of all the operations carried out. Advanced GIS innovations use digital data, for which different digitized information creation methods are utilized [2].

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GIS can relate to the information by utilizing area as the key variable. GIS accuracy depends upon source information provided with a high level of positional precision that relies on the GPS-derived positions. Airborne photography and satellite imagery are external sources that enhance the GIS output. Numerous disciplines can benefit from GIS innovation including the development and usage of hydrologic models at different levels [3].

Mosul Dam Lake is located between $36^{\circ} 37' 49''$ N $42^{\circ} 49' 23''$ E at the north of Mosul city. The shape of the lake is almost elongated where the River Tigris enters the upper zone and expands close to the dam site. The length of the lake is approximately 45 km and its width ranges from 2 to 14 km with a water surface area of about 380 km² at a maximum operation level of 330 m a.s.l [4]. The climate is hot and dry during the summer and cold and rainy during winter with occasional snowfall taking place in the mountainous region. The precipitation season within the Tigris River basin starts in October and lasts until May. The annual precipitation over the Tigris basin ranges between 450 to 1,000 mm [5]. The climate of the study area characterized by hot and dry summers and cold winters with rare snow [6]. The annual mean temperature is 19.5° C and the mean rainfall is 383 mm [7]. Figure-1 shows the Mosul dam lake.



Figure 1- Mosul Dam Lake (www.glovis.usgs.com).

Materials and methods

Twenty two stations within Mosul Dam Lake were chosen to cover all the lake's regions. The studied stations names and their coordinates are given in Table-1.

Table 1- Stations and their coordinates of Mosul Dam Lake that are investigated in the present study

Stations	Longitude	Latitude
S1	42.823795	36.637655
S2	42.858127	36.634625
S3	42.892545	36.630079
S4	42.9334	36.626497
S5	42.94267	36.653219
S6	42.900098	36.670294
S7	42.884992	36.692596
S8	42.888082	36.714892
S9	42.843793	36.707736
S10	42.802594	36.720396
S11	42.785085	36.741583
S12	42.753843	36.7259
S13	42.737707	36.752862
S14	42.720369	36.764139
S15	42.705607	36.784077
S16	42.687238	36.807308
S17	42.659343	36.801673
S18	42.649816	36.783527
S18	42.624067	36.788064
S19	42.594884	36.799749
S20	42.564071	36.822187
S21	42.514032	36.838881
S22	42.823795	36.637655

1. *In situ* measurement

Samples were taken in the period from July 2018 to April 2019, where July and August represent summer, September and October exemplify autumn, December and January state winter and March and April represent spring. Glass bottles of 1 liter size were washed with distilled water, labeled, and used to collect samples by inundation at 10-20 cm below water surface. The bottles were then kept in icebox and transported to the lab in the University of Mosul/ College of Science/ Department of Biology for the measurement of the below parameters [8].

a) Temperature

Water temperature and ambient temperature were measured in the field using electronic thermometer TA-288.

b) Dissolved Oxygen (DO)

Winkler's method was used to estimate the dissolved oxygen concentration. This method was described by the American Public Health Association (APHA) [8].

c) Biochemical Oxygen Demand (BOD)

Similar to the assessment of dissolved oxygen, Winkler's method was used to measure biochemical oxygen demand by calculating the difference between the values of dissolved oxygen for day one and day five, as follows:

$$\text{BOD} = \text{DO1} - \text{DO5}.$$

2. Geographical Information System(GIS) Work

All samples were collected during the passage of the satellite across the lake; the times of satellite passage were determined by the official website of landsat8. Remote sensing data used in this study was formulated as Tagged Image File Format (TIFF). These files were scanned by Landsat satellite (Landsat-8 OLI images; path: 168 and row: 37) which has many bands that were used to capture the satellite images, as shown in Table-2, which were downloaded from the website of United States Geological Survey (USGS) (www.glovis.usgs.com).

Table 2- Landsat-8 OLI Bands (USGS, 2019)

Band	Wavelength range (micrometers)	Spatial Resolution (meters)	Spectral Width (nm)
Band 1 - Coastal aerosol	0.430 – 0.450	30	2.0
Band 2 - Blue	0.450 – 0.510	30	6.0
Band 3 - Green	0.530 - 0.590	30	6.0
Band 4 - Red	0.640 - 0.670	30	0.03
Band 5 - Near Infrared (NIR)	0.850 - 0.880	30	3.0
Band 6 - SWIR 1	1.570 – 1.650	30	8.0
Band 7 - SWIR 2	2.110 – 2.290	30	18
Band 8 - Panchromatic	0.500 - 0.680	15	18
Band 9 - Cirrus	1.360 – 1.380	30	2.0

In the present study, ArcGIS 10.6 software was used for creating and using maps, compiling geographic data, analysing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database depending on Gaussian process method (Kriging). The produced maps represent the mean values of temperature, DO and (BOD during the period of study.

Results and discussion

During the period of study, the elevation of the lake was recorded every month at the time of samples collecting. Also, the area of the lake and the storage capacity were assessed (Table-3).

Table 3- Surface area and storage capacity of Mosul Dam Lake at different water levels during the study periods

Month/ Year	Lake elevation (m.a.s.l)	Area (Km ²)	Storage capacity (Km ³)
July/ 2018	311	216	4.278
August/ 2018	307	183.201	3.479
September/ 2018	304	159.678	2.962
October/ 2018	300	136.540	2.371
December/ 2018	310	208.211	4.062
January/ 2019	315	253.771	5.214
March/ 2019	321	310.2	6.935
April/ 2019	324	325	8

Our results showed that the area of the lake and water capacity were proportional with the elevation of the lake. The largest area and the largest storage capacity were recorded in April/2019, because of being preceded by the rainy season and melting of the snow in Turkey. While the smallest area and the minimal storage capacity were recorded in October/2018 due to being preceded by the dry season where there is no precipitation.

Mean values \pm SD of water and air temperatures, DO, and BOD₅ were calculated in the different 22 sites sampled from Al-Mosul Dam Lake during four seasons. Generally, values of water and air temperatures were higher in the hot summer season and lower in the cold winter season.

Also, correlation analysis between these examined variables was carried out using SPSS.

1. Water temperature

The highest mean value of water temperature (28.93 ± 0.47 °C) was recorded in site 22 during summer, while the lowest (7.5 ± 0.5 °C) was measured in both sites 1 and 2 during winter (Figs. 3 and 4). During September 2018, most of the global lands and ocean surfaces were reported to have a very

warmer climate) than that in the average conditions. The rising temperatures are the most significant aspect in the period of climate variability [9]. The most notable high temperatures were present across southern South America, Alaska, the southwestern and eastern contiguous U.S., most of Europe, the Middle East, as well as western and eastern Russia [10]. Global average temperatures are expected to rise an additional -16.3°C to -13.9°C, depending on future greenhouse gas emissions [11].

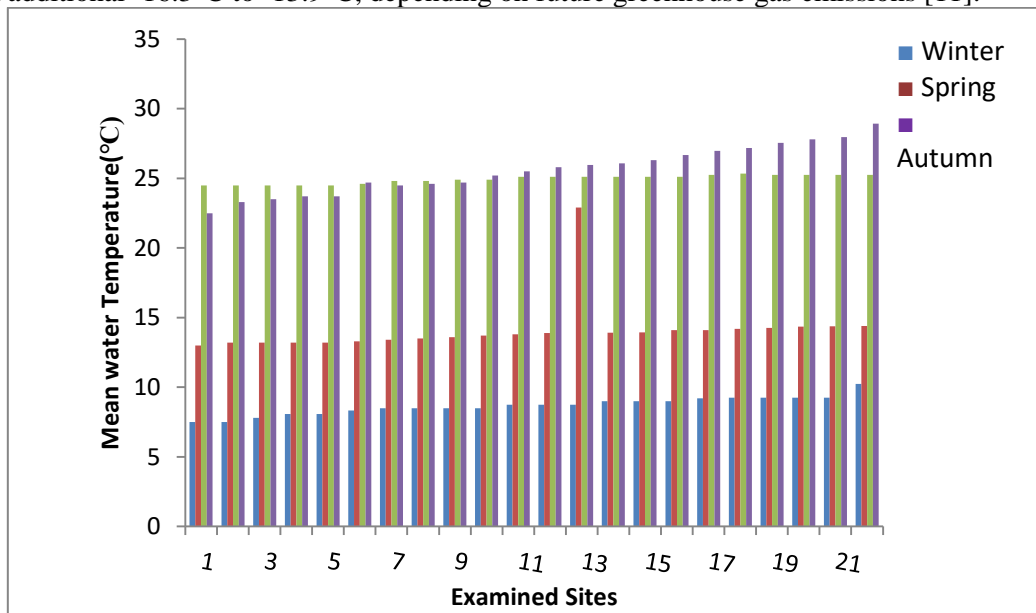


Figure 2- Mean water temperature (°C) recorded in 22 sites of Al-Mosul Dam Lake during the four studied seasons.

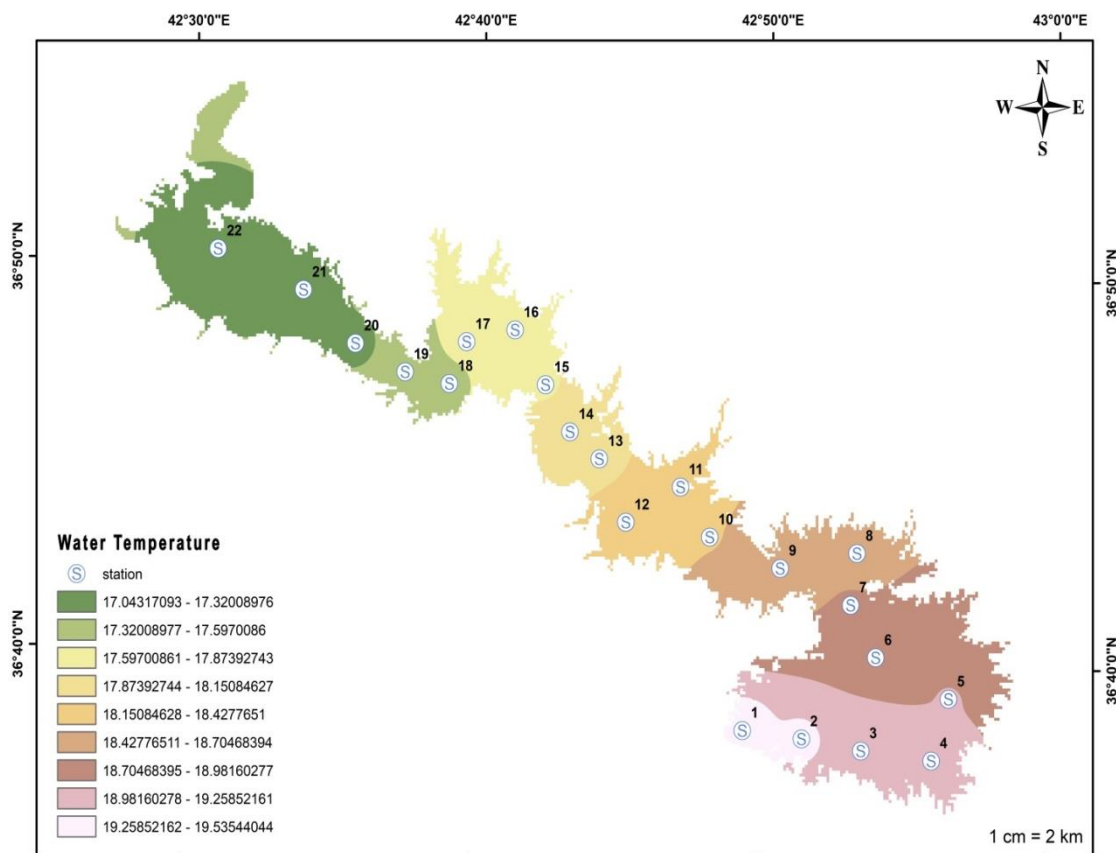


Figure 3- Spatial distribution of water temperature for the studied twenty two stations of the Mosul Dam Lake during 2018-2019.

2. Air temperature

The highest mean value of air temperature in the studied stations was 41.0 ± 2.0 °C, recorded in various sites during summer season, whereas the lowest mean value was 9.0 ± 0.0 °C, measured again in several sites, but during the winter season (Figures-4, 5). These results correspond to the findings of previous studies. Muslih and Błażejczyk [12] also found more significant changes in summer months compared to winter months, along with more warming in the southern part. The results obtained by Robaa and Al-Barazanji [13] using Sen's slope and MK method at 11 stations over Iraq during the period 1972–2011 are highly similar to the results from this study. Our results also agree with those of Salman *et al.* [14] which revealed that summer temperature increased at more stations compared to winter temperature.

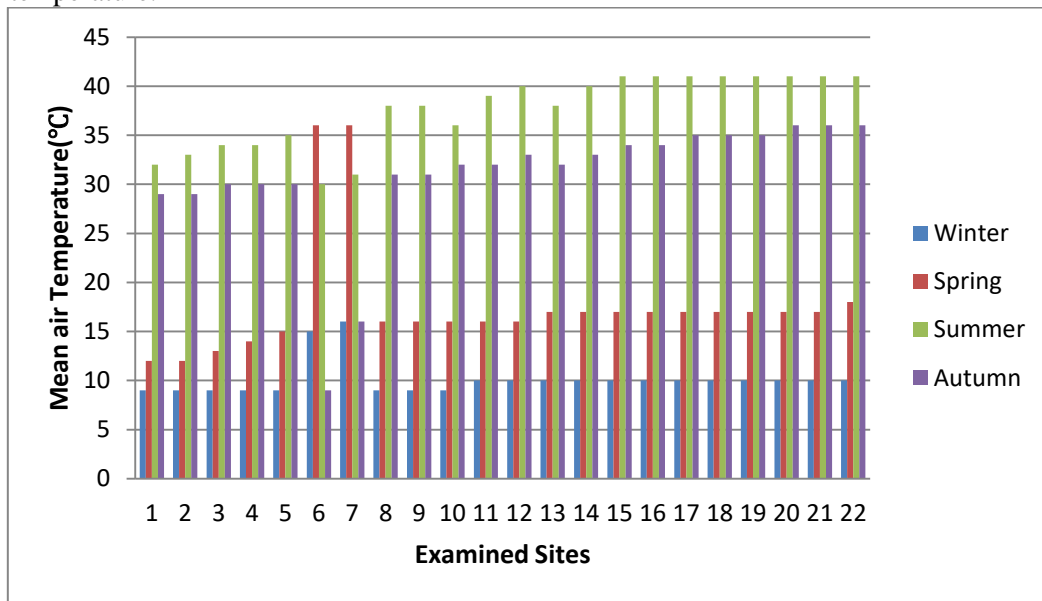


Figure 4- Mean air temperature (C°) recorded in the studied 22 sites of Al-Mosul Dam Lake during four seasons.

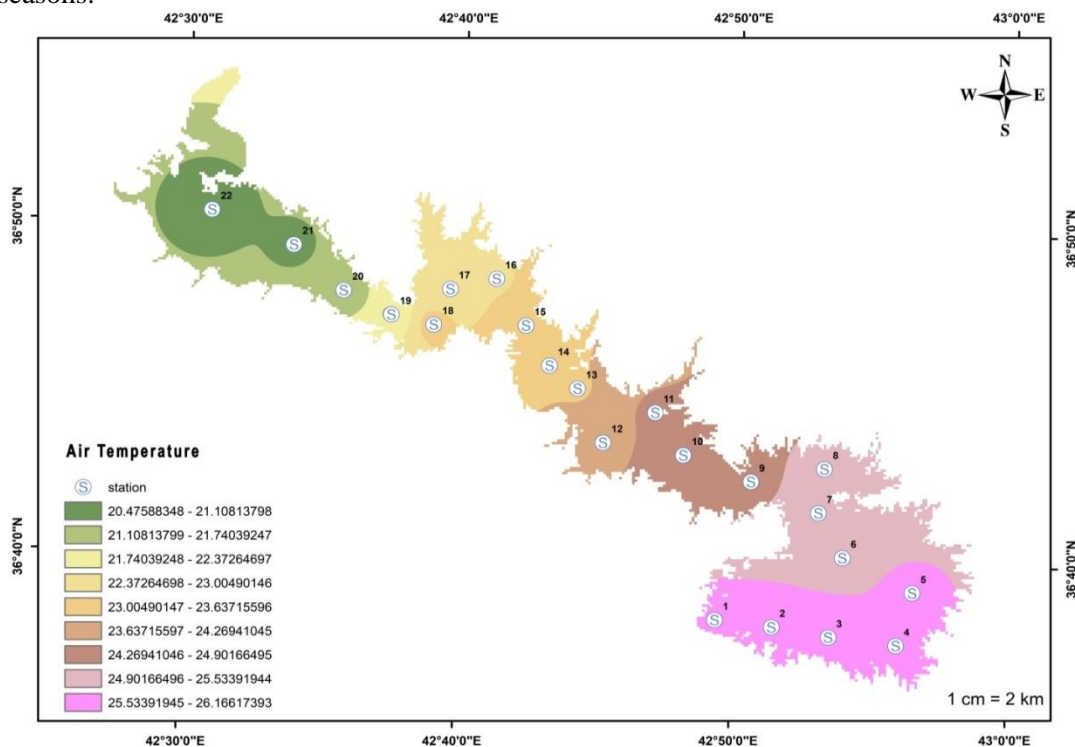


Figure 5- Spatial distribution of air temperature for the studied twenty two stations along Mosul Dam Lake during 2018-2019.

3. DO

Our study found that water DO had its highest mean value (12.33 ± 0.40 mg/l) that was recorded in site 22 during spring season. While the lowest mean value was 5.08 ± 1.2 mg/l in site 14 during winter season (Figures-(6 and 8)).

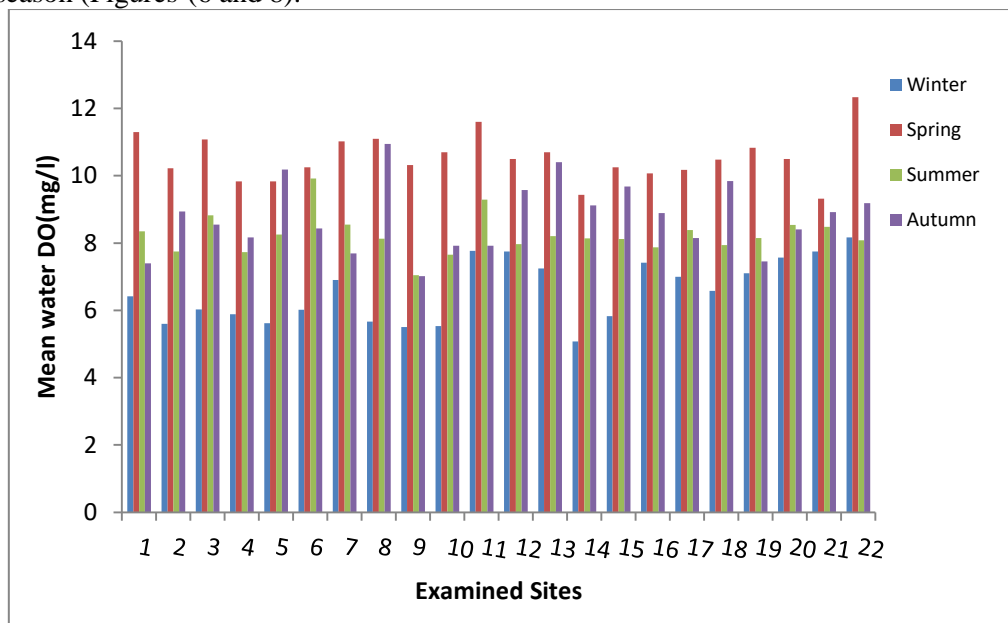


Figure 6- Mean water D.O. (mg/l) recorded in 22 sites of Al-Mosul Dam Lake during the four studied seasons.

Analysis of variance of the obtained data reveals significant differences ($P \leq 0.001$) between the studied sites and seasons, while the significant differences ($P \leq 0.05$) found by utilizing the least significant difference analysis confirmed such conclusion, with the mean values being 0.7079 mg/l for seasons and 2.08 mg/l for sites.

The biological activity peaks during the spring and summer when photosynthetic activity is driven by high solar radiation. Furthermore, during the summer, most lakes in temperate climates are stratified. The combination of thermal stratification and biological activity causes characteristic patterns in water chemistry [15, 16].

Frequent spring storms bring not only water to the lake, but an influx of nutrients from the landscape. This often leads to a series of spring algae and zooplankton blooms that allow nutrients in the lake to be cycled up through the food chain, which leads to a high concentration of dissolved oxygen [17].

The values of dissolved oxygen obtained by the present study show disagreement with those found by Al-Obaidy *et al.* [18], where oxygen levels of Dokan lake were between 3.55-12.30 mg/l, and with those of Toma [19] for Derbendikhan lake who reported a concentration of 6-9.5 mg/l. Furthermore, consistency with our study finding, Salah *et al.* [20] found that the DO of Al-Habbniya lake was 6.72-10.57 mg/l. The results of our study are also consistent with those of the study of Iscen [21] on Uluabat lake in Turkey where DO mean was 7.99 mg/l.

The overall DO mean was found to have a highest value in site 22, while the lowest value was recorded in site 9, which were 9.45 mg/l and 7.45 mg/l, respectively (Figure-7).

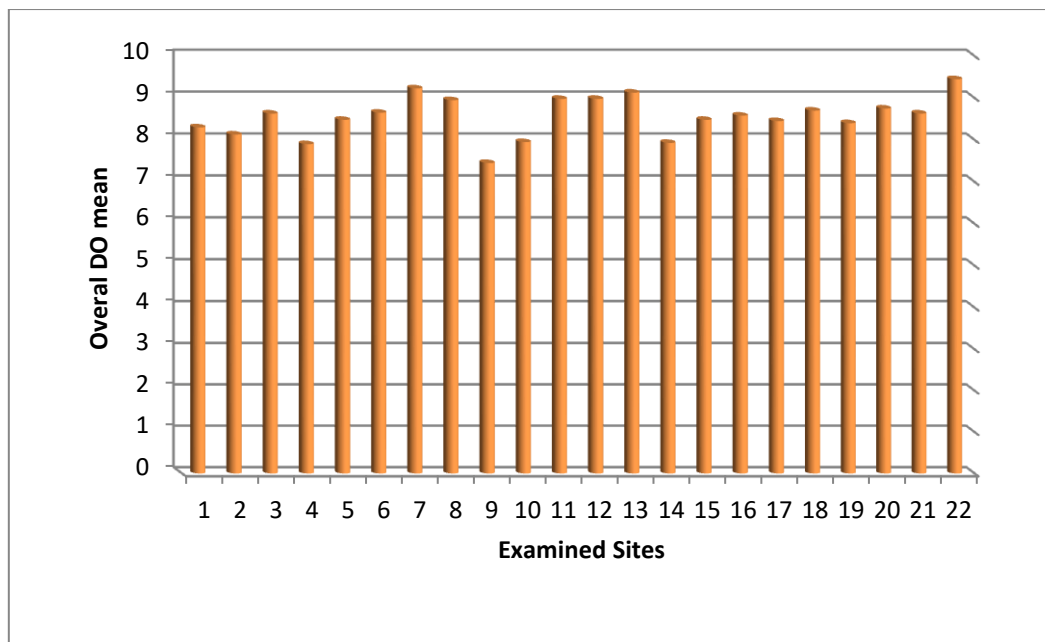


Figure 7- Mean water D.O. (mg/l) recorded in 22 different sites of Al-Mosul Dam Lake during the studied four seasons.

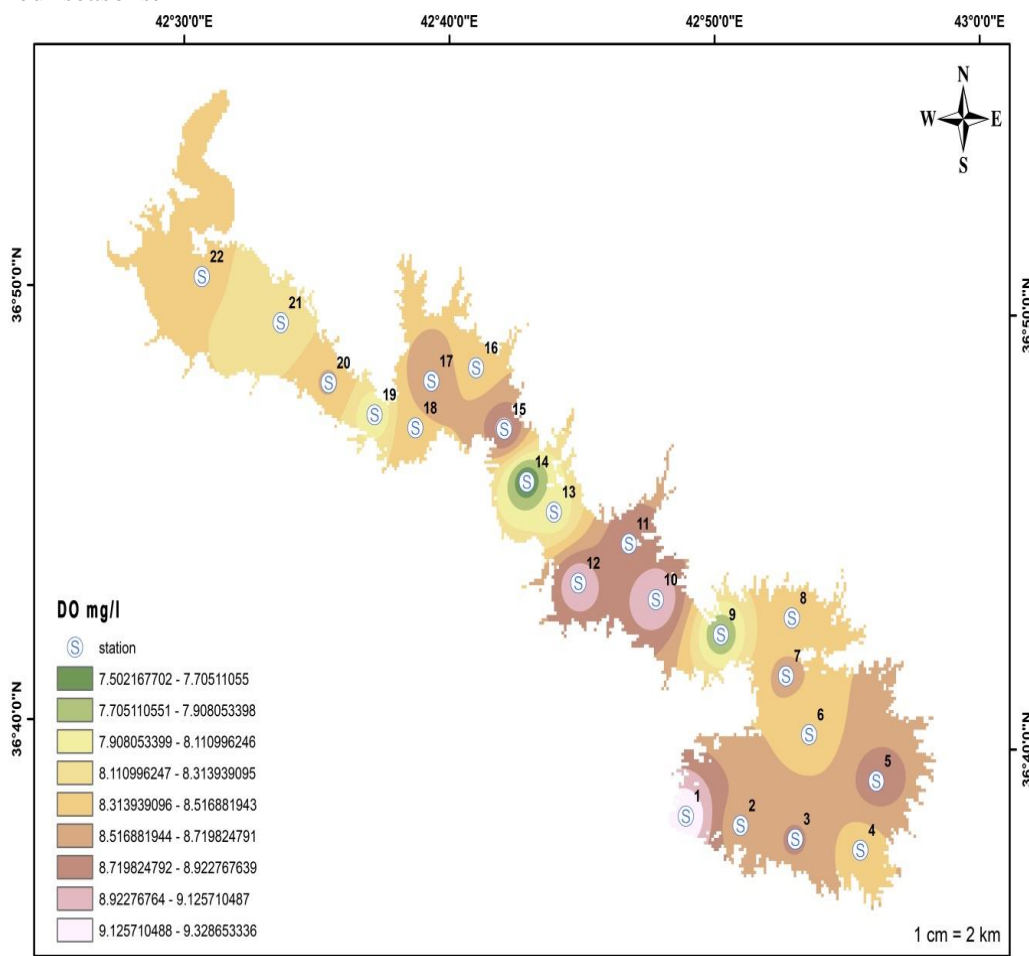


Figure 8- Spatial distribution of D.O. for the 22 stations along Mosul Dam Lake during 2018-2019.

4. BOD₅

The current analysis showed that the lowest BOD₅ mean value (1.32 ± 0.09 mg/l) was found in site 19 in the autumn season, while the highest was 7.375 ± 2.03 mg/l that was measured in site 13 during summer season Figures-(9 and 11).

Generally, the recorded BOD₅ values were within the permissible levels of Iraqi standards (Tables-2.4), with the exception of the values in sites 13 and 8 (5.23 and 5.3 mg/l, respectively). This could be due to the slight increase of levels of organic matters in these two sites.

The biochemical reactions are temperature dependent and the activity of the microorganism increases with the increase in temperature up to a certain value, whereas it drops with the decrease in temperature [22].

The estimated BOD values never reached critical values in most times of the study period, indicating good to moderate water quality conditions. The study results are in accordance with the known values of Iraqi inland waters [23, 24].

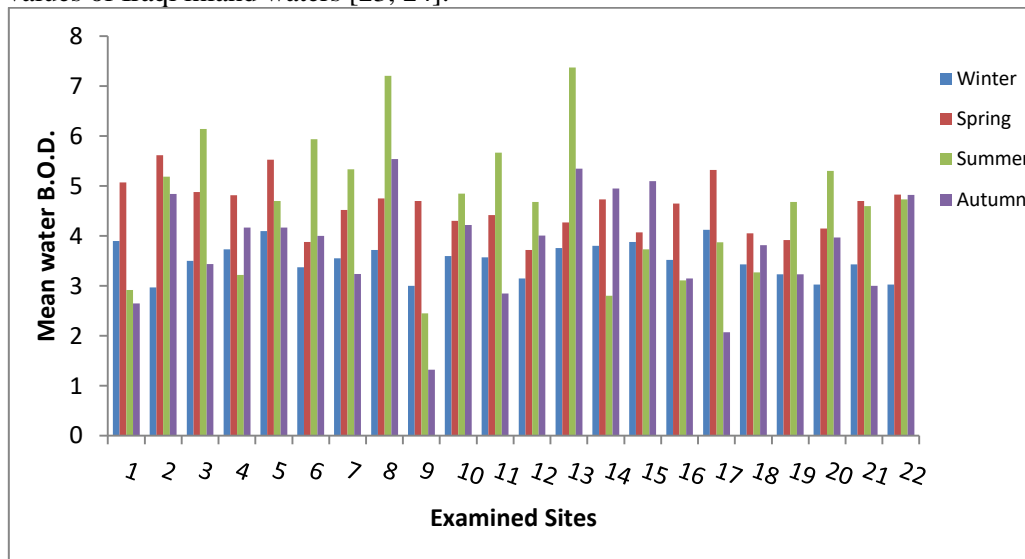


Figure 9- Mean water B.O.D. (mg/l) recorded in the 22 studied sites of Al-Mosul Dam Lake during the four seasons.

Statistical analysis of the BOD₅ results showed significant differences ($P \leq 0.001$) between both seasons and sites. Also, the results of the least significant analysis obviously illustrated such differences ($P \leq 0.05$), with the values being 1.494 mg/l and 0.977 mg/l for seasons and sites measurements, respectively.

On the other hand, the highest overall BOD₅ mean was detected in site 8 (5.3 mg/l), but the lowest mean value was found in site 9, which was 2.88 mg/l (Figure-10)

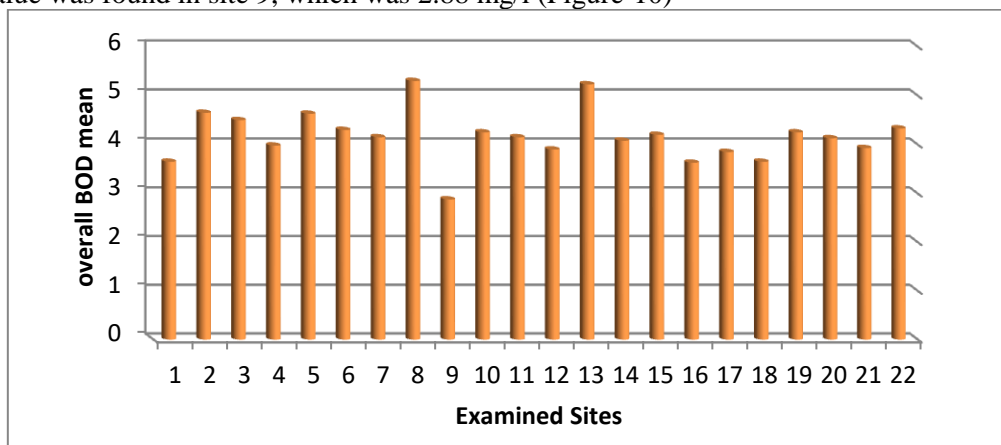


Figure 10- Overall B.O.D mean (mg/l) recorded in the 22 studied sites of Al-Mosul Dam Lake during the four seasons.

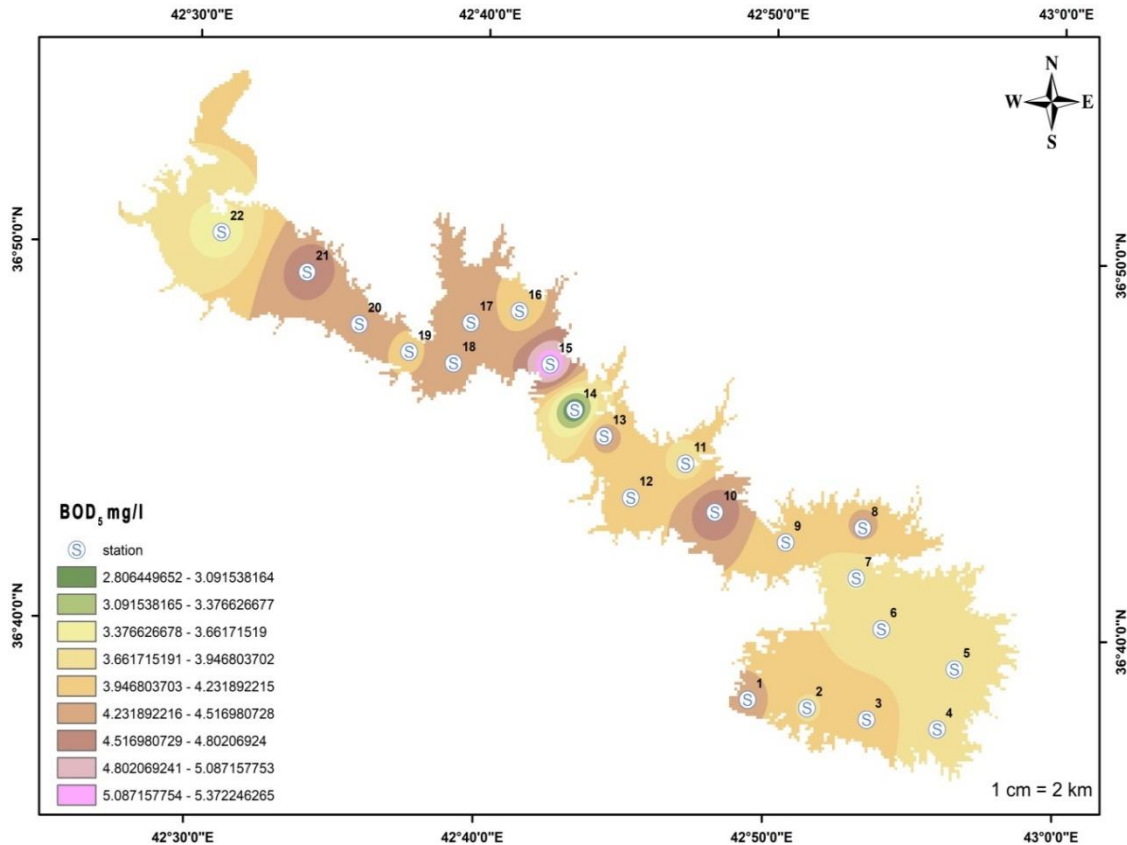


Figure 11- Spatial distribution of BOD₅ values for twenty two stations along Mosul Dam Lake during 2018-2019

Conclusions

The usage of GIS provided an efficient tool to illustrate the distribution of the investigated parameters. The field measurements showed that temperature, DO and BOD values of the Mosul Dam Lake were within the accepted ranges, which reflects the good state of the lake during the study period.

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