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Influence of Seasonal Variations on Water Quality in Hamrin Lake

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Abstract

The assessment of the vegetation changing patterns of the Hamrin Lake area over the period of 2013 to 2023. The analysis is based on the effects of spatially and temporally dynamic changes in surface water quality and climatic factors on the quality and function of the region's water basins over time. NDVI (Normalized Difference Vegetation Index) data provide the basis for seasonal and temporally dynamic analyses of vegetation growth patterns, while Landsat satellite images provide the basis for predicting vegetation growth levels via Supervised Classification. Additionally, the identification of the most dominant variables influencing surface water quality was carried out through Statistical/Redundant Tests. Our results indicate that many of the major variables contributing to surface water quality (in this case, pollutant concentration) were measured near the water quality monitoring stations. Nitrate concentration was found to be at its lowest in the summer months, while total phosphorus concentration was highest under spring weather conditions. NDVI values showed a gradual decline from spring through the summer months, whereas land use values were slightly increasing over the same season. Results from our analysis of Landscape Metrics revealed that connectivity of landscapes was the most influential variable affecting water quality in a seasonal manner, in contrast, water elevation was significant in affecting the majority of stream water quality.

Keywords: Climate variability, Trend analysis, Water quality, NDVI, Hamrin Lake.

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تأثير التغيرات الموسمية على نوعية المياه في بحيرة حمرين

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الخلاصة

تهدف هذه الدراسة إلى تقييم التغيرات التي طرأت على الغطاء النباتي في حوض بحيرة ررزازة بين عامي 2013 و2023. وسيتم ذلك من خلال دراسة كيفية تغير مساحة الأرض المغطاة بالمياه مع مرور الوقت، وذلك بناءً على متغيرين رئيسيين: 1) جودة المياه السطحية، و2) التغيرات المناخية. وسيتم إجراء تحليل موسمي وتحليل السلاسل الزمنية لنمو الغطاء النباتي باستخدام بيانات مؤشر الغطاء النباتي الطبيعي (NDVI)، ، ويتم استخدام تصنيف الصور الخاضعة للإشراف لصور Landsat لتقييم التغيرات في مناطق الغطاء النباتي. تم استخدام التحليلات الإحصائية والتكرارية لتحديد العوامل الرئيسية التي تؤثر على جودة المياه في المواسم المختلفة. تكشف النتائج عن تسجيل تركيز أعلى لمؤشرات تلوث المياه الرئيسية حول مواقع الرصد. كانت تركيزات النيتروجين النترات أقل عمومًا خلال فصل الصيف، بينما بلغت تركيزات الفوسفور الكلية ذروتها في الربيع. انخفضت مساهمة مؤشر الغطاء النباتي الطبيعي في جودة المياه من الربيع إلى الصيف، في حين زاد تأثير استخدام الأراضي خلال نفس الفترة. أشارت تحليلات مقاييس المناظر الطبيعية إلى أن اتصال الرقعة كان العامل الأساسي الذي يؤثر على جودة المياه عبر المواسم المختلفة، في حين ظهر مستوى المياه كمعلمة هيدرولوجية رئيسية تؤثر على جودة مياه الجداول. تشير هذه النتائج إلى أنه يجب مراعاة الاختلافات الموسمية في العوامل الرئيسية التي تؤثر على جودة المياه من أجل استراتيجيات فعالة لإدارة المياه.

الكلمات المفتاحية: تغيرات المناخ، تحليل المسار الزمني، جودة المياه، مؤشر الغطاء النباتي الطبيعي (NDVI)، بحيرة حمرين.

1. Introduction:

Water quality affects both ecological environments and Public Health. Therefore, freshwater of sufficient quantity and quality is required for Human, Social, and Economic Development. However, the continued degradation of water quality due to many factors creates additional complications for managing water quality as well as preventing degradation. Consequently, there are a number of climatic influences on water quality management, such as precipitation patterns, vegetative cover, soil type, and river discharge [1, 2]. The use for agriculture and cities has expanded substantially and, when combined with soil pollution and inadequate water management, has increased the chance that the surface water of lakes will be contaminated due to the movement of nutrients and other pollutants by way of runoff into the lake system. When compared to other types of land use, agricultural and urban land use types create negative relations with surface water quality; natural vegetation, palm trees, and grasslands create positive relations with surface water quality [3]. The overuse of fertiliser in agricultural lands (an example of overuse is an estimated requirement to produce global consumption of approximately 160 million ton of nitric oxide and 76 million ton of ammonium nitrate by (FOA2022) accounts for a large proportion of nitrogen and phosphorus levels found in water bodies [4]. Woodlands and grasslands help to mitigate land degradation and water depletion. They contribute significantly to water condition improvement [5]. Furthermore, land cover configuration play a critical role in the health and quality of water resources [6]. The arrangement of landscapes and the way land is used determines the quality of river water. Of particular importance for river water quality are the locations of yearly grasses, Alhagi species, grasslands, and the annual variety of these plants contributing to the functioning of the hydrological cycle (water movement) and the cycling of nutrients found in the soil to the river and, ultimately, the quality of water in the river, in Hamrin Lake. Additionally, the configuration of the landscape and seasonal variation will also impact water quality. The Hamrin Lake was built in the 1980s to create a second reservoir to assist with regulating flooding caused by the Diyala River. Lake region is also home to a national water storage area. The Lake is a large reservoir for storing water at the national level; the average annual rainfall during the rainy season from November to March is approximately 101.1 mm [7]. Annual runoff is very inconsistent from year to year and can be affected by rainfall or snowmelt in one part of the basin while the other parts experience little or no flooding because the rainfall pattern is inconsistent across the entire region. The average temperature for the Hamrin lake is from 14.5° C to 33.6° C [8]. While there are many canyons within the lake, these canyons seem to alternate with floods occurring at different times of year. The most commonly found soil types in the lake are clay soils in the northern portion of it and alluvial soils in the southern portion of the Hamrin lake. Most of the vegetation in the Hamrin lake occurs on shorelines around it. Aquatic plants and wetland vegetation (such as reeds, tamarisk, and submerged plants) are located near water [9]. Research conducted on water quality data for Lake Hamrin indicated that changes due to the seasons had a large effect on water quality in the Lake. Summertime increases in the amount of total salts and suspended solids occurred because of reductions in lake levels due to evaporation and increased wetness over the summer [8]. The rainy season has a significant positive effect on some of the physicochemical properties of the water in the lake. The increase in these properties is directly related to an increase in the amount and rate at which water enters the lake through spring rain and melting snow [10]. Remote sensing technology and GIS have been utilized to study seasonal fluctuations in the extent of Hamrin Lake and the associated water quality [11]. Using contour mapping to find flooded areas and to measure how much water is in Lake Hamrin, showed that variations in topographical elevations have a significant effect on how much water can be held in a lake. where the contour mapping is useful scientific instrument for managing water resources and for solving problems associated with water supplies [12].

The present study uses Normalized Difference Vegetation Index (NDVI) data to examine how water condition improvement has varied over the period 2013-2023 by utilizing three different methods: Coefficient of Variation, Linear Regression, and Hurst Exponent (using R/S analysis). Objectives of this study include: (1) to examine the temporal and spatial patterns of vegetation in the Hamrin Lake region; (2) to study the seasonal and spatial variability of the quality of surface aquatic systems; and (3) to quantify the major drivers of water quality throughout the year.

2. Methodology

2.1. Description of the Study Area

Lake Hamrin is in the southwestern Diyala Governorate of Eastern Iraq. Lake Hamrin is an artificial lake that was built through the construction of Hamrin Dam located on the Diyala River and is positioned near two approximate lines of latitude: (34°–35° North) and between Longitudes: (44°–45° East). This lake is one of the more important water reservoirs in Iraq. North of this lake is the Hamrin Mountain Range, while south of the lake lie the Central Sedimentary Plains [9]. These geographical features create an attractive landscape with many physical characteristics. The geography of the area has a semi-arid climate with hot summer weather and low spring rain fall rates. Hamrin Lake helps to regulate the flow of the Diyala River and to control floods which provides important benefits to the stability of the water resource. Also, water from this lake is used by farmers to irrigate their crops, which increases the local economic activity and improves the standard of living for the local people. The area being studied is also subject to many changes in water levels due to climate change and, also, due to problems associated with inadequate water use policies. There is a large variety of both aquatic and terrestrial species that inhabit Lake, which adds further environmental value to this site. Being near locations that contain large populations also adds to the area's economic importance. Overall, as shown in Figure (1), the study area is located in an economically important area which allows for an understanding of hydrological and environmental changes taking place within Iraq's eastern geographic region, the interaction between people and the environment [12].

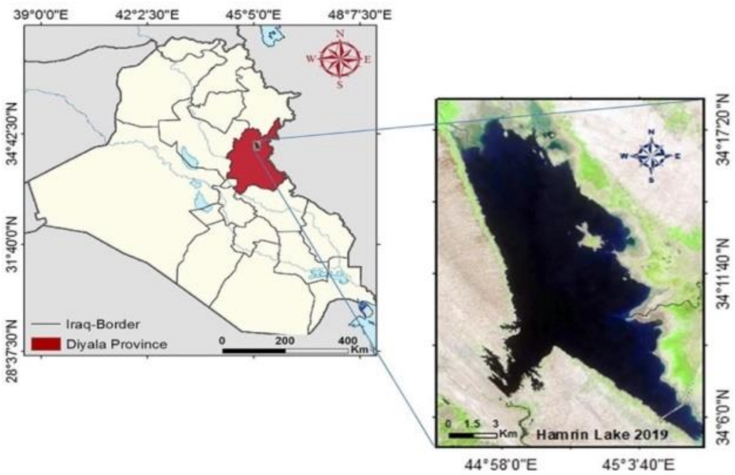


Figure (1): Survey of Land Cover and Monitoring Sections in Hamrin Lake.

2.2. Data preparation

1- Field data for water quality in Lake Hamrin were provided from 2013 to 2023.

2- Six criteria served to indicate water quality: Biochemical Oxygen Demand (BOD),Dissolved Oxygen (DO), Electrical

Conductivity (EC), Nitrate Nitrogen NN, Total Phosphorus TP, and Potential of Hydrogen (pH)), and these parameters were analyzed in the laboratories of the Iraqi Ministry of Water Resources.

3- Approximate data were provided through remote sensing, where visuals captured by the Landsat 8 satellite were used Satellite images play an effective role in remote sensing, as they can provide a lot of data accurately, quickly and at a lower cost, as the same area can be reworked and the difference found over the years can be found. In this study, images from the Landsat 8 satellite were used to find the vegetation cover. Band 4(Red) and Band 5(Near infrared) was used.

4- Programs (ENVI 5.3, QGIS 3.20.1, Arc map 10.4.1) were used to correct images and draw maps. ArcGIS and QGIS are used to manage datasets and apply some modifications to the data. Moreover, this software is used to draw maps and analyze transformations. In GIS, the images have been georeferenced to provide geographic coordinates such as latitude, longitude, or UTM coordinates. ENVI also allows for performing geometric processing and geo-correction through the sun angle and transforming the digital image into reflectance

5- Three monitoring sites (P1, P2, and P3) were established within Hamrin Lake to serve as locations where water quality samples could be collected from the lake and evaluated for quality through laboratory analysis.

2.3. Data collection and analysis

The Normalized Difference Vegetation Index (NDVI) is commonly used to identify plant growth on land surfaces from satellites (remote sensing). The NDVI is a vital resource for identifying healthy and actively growing plants as well as distinguishing between several categories of vegetation types and soil distributions based on how each category reflects light differently than other categories. The NDVI can provide accurate and timely information to the public on the status of plant and soil growth as well as potential future crop production [13].To calculate the NDVI, eq.1 was used[14]:

$$NDVI=\left(\frac{band_5-band_4}{band_5+band_4}\right) \text{ for Landsat 8} \quad \ldots\ldots\ldots(1)$$

To calculate the vegetation coverage, eq.2 was used[15]:

$$V_c=\frac{NDVI-NDNI_{min}}{NDVI_{max}-NDVI_{min}} \quad \ldots\ldots\ldots\ldots(2)$$

(Vc) represents vegetation coverage, (NDVI is the pixel value for vegetation index, and ($NDVI_{max}$) and ($NDVI_{min}$) are the maximum and minimum NDVI for Hamrin Lake.

To calculate the direction of vegetation coverage, eq. 3 was used [16]:

$$L=\frac{n*\sum_{a=1}^{n}(a*VC_a)-[\sum_{a=1}^{n}a\sum_{a=1}^{n}VC_a]}{n\sum_{a=1}^{n}a^2-[\sum_{a=1}^{n}a]^2} \quad \ldots\ldots\ldots\ldots(3)$$

Where (L) is the rate of change in vegetation cover, a is the number of years, it is the ranges (1-10), (n) is time series length, and (vc_a)is the vegetation coverage of (a).

The change range of vegetation coverage (B) using the following eq. 4 [17]:

$$B=L(n-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Extract the time-series mean eq. 5 is used [16]:

$$f'_{(\tau)}=\frac{1}{\tau}\sum_{t=1}^{\tau}f_{(t)} \quad ,\tau=1,2,\ldots,n \quad \ldots\ldots\ldots\ldots\ldots(5)$$

Where: (n) is the time series

To calculate a cumulative variation, eq.6 was used[17]:

$$X_{(t,\tau)}=\sum_{t=1}^{t}(f_{(t)}-f'_{(\tau)}) \quad ,1\leq t\leq \tau \quad \ldots\ldots\ldots(6)$$

To calculate the fluctuation trend, eq. 7 was used[18]:

$$R_{(\theta)}=Max\,X_{(t,\theta)}-Min X_{(t,\theta)} \ , \theta=1,2,..,n \quad \ldots\ldots\ldots\ldots(7)$$

To calculate the standard deviation eq, 8 was used[18]:

$$S_{(r)}=[\frac{1}{\tau}\sum_{t=1}^{t}(f_{(t)}-f'_{(\tau)})]^{1/2} \ldots\ldots\ldots\ldots\ldots(8)$$

To calculate the Hurst exponent, eq, 9 was used, where the Hurst exponent was employed to project variation in the time series [18]:

$$\frac{R_{(\tau)}}{S_{(r)}}=(c\tau)^H \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where: (H) represents the Hurst exponent, and its value ranges (0-1). If the value of H = 0.5, the sequence is random. If the value of H is more significant than 0.5, it means that the sequence is consistent. If the value of H is less than 0.5, the trend is opposite to the future [18].

3. Results and Analysis

3.1 Yearly Variations in NDVI-Based Vegetation Greenness

The results showed the annual changes in the vegetation cover of the study area from 2013 to 2023. the results in table 1 showed an apparent decrease over the ten years as the value of (B) decreased slightly by 0.05.

The spatial patterns of vegetation cover change were quantified using the Mann-Kendall test [19], where the apparent decrease in vegetation cover according to the expected values through remote sensing was NDVI in 2023, which was 0.69 of the total area. The low area was 0.33, and all Hurst indices were approximately 0.80, meaning that the time series indicates a consistent future trend, and thus, the vegetation cover continues to degrade.

Table 1, Dynamics of Vegetation Greenness in Three Watersheds locations

Watershed	Mean Vegetation Coverage		Hurst Exponent B(%)	
	2013	2023		
P1	0.57	0.61	0.80	2.1
P2	0.58	0.69	0.82	2.0
P3	0.64	0.75	0.84	2.2

3.2. Seasonal Fluctuations in the Normalized Difference Vegetation Index

The results showed that the difference index during seasonal fluctuations from spring to summer from 2013 to 2023 was that the vegetation cover index in spring during the ten years ranged from 0.66 to 0.81, and in summer, the vegetation cover was 0.64 to 0.74. The largest rate of increase in vegetation cover was in Spring, when the value of (L) reached less than 0.04, indicating the sustainability of natural plants, trees, and Alhagi, and grasslands as in Figure (2), the least variation of the vegetation cover index was in the summer season, flowing the classification framework proposed by Nielsen and Poma [20], the coefficient of variation is considered weak if it is less than 10%, moderate if it ranges between 10% and 100%, and strong if it exceeds 100%. The extent of change in spring was moderate, but in summer, it was weak. Figure (2) shows the onset of seasonality on NDVI. In addition, the NDVI index in spring was the largest.

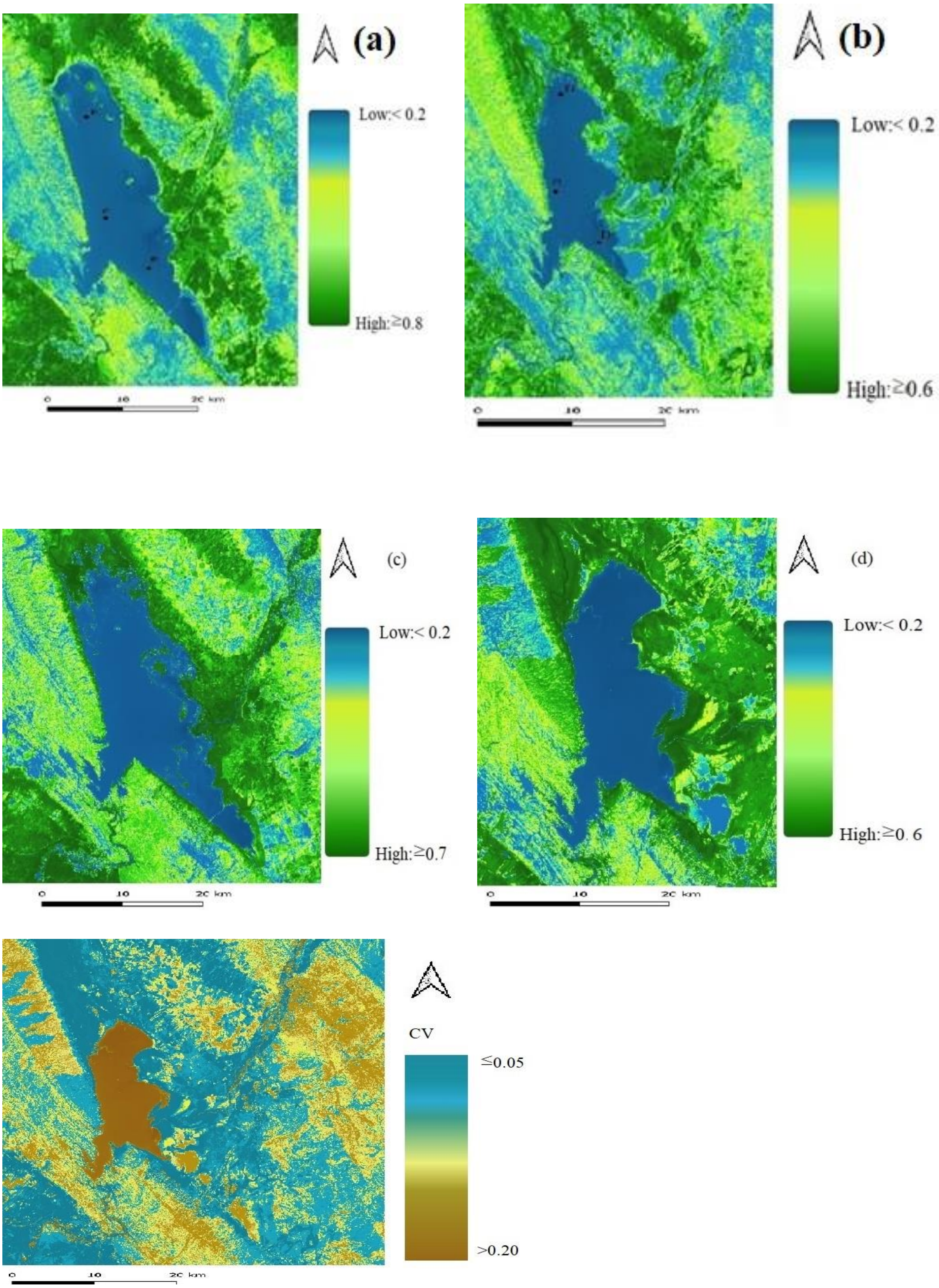


Figure (2): Spatial distribution on NDVI (a. Spring2013, b. Spring2023, c. Summer2013, and d. Summer2023) and CV=Coefficient of Variation(b) in Hamrin Lake (2013-2023).

3.3. The spatial and seasonal variation of vegetation cover indicators

The urban and barren lands record the highest percentages within the low NDVI category (<0.2), accounting for approximately 65–72% of the area, as shown in table 2, which explains the predominant dark blue color in Figure (2), especially in the mountainous regions and hills surrounding the lake. This pattern is evident in spring (a and b) as well as in summer (c and d), reflecting the limited permanent vegetation in these categories regardless of the season. The agricultural lands (including palm groves) are concentrated at a rate of approximately 70% within the medium to high NDVI categories (0.4–0.8) as shown in table 2. This corresponds with the extensive spread of light and dark green colors in the images in Figure (2), resulting from the availability of moisture and improved climatic conditions, with an average CV (0.05–0.15) reflecting the regularity of agricultural activity in this season.

As for the natural vegetation and scattered trees, the table 2 showed that more than 60% of their area falls within the NDVI categories (0.4–0.8) with a significant contribution in the high category (≥0.8),

Table 2, Statistics for NDVI areas and CV for Species in and around Hamrin Lake.

Variable	Grade	Urban Areas	Barren Land	Agricultural Land (Palm Groves)	Natural Vegetation	Scattered Trees	Reeds & Wetlands
NDVI	< 0.2	65.0	72.0	5.0	3.0	1.0	0
	0.2–0.4	25.0	23.0	20.0	15.0	10.0	5.0
	0.4–0.6	8.0	4.0	40.0	35.0	25.0	15.0
	0.6–0.8	2.0	1.0	30.0	35.0	40.0	45.0
	≥ 0.8	0	0	5.0	12.0	24.0	35.0
CV	≤ 0.05	70.0	60.0	15.0	10.0	8.0	5.0
	0.05–0.10	20.0	25.0	30.0	25.0	22.0	20.0
	0.10–0.15	7.0	10.0	30.0	35.0	30.0	40.0
	0.15–0.20	3.0	4.0	15.0	20.0	25.0	25.0
	> 0.20	0	1.0	10.0	10.0	15.0	10.0

especially in spring. From Figure (2) a and b can conclusion that the spatial distribution of green colors on the slopes and valleys, with a relatively higher CV (0.10–0.20) indicating the sensitivity of these categories to climatic changes.In the summer, the table 2 shows a general decline in NDVI for natural vegetation cover, with a significant portion of the area shifting to the (0.2–0.4) category, which is visually evident in the reduction of green areas and the expansion of yellow and bluish colors in Figure (2) c and d. This is attributed to thermal stress and the absence of rainfall, which is confirmed by the relatively high CV values (>0.15).

Applications of NDVI are varied; however, one of the most common applications of NDVI is to provide a spatial representation of cropland regions. Comparison of reed and wetland environments to NDVI has shown that 80% of these environments are found in the ≥0.6 category for both spring and summer seasons (western regions of Hamrin Lake; as in Figure (2)). Spatial patterns of reed and wetland vegetation types change seasonally and exhibit a high coefficient of variation (CV) of 0.10 to 0.20 depending on the annual variability of the depth of water present in reed and wetland areas.

3.4. The Change in Water Quality Parameters per Location Monitored

The three monitoring locations (P1-P3), as shown in table 3, show distinct changes throughout their associated monitoring locations. These results mirror those of the NDVI maps developed for both years 2013, and 2023, and thus correspond to similar times of the year (Spring and Summer) as both seasons showed an increase in vegetation activity surrounding these sampling locations. The lowest recorded pH of 7.80 within Section P1 and the corresponding EC of 7.90µS/cm, suggest that both of these values correspond to Section P1 being positioned between an area that has a moderate level of vegetation activity (within the NDVI maps), and an area that is located near regions with less-intensive agricultural activity.

In Section P2 and Section P3, however, both pH levels and EC values were substantially higher, with the highest recorded values within P3. The higher pH and EC levels can therefore be attributed to higher concentrations of dissolved minerals and salts which can arise from increased agricultural runoff and excess use of fertilizers within the greater area surrounding Lake P3 (as indicated in images a and b). This assessment supports the conclusion of environmental impacts related to agricultural runoff.

As in table 3, Dissolved oxygen also showed no significant difference between all three sections since they all fall within the same category (a), and therefore, based on the NDVI maps, the water contained within the lake maintained a relatively stable condition while the surrounding vegetation cover experienced significant seasonal differences between Spring and Summer (c and d). Much lower values of dissolved oxygen likely occur one to two months in summer due to increased temperatures as demonstrated by low NDVI values found in Figure (2) during this time period. Nitrate nitrogen (NN) levels were found to exceed the recommended maximum nitrate level for all three river sections as shown in table 3, but there was no statistical difference between the river sections. This supports the idea that agricultural practices as shown in Figure (2) have impacted a relatively large area around the lake and can clearly be seen in the light and medium green sections.

Total phosphorus (TP) levels in the each river section were significantly different from each other as in table 3, with the Section 1 having the lowest TP value while Sections 2 and 3 demonstrated an increase in TP levels. This can be attributed to increased nutrient input from agricultural practices occurring in the surrounding area that contributed to the increased NDVI levels for the agricultural areas. Although no statistical differences were found among the BOD levels, it can be inferred that there is a level of organic loading consistency, regardless of the seasonal change in levels of vegetation cover.

Table 3, Water quality standards (mean ± standard deviation) across monitoring sections.

Watershed	pH	EC (µS/cm)	DO (mg/L)	NN (mg/L)	TP (mg/L)	BOD (mg/L)
P1	7.80 ± 0.20[a]	7.90 ± 0.45[b]	10.01 ± 1.10[a]	2.72 ± 1.40[a]	0.03 ± 0.01[b]	11.8 ± 0.25[a]
P2	8.30 ± 0.35[b]	9.80 ± 0.46[a]	10.30 ± 1.03[a]	2.90 ± 2.07[a]	0.09 ± 0.03[a]	14.2 ± 0.60[a]
P3	8.35 ± 0.25[ab]	10.99 ± 0.50[a]	10.80 ± 1.05[a]	2.88 ± 1.20[a]	0.07 ± 0.07[a]	15.03 ± 0.30[a]

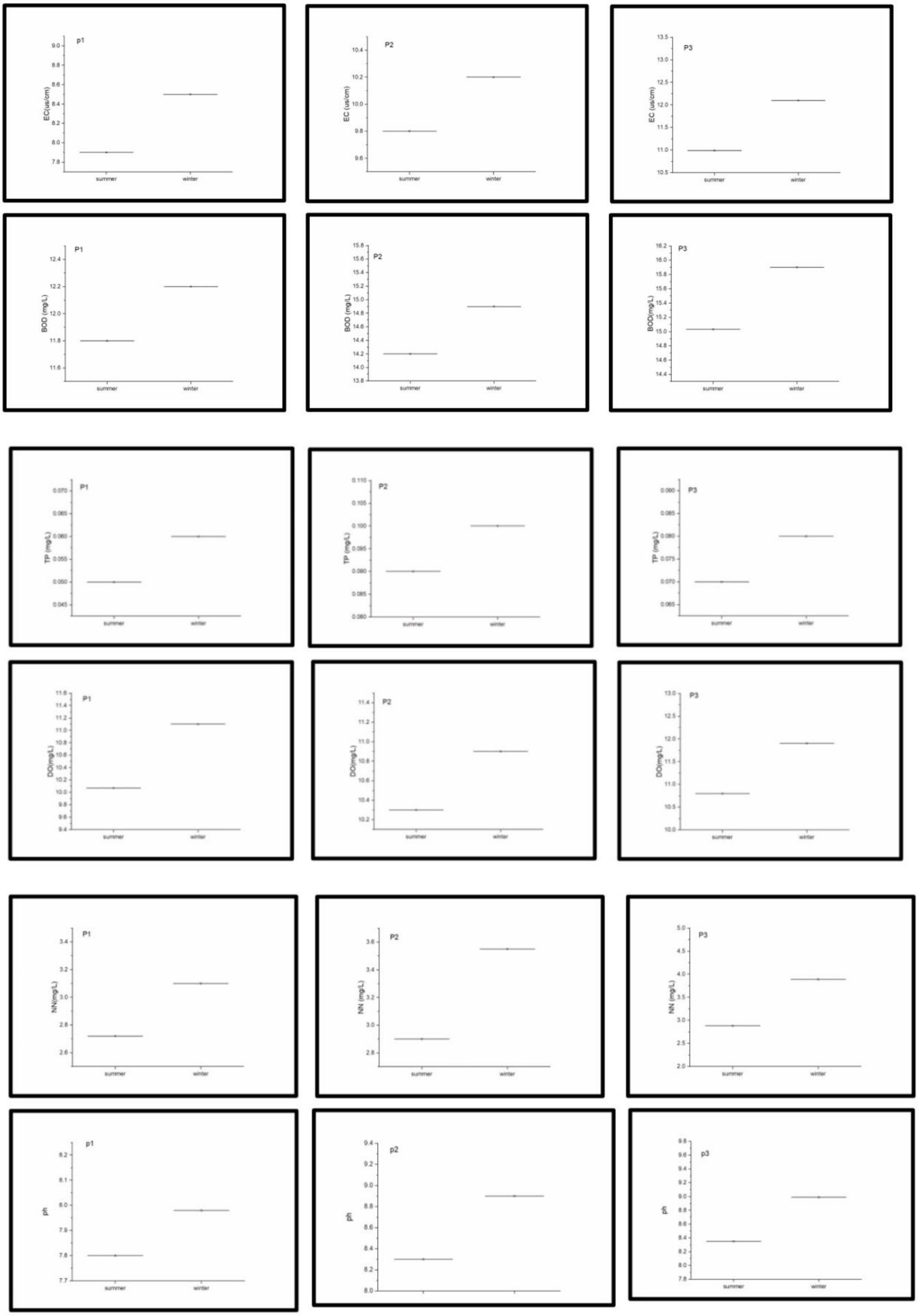
4. Interpretation and Discussion

4.1 Spatiotemporal Variation in Water Quality

Results showed that for seasonal changes, the pH concentration was lower in summer than in winter, where the pH increased, perhaps due to the decrease in temperature. The reduction in the amount of electrical conductivity (EC) in the lake during the summer months is a direct result of a reduction in the amount of water flowing into the lake during that time of year due to lower runoff and less ionic material being added to the lake by other means [21]. As for DO, its concentration was lower in summer, where the DO concentration increased in spring, and DO concentration increased as water temperature decreased. BOD did not show significant changes in seasonal variation, while NN was at its highest in winter, where NN depends on the amount of rainfall, and NN decreases in summer. TP's concentration increased more in winter than in summer because it depends on the pH value [22], which increases in winter. As for spatial changes, both EC and TP were lower in the upper level of the lake or the lake stream because their concentrations are higher downstream where pollutants accumulate. pH was lower in site p1 than in sites p2 and p3 because the latter part accumulates pH values, while BOD did not show significant differences in sites. As for NN and TP, the standard deviation was the most variable. Thus, NN and TP contributed the most to the pollution of Lake Hamrin water in both seasonal and spatial variations as shown in Figure (3).

4.2. Controls on Water Quality

Seasonality plays a significant role in shaping water quality and its controlling factors. The natural vegetation index was the most influential factor in water quality in Lake Hamrin, as shown in table 3. The increase in the natural vegetation index contributed to water quality, as it absorbs soil salinity and thus reduces the lake's salinity [23]. Natural vegetation flourishes more in spring [24]. The contribution of low water to water quality was inconsistent. Thus, NDVI negatively affects water quality [25], as it is consistent with agricultural activities and sanitation, which affect water quality. The rate of increase in the P1 site or the upper section in the natural vegetation index was relatively better water quality, especially in the presence of NN and TP[26]. The correlation of NN, TP, and the natural vegetation index was negative in the upper section P1 due to the anthropogenic and agricultural activities that significantly affected the water quality in addition to overfishing as shown in Figure (3). The increase in NDVI led to an improvement in the water quality [27] in Lake Hamrin, whether the vegetation cover was natural vegetation or agricultural land, which is more in the rainy seasons than in the dry seasons [28], which increases the arid lands. consequently, both land attributes and land-use patterns significantly affect water quality.


p1
EC(us/cm)
summer
winter
P2
EC (us/cm)
P3
EC (us/cm)
P1
BOD (mg/L)
P2
BOD (mg/L)
P3
BOD(mg/L)
P1
TP (mg/L)
P2
TP (mg/L)
P3
TP (mg/L)
P1
DO(mg/L)
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DO(mg/L)
P1
NN(mg/L)
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NN (mg/L)
P3
NN (mg/L)
p1
ph
p2
ph
p3
ph

(a) position1 (b) position2 (c) position3

Figure (3): Differences in Water Quality Across Seasons: Significant Variations Noted with Letters (L < 0.05).

5. Conclusions

The high vegetation index reflects good water quality in water bodies without human intervention in the ecosystem, as the vegetation index shows a negative correlation in urban areas and thus affects water quality due to the consistency between the variables in the vegetation index and pollutants. Apparent changes in water quality during Seasonal variation were observed. Water quality results attributable to the collective influence of vegetation, hydrological processes, and land cover composition and configuration. It also shows the various factors that affect seasonal variability in aquatic conditions. The increase in rural or urban areas leads to intensified variability of water characteristics, so the quality of urban runoff water must be controlled. The investment of groundwater and flowing water in dry seasons has a positive effect on improving surface water quality. Therefore, the concerned authorities in water management should incorporate seasonal shifts in the primary determinants of water conditions, and their impact on water quality.

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