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# Assessment of trophic status of three ecosystems in southern Iraq based on The Trophic State Index (TSI)

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## Abstract

Aquatic ecosystems are under increasing pressure from direct and indirect human activities, their areas and conditions continue to deteriorate, so many of them require treatment to maintain main functions and associated ecosystem services. Good water quality paramount to supporting the life of the organism. This study aimed to assess the trophic state of some water bodies. Eastern Hammar marsh, Al-Chebiyesh marsh, and Euphrates River. Carlson's index used CTSI which collects three variables that affect the level of trophic status in the water body (chlorophyll *a*, total phosphorus, and water transparency) Sampling was carried out from six stations two stations for each water body during period extended from November 2020 to October 2021. Water temperature, depth, turbidity, light penetration, Chl-*a*, and total phosphorus are the indicators monitored. The classification of stations varied according to $TSI_{chl\text{-}a}$, $TSI_{SD}$ and $TSI_{TP}$. The trophic status index CTSI values compared with Carlson and Simpson (1996) and shown The Eastern Hammar and Al-Chebiyesh were classified as Mesotrophic with values (46.1-45.9) respectively and the Euphrates classified as Oligotrophic with value (37.1).

**Keywords:** CTSI, Chlorophyll *a*, wetlands, ecosystems

## Introduction

Wetlands provide important and diverse benefits to people around the world, contributing to provisioning, regulating, habitat, and cultural services. Critical regulating services include water-quality improvement while key habitat services are provided by wetland biodiversity (Clarkson *et al.*,2017).

Eutrophication is the process of enrichment of water with plant nutrients, primarily nitrogen and phosphorus, which stimulate primary aquatic production and in its more serious manifestations, lead to visible algal blooms and phytoplankton and promote the growth of attached algae on macrophytes (UNEP, 2003).

Carlson (1977) relied on three variables to evaluate the nutritional status of the water surface, which are generally interrelated, which are chlorophyll A, total phosphorus, and the depth of Secchi disk to estimate light penetration, which is a commonly used method that can provide quick information about the trophic status of the aquatic environment, as the index value is divided 1-100, and through it one can Giving an idea of the productivity of the water body (Lenard and Ejankowski, 2012.

The researchers paid attention to monitoring the nutritional status of water bodies, so the study was AL-Abbawy (2012) who classified the waters of the Shatt al-Arab as mesotrophic, indicating that there is a negative correlation between transparency and each of chlorophyll-*a* and total phosphorus, while the association of chlorophyll-*a* with total phosphorus was positive. The index was also adopted as one of the measures to evaluate Eastern Al-Hammar Marsh. To find out its suitability for declaring it a natural reserve by Radee (2014), as he showed that index values based on Secchi disc $TSI_{SD}$ are high compared to values based on total phosphorus $TSI_{TP}$. Marsh was classified as mesotrophic, followed by a study by Al-Saboonchi *et al*. (2016), which also classified Eastern AL-Hammar Marsh as mesotrophic, indicating there is a variation in index values as a result of the variation in nutrients amount received, as the region is affected by the tidal phenomenon of the water coming from the Shatt Al-Arab River, as well as the variation in the density and activity of macrophytes during study period.

Eastern AL-Hammar marshes continued to be classified within the category of mesotrophic, with a value of 40.9), despite the seasonal and locational changes in index values for the study area (Rasheed, 2019).

Hussain and Sabbar (2020) applied an index to assess the trophic status of AL-Hammar and Chabayish marshes, indicating that both the tidal and non-tidal marshes are highly nutritious due to the direct release of untreated domestic sewage and agricultural drainage water. Both marshes were classified as Eutrophic.

Al-Asadi (2019) classified the Central Marshes as mesotrophic, with an annual rate of 46.85, indicating that the arrangement of the most influential variables on index, which had a direct relationship with it, were as follows: total phosphorus, chlorophyll, and Secchi disc. It also indicated that untreated sewage water and low water discharges during the autumn season contributed to an increase in chlorophyll values, a decrease in water transparency, and thus an increase in the value of the trophic index.

Shekha *et al*. (2017) classified Duhok Lake as mesotrophic during Autumn season, while it was classified as hypertrophic in the other seasons.

Based on the results of Marhoon *et al*. (2020). The water quality of Al-Sabil River in Al-Qadisiyah varies in its trophic status from oligotrophic to eutrophic, but it is often low in nutrients during months and seasons.

Globally several studies were performed to evaluate the trophic status of some water bodies such as Rahmati *et al*., (2011); Devi Prasad and Siddaraju, (2012); Rahul *et al*.,( 2013); Cunha *et al*.,( 2013); Markowski, (2017); Ekhator *et al*., (2019) ; Nojavan *et al*., (2019); Lopes *et al*. (2019); Madrid *et al*., (2020); Bilgin (2020) and Kim and Kim (2021).

## Materials and Methods

Wetlands are one of the world's three major ecosystems. They not only maintain regional ecological balance but also provide an important guarantee for human survival. Wetland ecosystem health assessment serves as the foundation for wetland protection, management, and restoration (Sun *et al*., 2022). Wetland ecosystems are suffering structural damage, gradual functional decline, significant reductions in wetland area, reduced biodiversity, severe water pollution, and eutrophication of water bodies (Mao *et al*., 2022 ; Wu *et al*., 2022). Three aquatic ecosystems were chosen for this study, located in northern part of Basra Province, represented by eastern AL-Hammar Marsh, AL-Chibayish Marsh and Euphrates River. Each ecosystem included two stations (Table1&Figure 1).

Table 1. Latitudes and Longitudes of the study stations

| Position | Station name | Station number | Latitudes (North) | Longitudes (East) |
|---|---|---|---|---|
| **Eastern AL-Hammar marshes** | Munissafa | S1 | N: 30° 41′ 45.87″ | E: 47° 32′ 59.56″ |
| | Al Burka | S2 | N: 30° 41′ 22.16″ | E: 47° 37′ 4.78″ |
| **Chebiyesh marshes** | Al-Shutayt | S3 | N: 30° 59′ 3.45″ | E: 47° 8′ 39.80″ |
| | Al-Shutayt | S4 | N: 30° 58′ 51.04″ | E: 47° 10′ 47.90″ |
| **Euphrates River** | Saleh River's | S5 | N: 30° 57′ 7.18″ | E: 47° 9′ 2.74″ |
| | Saleh River's | S6 | N: 30° 57′ 8.88″ | E: 47° 7′ 42.81″ |

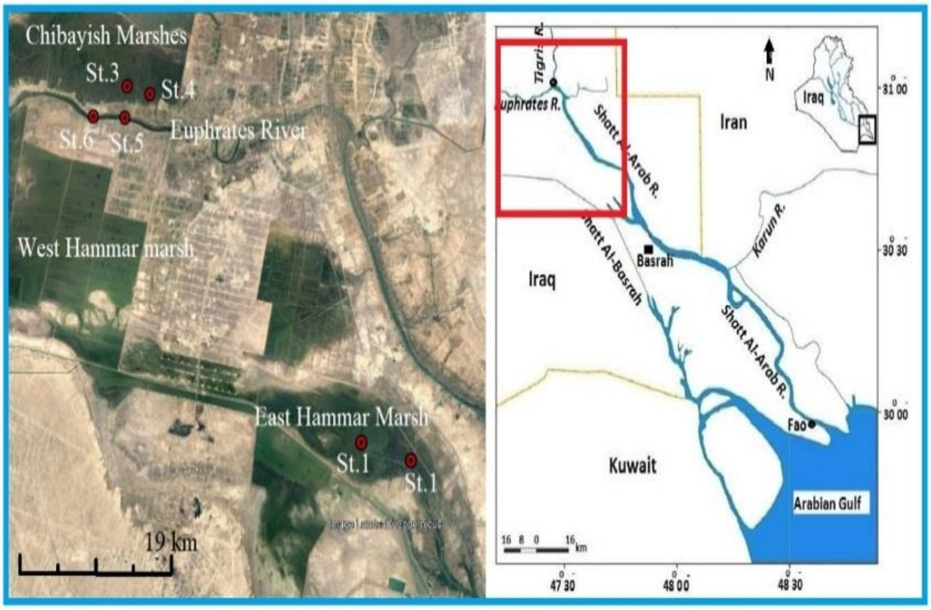


Figure **1.** The Map of study area.

**Water Sample Collection**

Water samples were collected in three replicates monthly from six stations from November 2020 to October 2021. The temperature(°C), Depth (cm) and Turbidity (NTU). Secchi's disc of 30cm in diameter was used to measure light penetration (cm). These variables were measured in the field immediately during sampling.

Water samples for laboratory measurement were refrigerated in an ice box immediately.

after collection until further analysis. Chl-*a* was estimated using a spectrophotometer after extraction in 90% acetone following Lind (1979). The concentration of total phosphorus was determined according to APHA (2005) method.

**Trophic state Index calculation**

TSIs on the Chl-*a*, TP, and SD using the methods proposed by Carlson (1977). Carlson's TSI (CTSI) can be obtained by calculating the arithmetical average of the three TSIs.(Table2)

The formulas for calculating TSI values from TP, SD and Chl-*a* are:

$TSI_{TP} = 14.41 \ln TP\ (\mu g/L) + 4.15$ (1)

$TSI_{SD} = 60 - 14.41 \ln (SD)\ (meter)$ (2)

$TSI_{Chl\text{-}a} = 9.81 \ln Chl\text{-}a\ (\mu g/L) + 30.6$ (3)

$CTSI = (TSI_{Chl.\,a} + TSI_{TP} + TSI_{SD}) / 3$ (4)

Table 2. The range of TSI values according to Carlson and Simpson (1996).

**The TSI scale**

| **TSI** | **Chlorophyll-a** | **Total phosphor** | **Secchi disc** | **Ecological attributes** |
|---|---|---|---|---|
| <40 | 2.6-20 | 0-1.2 | >8-4 | **Oligotrophic**-low productivity |
| 40-50 | 20-56 | 21-24 | 4-2 | **Mesotrophic**-moderate productivity |
| 51-70 | 56-155 | 24-96 | 2-0.5 | **Eutrophic** -high productivity |
| >70 | 0-2.6 | 96-483+ | 0.5-<0.25 | **ereutrophic** -very high productivity |

**Statistical analysis**

SPSS software program was used in data analysis, and PCA to assess the relationship between environmental variables and TSI.

Results and Discussion

Table 2 and figures 2-5 showed that the temperature data underscored substantial divergences among the examined locations. In the Eastern AL-Hammar marshes, the minimum temperature registered was 13°C in February, while the maximum reached 33°C in August. This notable temperature range implies the marshes' susceptibility to seasonal fluctuations, emphasizing the region's climatic heterogeneity. Al-Chebiyesh exhibited a more confined temperature range, with a minimum of 14°C in February and a maximum of 33°C in August. The Euphrates River displayed temperature dynamics like Al-Chebiyesh, further highlighting the role of climate in shaping these ecosystems.

Insights into hydrological dynamics were gleaned from water depth measurements. Al-Chebiyesh demonstrated a robust minimum water depth of 65 cm in October, indicative of its potential resilience to seasonal water level fluctuations. In contrast, the Eastern AL-Hammar marshes displayed the lowest minimum water depth of 32 cm in August, rendering it more vulnerable to shifts in water availability. The Euphrates River exhibited a wider spectrum of water depths, underlining the influence of river flow dynamics on water levels.

Chlorophyll-a (Chl-a) concentrations, indicative of algae presence and primary productivity, revealed noteworthy patterns. The Euphrates River recorded the lowest minimum Chl-a concentration of 0.8 µg/L in September, potentially attributed to elevated water flow rates and dilution effects. However, it also logged the highest maximum Chl-a concentration of 15.06 µg/L in February, hinting at intermittent nutrient enrichment events. Al-Chebiyesh displayed relatively consistent Chl-a concentrations, suggesting stable primary productivity. The Eastern AL-Hammar marshes exhibited intermediate Chl-a concentrations, reflecting a balance between nutrient availability and other ecological factors.

Total phosphorus (TP) concentrations, offering insights into nutrient enrichment, unveiled distinct trends. The Eastern AL-Hammar marshes showcased the lowest minimum TP concentration of 0.83 mg/L in September, indicating relatively modest nutrient input. Al-Chebiyesh reported a comparable minimum TP concentration yet recorded a higher maximum TP concentration of 1.08 mg/L in February. The Euphrates River displayed the highest TP concentration variability, with a minimum of 0.8 mg/L in September and a maximum of 1 mg/L in February.

Sediment deposition (SD), influencing water clarity and nutrient cycling, displayed pertinent characteristics. The Eastern AL-Hammar marshes recorded the highest minimum SD of 10 cm in October, suggestive of sediment influx during that period. Al-Chebiyesh and the Euphrates River exhibited similar SD trends, with the former reporting a minimum of 7 cm in October, while the latter registered a minimum of 46.4 cm in February.

The Trophic State Indices (TSI) for Chl-a, TP, and SD, in conjunction with the Cumulative Trophic State Index (CTSI), provided a holistic appraisal of ecological conditions. The Eastern AL-Hammar marshes demonstrated moderate TSIChl-a and TSI TP values, signifying a balanced nutrient regime. Al-Chebiyesh exhibited relatively lower TSIChl-a and TSI TP values, implying diminished nutrient enrichment. The Euphrates River showcased elevated TSIChl-a and TSI TP values, indicating a heightened potential for nutrient-driven productivity. The CTSI corroborated these observations, shedding light on the comprehensive ecological status of each location

Table 3. Monthly variations of water parameters at stations during the study period

| location | Statistic | Tem. (°C) | Dep.(cm) | Chl-*a*(µg/L) | TP (mg/L) | SD (cm) | $TSI_{Chl-a}$ | $TSI_{TP}$ | $TSI_{SD}$ | CTSI |
|---|---|---|---|---|---|---|---|---|---|---|
| Eastern AL-Hammar marshes | Min. | 13/Feb | 32/Auq. | 6.2/Feb. | 0.85/Sep. | 10/ Oct. | 48.5/Feb. | 1.8/Aug. | 70.2/Jun. | 43.8/Aug. |
| | Max. | 33/Auq. | 243/Dec. | 19.13/Sep. | 1.26/Feb. | 49/Jun. | 60.5/Sep. | 7.5/Feb. | 90.6/Jan. | 49.4/Sep. |
| | Avg. | 23 | 107.7 | 11.4 | 1.06 | 28.1 | 54.1 | 4.7 | 79.5 | 46.1 |
| Al-Chebiyesh | Min. | 14/Feb. | 65/ Oct. | 5.2/Feb. | 0.83/Sep. | 7/ Oct. | 47.9/Feb. | 1.5/Aug. | 73.9/Feb. | 42.1/Feb. |
| | Max. | 33/Auq. | 175/ Feb. | 16.01/Sep. | 1.08/ Feb. | 38/Feb. | 59.5/Sep. | 5.3/Feb. | 98.3/ Oct. | 53.6/Sep. |
| | Avg. | 23.04 | 104.2 | 9.63 | 0.95 | 24 | 52.3 | 3.4 | 82.4 | 46 |
| Euphrates River | Min. | 14/Feb | 120/ Oct. | 5.01/Feb. | 0.8/Sep. | 97/Sep. | 46.4/Feb. | 0.9/Aug. | 49.3/Feb. | 32.7/Feb. |
| | Max. | 32/Auq. | 380/Feb. | 15.06/Sep. | 1/ Feb. | 218/Feb. | 59.5/Sep. | 4.2/Feb. | 68.6/Apr. | 40.5/Sep. |
| | Avg. | 22.7 | 232.5 | 10.1 | 0.89 | 141 | 53.6 | 2.3 | 58.2 | 37 |

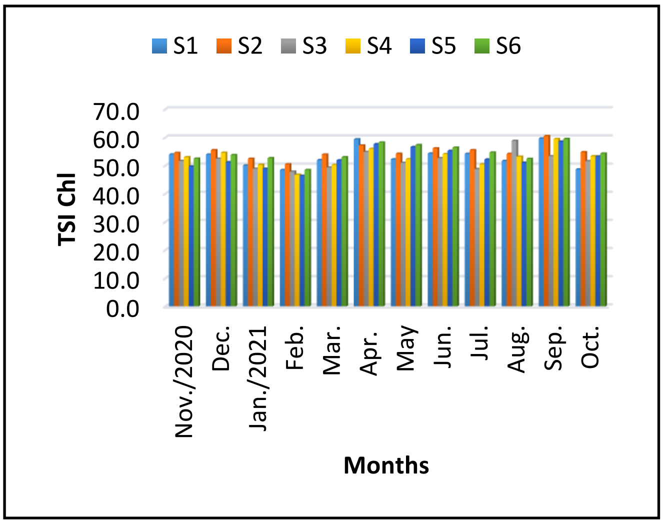


**Figure 2.** Monthly variations of TSIChl-*a*.

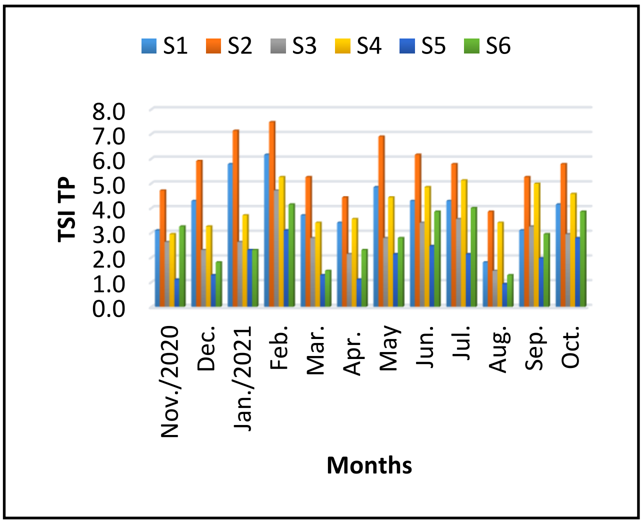


**Figure 3.** Monthly variations of TSITP.

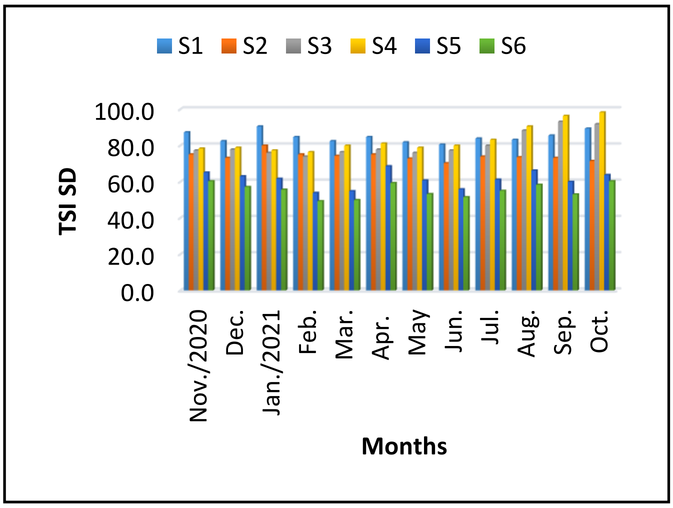


**Figure 4.** Monthly variations of TSISD

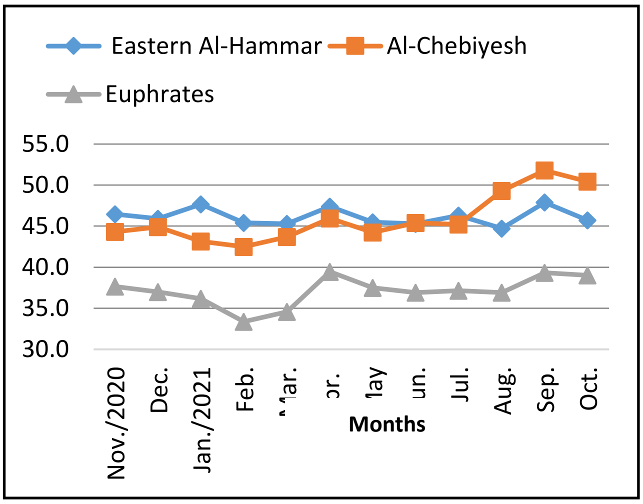


**Figure 5.** Monthly variations of CTSI

Figures 6 and 7 explained that the TSI value for the Eastern AL-Hammar marshes indicates a moderate trophic state. This suggests that marshes experience a balanced nutrient regime, where primary productivity, often driven by nutrient availability, is relatively stable. Although the trophic state is not excessively high, it is essential to monitor the health of the ecosystem and prevent any potential increases in nutrient enrichment that might lead to eutrophication. Like the Eastern AL-Hammar marshes, the Chebiyesh marshes also exhibit a moderate trophic state with a TSI value of 45.9. This indicates a similar nutrient balance and primary productivity level as observed in the Eastern AL-Hammar marshes. Ongoing monitoring and management efforts are critical to maintain this state and avoid shifts towards higher trophic levels. The Euphrates River has a low TSI value of 37.1, suggesting a lower trophic state than that of marshes. This might be an indication of low nutrient concentrations and primary productivity in the rivers. While a lower trophic state can prevent algal blooms and water quality deterioration, it is essential to ensure that the ecosystem remains sufficiently productive to support aquatic life.

TSI was associated negatively with light penetration (r= -0.934, p<0.01), positively with total phosphorous (r=0.469, p<0.01), and weakly positive with chlorophyll -*a* (r=0.525, p< 0.01) and strongly positive with turbidity (r=0.874, p<0.01).

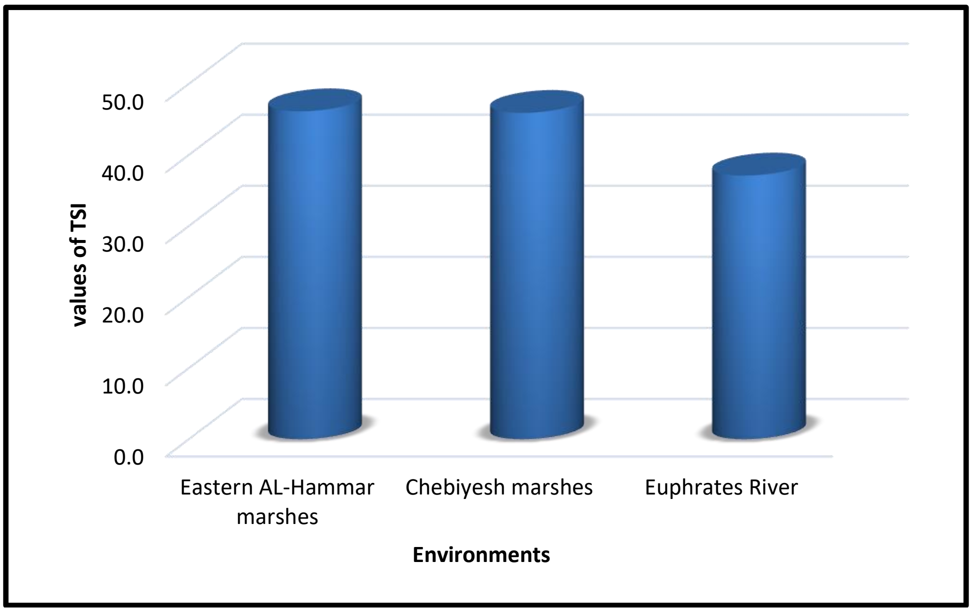


**Figure 6.** Annual rate of CTSI

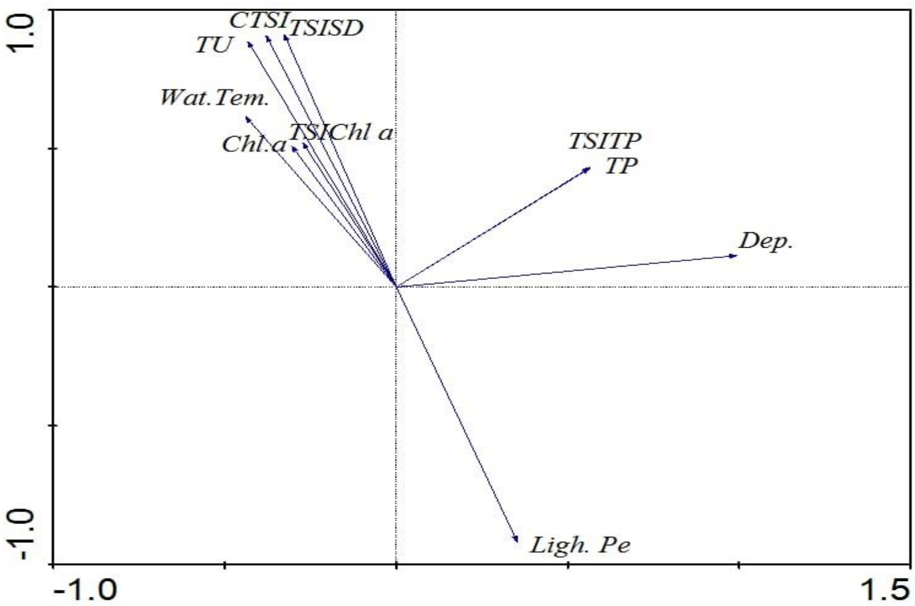


**Figure 7**. PCA analysis between TSI items and some environmental parameters

Eutrophication is a process by which water bodies receive excess nutrients that stimulate excessive plant growth (Lopes *et al*., 2019). This process occurs naturally but can be accelerated by human activities that increase nutrient inputs, such as wastewater discharge (Kantawanichkul *et al*., 2009; Watanabe *et al*., 2015). The overabundance of nutrients such as nitrogen and phosphorus can promote algal blooms, which deplete dissolved oxygen as they decay, resulting in fish death and loss of other aquatic life (Shinde & Gawande, 2016). Eutrophication also enables pathogens to proliferate, posing health risks to over 20% of the global population that relies on surface waters (Krantzberg *et al*., 2010; Smith & Schindler, 2009). Regular water quality monitoring is critical to mitigate pollution and eutrophication. The Carlson Trophic State Index (CTSI) is commonly used to assess the trophic status of water bodies based on the total phosphorus, chlorophyll-a concentration, and Secchi disk transparency (Carlson, 1977). These three parameters provide an integrated measure of the algal productivity and biomass. The CTSI assigns oligotrophic, mesotrophic, eutrophic, and hypereutrophic trophic states.

In this study, the CTSI indicated eutrophic conditions at all stations based on chlorophyll-a, likely reflecting substantial nutrient inputs that stimulate phytoplankton growth. Chlorophyll-a is considered a robust metric of trophic status, given the short generation time of phytoplankton, which allows it to respond quickly to nutrient availability (Lyche-Solheim *et al*., 2013; Katsiapi *et al*., 2016). Elevated temperatures and sunlight exposure further promote algal growth in these waters. However, Secchi disk transparency varied substantially between stations, with shallower marshlands classified as hypereutrophic and deeper river sites classified as eutrophic. Turbidity from sediment resuspension likely decreased transparency more than phytoplankton biomass in marshlands. Compared to algal metrics, light attenuation can be influenced by inorganic particulates (Heiskary 1985). The inverse relationship between transparency and total phosphorus also contradicts expectations, suggesting that factors other than algal abundance dominate (Bennion & Smith, 2000).

In contrast, the total phosphorus CTSI values indicated oligotrophic conditions at all stations. Other studies have also found weak relationships between phosphorus and algal proliferation, attributed to most phosphorus being bound in unavailable forms (Jekatierynczuk-Rudczyk *et al*., 2014).

These results highlight the limitations of the CTSI for systems with high inorganic turbidity. Alternative indices that place lower weight on transparency, such as the Toledo Trophic State Index, may be more appropriate for such waters (Toledo, 1983; Klippel *et al*., 2020). A multimeric approach incorporating chlorophyll-a, phosphorus, and turbidity measurements could provide a more accurate assessment. Further studies on the bioavailability of phosphorus in these systems are required.

## Conclusion

The classification of study stations differed according to values of TSI terms, which are $TSI_{Chl\text{-}a}$, $TSI_{TP}$, and $TSI_{SD}$, as aresult of difference in the percentage of influence of factors included in the index on the estimation of the trophic status of water bodies. The inorganic turbidity clearly affected the trophic status values of shallow water bodies.

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# تقييم الحالة التغذوية لثلاثة نظم بيئية في جنوب العراق بناء على مؤشر الحالة الغذائية (TSI)

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**المستخلص:**
تتعرض النظم البيئية المائية لضغوط متزايدة من الأنشطة البشرية المباشرة وغير المباشرة، وتستمر مناطقها وظروفها في التدهور، لذلك يحتاج الكثير منها إلى العلاج للحفاظ على الوظائف الرئيسية وخدمات النظام البيئي المرتبطة بها .نوعية المياه الجيدة أمر بالغ الأهمية لدعم حياة الكائن الحي .هدفت هذه الدراسة إلى تقييم الحالة الغذائية لبعض المسطحات المائية شملت هور الحمار الشرقي وهور الجبايش ونهر الفرات .استخدم مؤشر كارلسون CTSI الذي يجمع ثلاثة متغيرات تؤثر على مستوى الحالة الغذائية في الجسم المائي) الكلوروفيل أ ، الفوسفور الكلي ، وشفافية الماء (تم أخذ العينات من ست محطات محطتين لكل مسطح مائي خلال الفترة الممتدة من تشرين الثاني 2020 إلى تشرين الاول 2021 درجة حرارة الماء ، والعمق ، والتعكر ، واختراق الضوء ، و Chl-a ، والفوسفور الكلي هي المؤشرات التي تم رصدها .اختلف تصنيف المحطات وفقا ل TSIchl-a و TSISD و .TSITP تم تصنيف قيم مؤشر الحالة الغذائية CTSI مقارنة مع Carlson and Simpson (1996) والموضحة تم تصنيف هوري الحمار الشرقي والجبايش على أنهما متوسطا التغذية بقيم-46.1) (45.9على التوالي وأما الفرات مصنفة على أنها قليلة التغذية بقيمة (37.1).

الكلمات المفتاحية CTSI :، الكلوروفيل أ ، الأراضي الرطبة ، نظام بيئي