

Original Research Article

Water Quality Monitoring of Tigris and Euphrates basin by Using Geographic Weighted Regression (GWR)

ABSTRACT

A vital resource, water is necessary for agriculture, industry, ecosystems, and life itself. Since pollution, climate change, and unsustainable land use practices reduce access to clean water, water quality degradation has grown to be a serious environmental concern on a global scale. This is especially true in Iraq, where growing urbanization, and agricultural runoff have severely contaminated the nation's two main water sources, the Tigris and Euphrates. This study uses remote sensing and geospatial analysis tools to evaluate the Tigris and Euphrates rivers' water quality. Data from Landsat 8, Sentinel-5P, and other sources were used to assess key factors, such as salinity, turbidity, soil pH, nitrogen dioxide (NO₂) levels, and chlorophyll concentrations. Five risk levels, from very low to very high, were used to classify the water quality using the Analytical Hierarchy Process (AHP). Significant regional differences in water quality were found by the researchers. While turbidity data indicated increased silt concentrations in some areas, high salinity levels were noted in downstream zones. The NO₂ data showed areas of pollution that were associated with both agricultural and industrial activity. Areas at danger of eutrophication were indicated by amounts of chlorophyll, which is a measure of phytoplankton levels. Measurements of soil pH also revealed changes that can impact water chemistry and nutrient availability. Regions in need of immediate water management actions were identified with the aid of the AHP categorization. To sum up, this research offers a thorough evaluation of the water quality in the Tigris and Euphrates basins, providing information on possible causes of contamination and locations that may require attention. These findings will ensure that Iraq's vital water resources be used sustainably by guiding future water management plans.

1. INTRODUCTION

One of the most crucial natural resources for the continuation of life on Earth is freshwater. Of the 2.5% fresh water on Earth, just 1% is fit for consumption by humans (Ahmad et al., 2014). Water is a precious natural resource that is necessary for both human survival and the wellbeing of ecosystems. According to (Mantzaferi et al., 2009), water is made up of freshwater bodies like lakes, rivers, and groundwater as well as coastal water bodies. The intricate interplay between both human and natural processes in location and time determines the state of the water quality. The approximation and evaluation of the environmental state and trends of aquatic ecosystems (springs, streams, rivers, fiords,

estuaries and marine water) is the goal of monitoring their qualitative and quantitative parameters.

The majority of Iraq's naturally occurring renewable water resources are imported, and the country's surface water from the Tigris and Euphrates rivers is its main supply of water. Iraq, Turkey, Syria, and Iran are countries that share the Tigris and Euphrates rivers (Ewaid & Abed, 2017). The water quality of Iraq's rivers is influenced by both internal and external factors, both controlled and uncontrolled (Al-Ansari, 2013). Climate change and its effects, such as decreased precipitation and rising temperatures, are uncontrollable factors ((Abahussain et al., 2002); (Amin et al., 2016); (Al-Ansari, 2016); (Al-Ansari, AlJawad, et al., 2018); (Al-Ansari, Adamo, et al., 2018); (Kibaroglu, 2019)). The Arabian Peninsula's total water resources fell between 0 and 250 mm between 2002 and 2015 (Frenken, 2009). Although their effects are more localized, the controlled factors have a substantial detrimental impact on water resources ((Al-Ansari, AlJawad, et al., 2018); (Adamo et al., 2018)). Building dams and implementing irrigation projects in the higher catchment areas are the primary examples of controlled factors ((Abahussain et al., 2002); (Issa et al., 2014); (Al-Ansari, Adamo, et al., 2018); (Kibaroglu, 2019)). Because Turkey provides nearly 80% of the water supply to the Euphrates and Tigris Rivers, dam construction within the higher portions of the Tigris and Euphrates catchments (Turkey, Syria, and Iran) has a considerable impact on surface water in Iraq (Adamo et al., 2018).

Iraq's capacity to supply water started to steadily deteriorate by 2005. The nation will run out of freshwater by 2035, both in terms of quantity and quality, to meet its needs for development ((Kuriqi, Ali, et al., 2020); (Kuriqi, Pinheiro, et al., 2020)). Only a significant reform in water allocation and usage can stop this worrying trend. The population of the regions of Turkey, Syria, and Iran that are within the Euphrates and Tigris River watersheds is predicted to grow by more than nine million people over the course of the next 20 years (Mahil et al., 2020).

With the ability to integrate geographic and temporal data to examine the distribution and causes of water contaminants, Geographic Information System (GIS) have become an increasingly useful tool in the evaluation and monitoring of water quality. GIS enables a thorough understanding of how many factors influence water quality across different regions by merging datasets such as land use, hydrological parameters, and pollution sources (Mantzaferi et al., 2009). Geographic Information System (GIS) is a powerful tool for environmental management and policy-making because of its spatial analysis capabilities, which enable the identification of pollution hotspots and the visualization of trends over time (Ibrahim et al., 2018). Additionally, by taking into consideration geographical heterogeneity, GIS-based models like Geographic Weighted Regression (GWR) improve conventional water quality evaluations and offer more precise and focused insights into the variables influencing water quality (Khafaji et al., 2022). These cutting-edge GIS uses assist focused interventions meant to preserve and replenish water resources in addition to increasing the accuracy of water quality evaluations.

Numerous research on the effectiveness of remote sensing as a technique for water quality monitoring have been published ((Khlif et al., 2022.); (Chabuk et al., 2020)). The science and art of gathering data about an object, region, or phenomenon by analyzing images taken by a device that is not in close proximity to the object, region, or phenomenon being studied is known as remote sensing.

Significant differences in the Euphrates River's water quality have been noted in earlier investigations. Studying the changes in water quality within the Iraqi borders between 2009 and 2010, (Al Bomola, 2011) discovered rising pollution concentrations and erratic water

release, primarily caused by upstream control from Turkey and Syria, which led to declining water quality downstream. In 2015, a study was carried out by (Al-Obeidi, 2017) to determine the Total Dissolved Solids (TDS) concentration in the Euphrates River within the governorates of Al-Qadisiyah and Al-Muthana. The results showed a significant variation in TDS concentrations, ranging from 527 to 8020 mg/L, indicating significant regional variations in water quality.

By utilizing remote sensing and GIS-based methodologies, this study aims to close this gap by offering a thorough evaluation of the basin's water quality. The study is to determine the main sources of pollution, examine the temporal and spatial trends of important water quality indices, and create spatial maps that can direct focused management actions. In doing so, the study hopes to support the creation of more sensible and evidence-based water management plans that will guarantee the preservation and sustainable use of water resources in the Tigris and Euphrates basin. These goals make this research both topical and vital because they are critical for maintaining the socioeconomic well-being of the local population as well as for protecting the health of the environment.

2. MATERIAL AND METHODS

2.1 Study Area

The Euphrates River inside the borders of Iraq is the subject of the research area as can be seen in **Figure 1**. Because of its vital relevance to residential water supply, industry, and agriculture, this region has been the subject of multiple water quality evaluations. The Tigris and Euphrates basin is an important lifeblood that spans many countries, particularly between 29°N and 41°N latitude and 36°E to 46°E longitude (Al-Ansari, 2016). These rivers, which have their source in the highlands of southeast Turkey, are vital to the survival of human populations, agriculture, and ecosystems across their whole journey.

The Tigris and Euphrates rivers, which rise in Turkey and run through Syria and Iraq before joining the Shatt al-Arab to empty into the Persian Gulf, are included in the research area. While the Tigris, fed by tributaries from the Zagros Mountains, supports extensive agricultural activities across its basin, the Euphrates is essential for industry and agriculture, especially in the arid regions of the Syrian Desert and the fertile plains of Iraq ((Al-Ansari, 2016); (Al-Ansari et al., 2019)). The normal flow patterns of these rivers have been greatly disrupted and the quality of the water has been deteriorated due to dam construction projects like the Greater Anatolia Project (GAP) in Turkey, excessive water withdrawals, and industrial pollution. Reduced river flows, more frequent droughts, and increased water scarcity are all consequences of climate change ((Abdelmohsen et al., 2022); (Mianabadi & Amini, 2019)). For the transboundary water resources to be managed sustainably, these issues must be resolved.

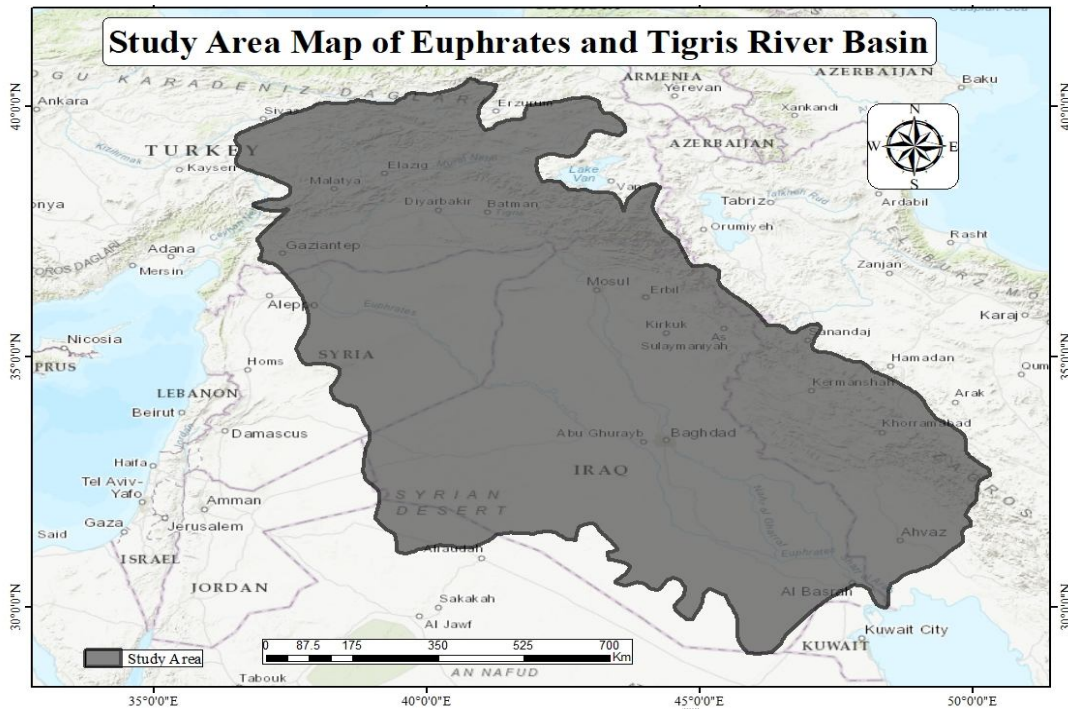


Figure 1: Study area map of Euphrates and Tigris Basin.

2.2 Methodology

This study evaluates the quality of the water in the Tigris and Euphrates basins using a variety of satellite data and remote sensing techniques. Topographic information is derived from the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data. Salinity and turbidity indices are calculated using Landsat 8 images. Sentinel-5P data is used to monitor nitrogen dioxide (NO₂) levels, and soil pH is evaluated to see how it affects water quality. Global Change Observation Mission-Climate (GCOM-C) data are used to assess phytoplankton levels using chlorophyll concentration. In order to integrate and assess water quality throughout the river basins, these factors are analyzed using the Analytical Hierarchy Process (AHP), which makes management and conservation plans more feasible. The methodology applied in this research can be illustrated by the flow chart in **Figure 2**.

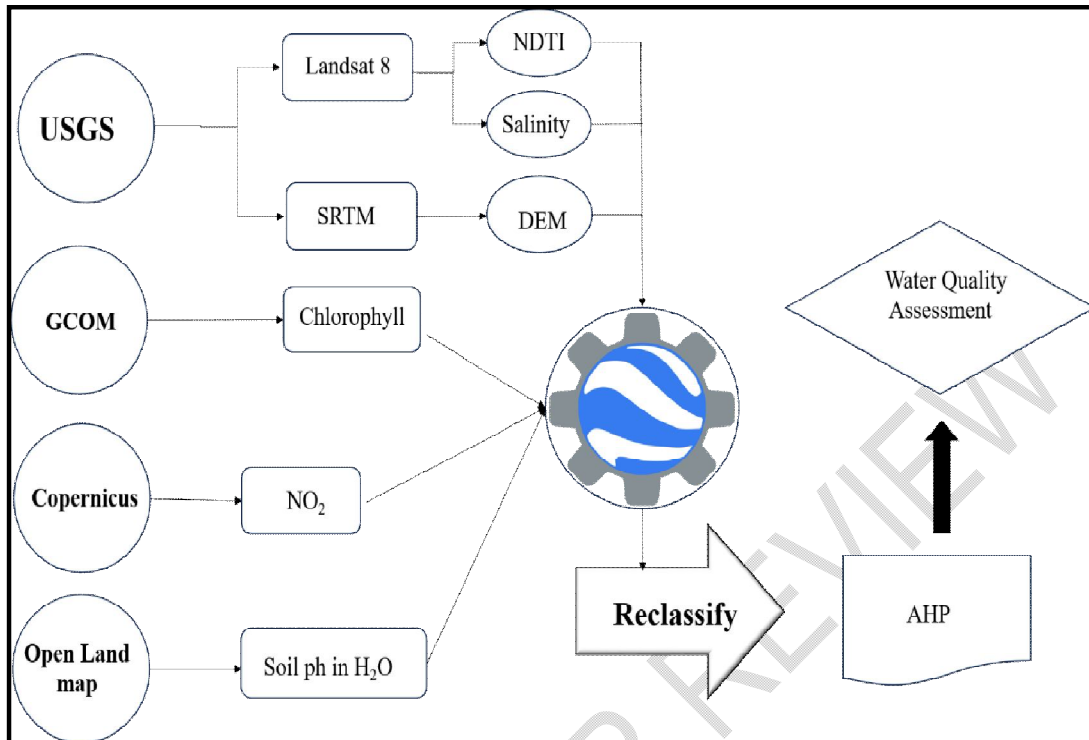


Figure 2: Flow chart of methodology

2.3 Datasets used in the study

The datasets used in this work are essential for evaluating the Tigris and Euphrates basin's water quality and provide important insights into the dynamics of the river ecosystem. These datasets, which come from reliable sources, comprise high-resolution Digital Elevation Models (DEM) from Copernicus, Landsat 8 imagery from Google and the USGS, and measurements of chlorophyll-a from the Global Change Observation Mission (GCOM). The thorough analysis is made possible by additional data on soil pH from EnvirometriX Ltd. and nitrogen dioxide (NO₂) concentrations from the European Union/ESA/Copernicus. This allows for a full understanding of environmental conditions throughout the region. The detailed description of data is listed in **Table 1**.

Table 1: Datasets used in the study.

Datasets	Data Sources	Resolution
DEM(SRTM)	Copernicus	30 Meter
Landsat 8 Image	USGS/Google	30 Meter
Chlorophyll-A	Global Change Observation Mission (GCOM)	4638.3 Meter
Soil PH	EnvirometriX Ltd	250 Meter
NO2	European Union/ESA/Copernicus	1113.2 Meter

2.4 Image Preprocessing

A thorough preprocessing step was performed on Landsat 8 imagery to guarantee the accuracy of the ensuing water quality indexes. Preprocessing included radiometric

calibration to account for sensor errors and atmospheric correction utilizing the Dark Object Subtraction (DOS) approach to reduce atmospheric interference. According to (Chander et al., 2009), these procedures were necessary in order to obtain consistent reflectance values, which were necessary in order to accurately represent different water quality metrics throughout the study area.

2.5 Salinity Assessment

Using Landsat 8 data, salinity levels—a measure of the concentration of dissolved salts in the water—were determined. The salinity index was calculated using the **Equation 1**.

$$\text{Salinity Index} = \frac{SR_{B4}}{SR_{B3} - 1} * 1000$$

where SR_B4 and SR_B3 represent the reflectance values of Bands 4 (red) and 3 (green), respectively. This index showed areas of the river basin with higher salt levels, which could be the result of saline water incursion or agricultural runoff. It also gave a spatial picture of salinity fluctuations within the river basin (MMM et al., 2016).

2.6 Normalized Difference Turbidity Index (NDTI)

Turbidity, which measures the amount of suspended sediments in the water, was measured using the Normalized Difference Turbidity Index (NDTI) (Adjovu et al., 2023). **Equation 2's** formula was used to calculate the NDTI.

$$\text{NDTI} = \frac{SR_{B4} - SR_{B3}}{SR_{B4} + SR_{B3}}$$

SR_B4 and SR_B3 corresponding to the reflectance values of the red and green bands, respectively. In areas affected by erosion or by human activities that lead to sedimentation, this measure is especially important for tracking water clarity and identifying sediment plumes.

2.7 Reclassification and Analysis

All derived metrics (DEM, NDTI, salinity, chlorophyll-a, soil pH, and NO₂) were classed into standardized groups based on pertinent water quality standards in order to facilitate a thorough investigation. This categorization made it possible to combine various datasets into a coherent framework and provide a multifaceted understanding of the water quality in the Tigris and Euphrates basin. The dynamics of the water quality in the area were then thoroughly understood by layering and analyzing these data collectively using Geographic Information Systems (GIS) technologies (Gitau et al., 2016).

2.8 Analytical Hierarchy Process (AHP)

An analytical hierarchy process (AHP) was used in the research area to assess the general quality of the water as a tool for decision-making. The application of Analytic Hierarchy Process (AHP) enabled the prioritization of areas that needed immediate care by evaluating various water quality metrics and allocating weights according to their relative importance. The findings of AHP provided a hierarchical understanding of the variables influencing water quality, which aided in the development of focused management plans meant to reduce pollution and maintain the health of the river ecosystem (Saaty, 2008). **Table 2** facilitates comprehension and use of the relative importance scale.

Table 2: Fundamental scale of absolute numbers for evaluating importance.

Intensity of Importance	Definition
1	Equal Importance
2	Weak or Slight
3	Moderate Importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus
7	Very Strong or Demonstrated Importance
8	Very, Very Strong
9	Extreme Importance
Reciprocals of Above	Reciprocal Values
1.1–1.9	Reasonable Assumption

3. RESULTS AND DISCUSSION

The Tigris and Euphrates basins' water quality dynamics were thoroughly evaluated in this study by utilizing a variety of datasets. The Shuttle Radar Topography Mission (SRTM) produced the Digital Elevation Model (DEM), which was significant in illuminating the topography of the river basins. Significant elevation changes and steep gradients, especially upstream, were shown in the investigation to have an impact on sediment movement and water flow.

A thorough understanding of the changes in water quality throughout the river basins was supplied by the assessments of salinity and turbidity obtained from Landsat 8 imagery. Higher evaporation rates and decreased upstream flow were found to be consistent with higher salt concentrations in downstream regions as indicated by the salinity index. The salinity's regional distribution highlights how hydrological changes affect the quality of the water. The Normalized Difference Turbidity Index (NDTI), which measures the influence of human activity on sediment load, showed higher turbidity levels close to industrial and agricultural sectors. Moreover, substantial nitrogen pollution was found through real-time monitoring of nitrogen dioxide (NO₂) using Sentinel-5P data. This pollution was found mostly in urban and industrial areas, where it contributed to nutrient enrichment and possible eutrophication. Measurements of the pH of the soil revealed variations in acidity related to farming activities; more acidic soils in regions with intensive farming could increase the leaching of metals into water bodies. High nitrogen inputs caused enhanced phytoplankton population and algal blooms, according to data on chlorophyll concentration from GCOM-C. By incorporating these variables into the Analytical Hierarchy Process (AHP), it was possible to conduct a thorough evaluation of the water quality and pinpoint the regions that needed focused management actions. This multifaceted approach offers insightful information about the intricate relationships between anthropogenic activities and natural processes, which is crucial for creating practical plans to improve the ecosystem health and water quality in the Tigris and Euphrates basins.

3.1 Digital Elevation Model (DEM) Analysis:

The examination of the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data yielded significant information about the topography of the Tigris and Euphrates basins. Understanding the elevation variations as mapped in **Figure 3** throughout these river basins is essential for comprehending the hydrological processes and sediment transport

mechanisms that affect water quality. The 30m resolution of the DEM data made this possible.

Significant height differences are a feature of the terrain of the Tigris and Euphrates basins, especially in the upper sections where the rivers begin. These areas' high gradients are a sign of swift water flow, which exacerbates erosion and raises the amount of silt that rivers carry. When carried downstream, these sediments raise turbidity levels, which impacts aquatic ecosystems and water quality (Al-Ansari, 2016). Additionally, the DEM study pinpointed crucial locations where these steep slopes give way to flatter terrain and sediment deposition zones. Understanding how sediments settle and build up—possibly building sedimentary barriers or changing the flow of a river—is essential for determining how to reduce the danger of flooding and increase agricultural production. These deposition zones play a major role in this process. The topography is often flatter at the lower portions of the river basins, where sediment accumulation is permitted by a more stable flow regime with lower velocity, as seen by the DEM data. In the Mesopotamian plains, where the Tigris and Euphrates rivers meet to form the Shatt al-Arab, this deposit is especially noticeable. This region's flat topography facilitates widespread agricultural practices, but it also renders the area vulnerable to salinization and waterlogging, which are made worse by higher evaporation rates and decreased flow velocity (Abdelmohsen et al., 2022).. As a result, the DEM analysis offers fundamental knowledge about how topography affects sediment movement, hydrological patterns, and water quality, providing crucial information for creating efficient water management plans.

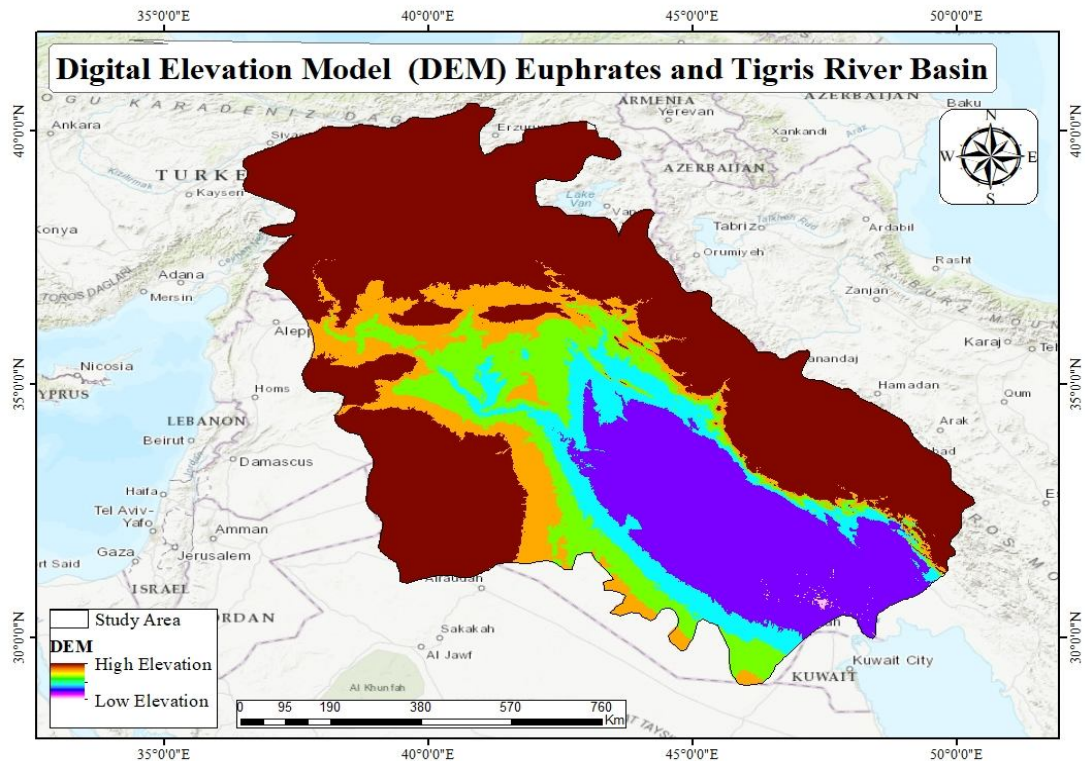


Figure 3: Digital Elevation Map

3.2 Analysis of Salinity Levels in the Tigris and Euphrates Basins

Knowing the salt levels in the Tigris and Euphrates basins was essential to comprehending the water quality and how it affected ecosystems and agriculture. Salinity, or the amount of dissolved salts in water, is a major factor in deciding whether river water is suitable for home consumption or agriculture. Based on the reflectance values of Bands 3 and 4, which correspond to the red and near-infrared parts of the spectrum, a salinity index was computed using Landsat 8 images.

The findings in **Figure 4** showed that the river basins had five different salinity classes, ranging from -0.31 to -0.26, -0.25 to -0.23, -0.22 to -0.2, -0.19 to 1, and 1.01 to 5. These numbers show that the salt levels in the research area fluctuate. The salinity values in the negative range (-0.31 to -0.19) indicate salt concentrations that are comparatively lower. These lower values are generally linked to freshwater areas, where there is little dissolved salt present and the water is suitable for irrigation and other purposes. However, the concentration of salt in the water increases noticeably when the salinity levels rise above 1.0, especially in the 1.01 to 5 range. These higher numbers show where the salinity has increased in the rivers, perhaps as a result of things like evaporation, runoff from agriculture, and decreased water flow downstream.

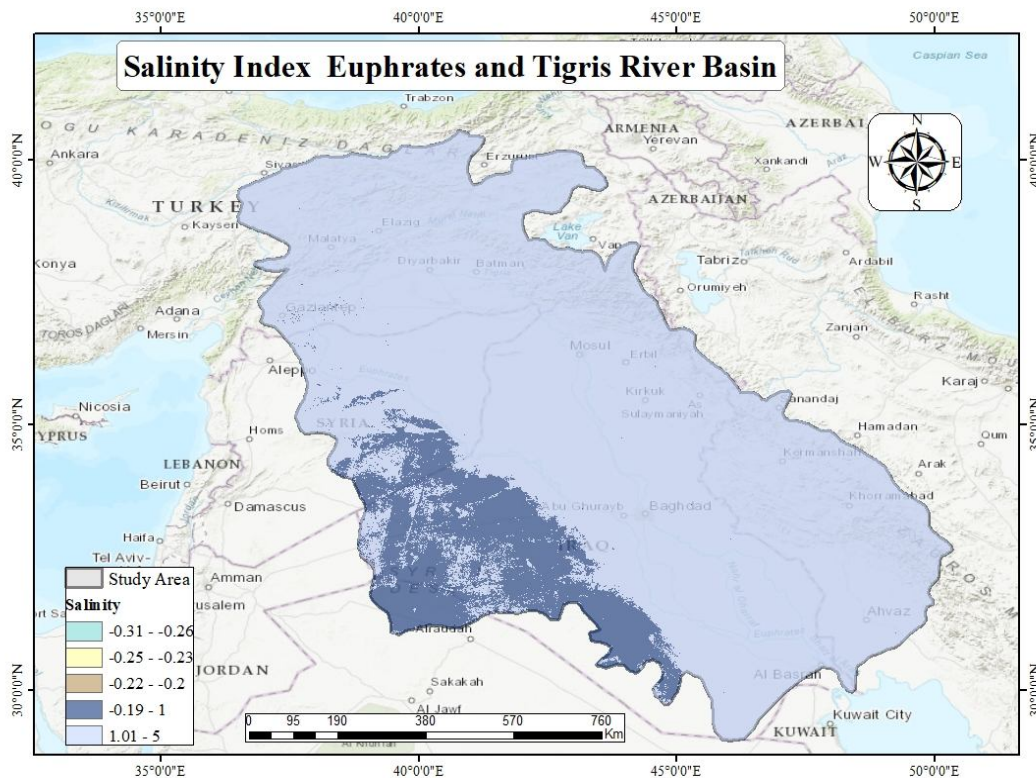


Figure 4: Salinity Index Map

Increased salinity can have a detrimental effect on agricultural production, resulting in soil salinization and lower crop yields, particularly in the 1.01 to 5 range. These high salinity concentrations are frequently observed downstream of rivers when water flow slows and salts build up as a result of both natural hydrological processes and human impacts, such as

industrial effluents and irrigation techniques (Rahi & Halihan, 2018). Thus, it is essential to monitor and control salinity in these areas in order to preserve the natural equilibrium and guarantee sustainable farming methods.

3.3 NDTI

An important tool for determining water turbidity and the amount of suspended material in a body of water is the Normalized Difference Turbidity Index (NDTI). NDTI values were obtained for this investigation using reflectance values from Bands 4 (red) and 3 (green) on Landsat 8 images. The Tigris and Euphrates basins' many regions could all be consistently examined for turbidity thanks to this uniform metric. Five classes were created from the NDTI data, each of which represented a different turbidity level.

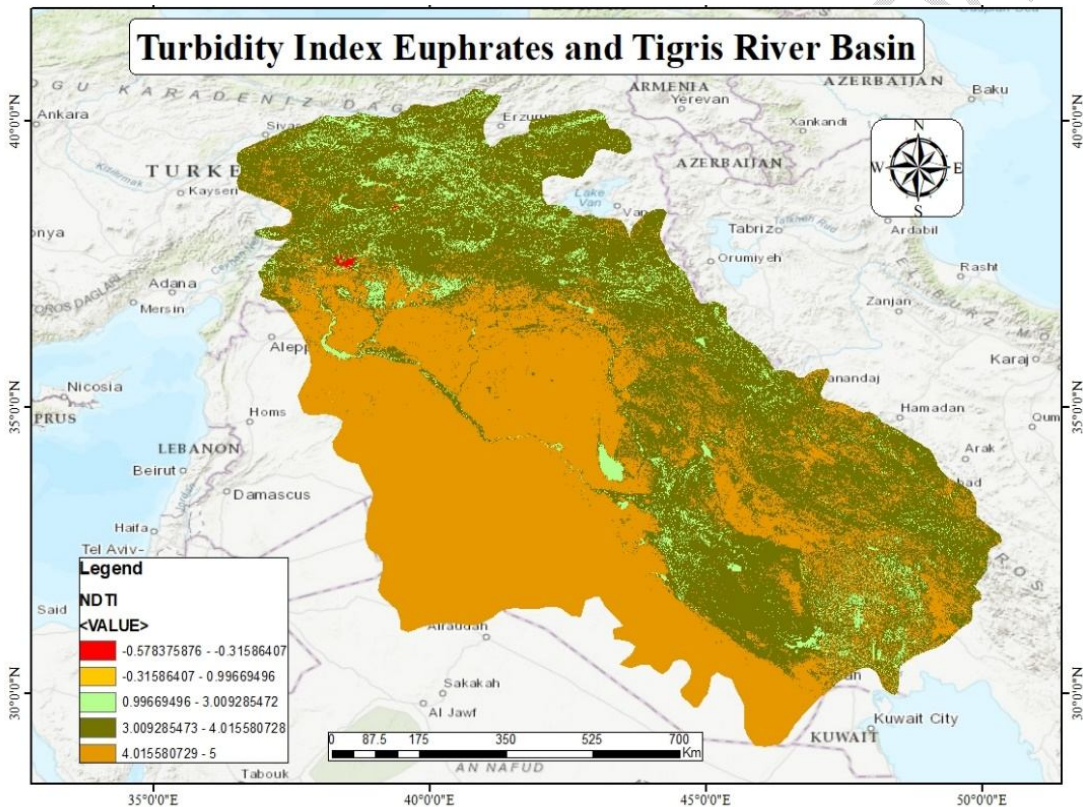


Figure 5: Turbidity Index Map

With readings as mapped in **Figure 5** ranging from -0.57 to -0.31, the first class denotes regions with the lowest turbidity, which usually means that the water is clearer and has less suspended sediments. These locations are frequently found in parts upstream or in places where there is little to no human activity. The somewhat higher turbidity in the second class, which ranges from -0.31 to 0.99, may be the result of moderate agricultural runoff or urban effluents. With values ranging from 0.99 to 3.00, the third class denotes moderate turbidity levels, which are probably influenced by increasing sediment present as a result of human activity or natural erosion. The fourth class, which falls between 3.00 and 4.01, exhibits considerable turbidity and is frequently linked to industrial discharge or intensive land use. With values ranging from 4.01 to 5.00, the fifth class has the highest turbidity levels, which

are generally found in locations that have been heavily affected by pollution or significant sedimentation. This thorough categorization of NDTI values offers insightful information on the geographical distribution of turbidity throughout river systems, emphasizing crucial regions that require the focus of water quality management initiatives. The study provides a thorough assessment of the state of the river ecosystems by combining NDTI with other water quality metrics. This is crucial for creating plans for sustainable water resource management and efficient pollution control.

3.4 Soil pH

Since soil pH has a direct impact on nutrient availability and the general health of aquatic habitats, it is a critical indicator for evaluating water quality. In order to shed light on the acidity or alkalinity of the soils in the Tigris and Euphrates basins, this study used soil pH data. The information was acquired from EnvirometriX Ltd., a company that provides high-resolution soil pH measurements that are essential for comprehending how soil characteristics and water quality interact. (Montazeri et al., 2023).

To draw attention to regional differences, the pH values in the research area were divided into distinct ranges. To standardize the data for comparison with other water quality measures, the pH values of the soil were multiplied by ten. The ensuing categories make it possible to understand soil acidity levels more clearly, which has an impact on the chemistry of the water and the biological activity in river systems.

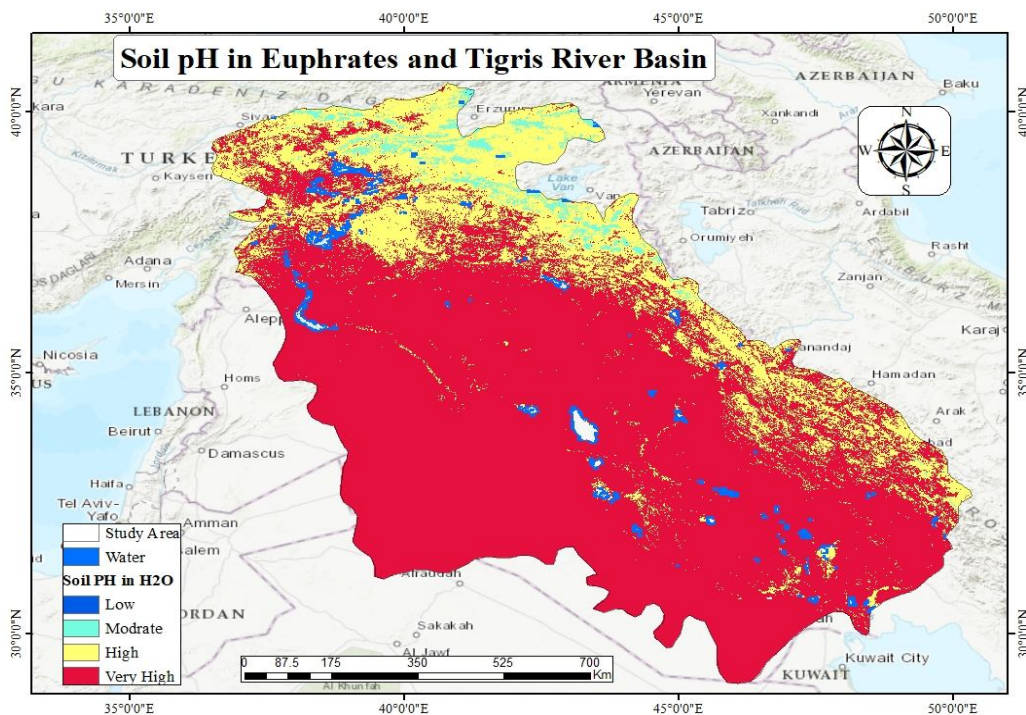


Figure 6: Soil pH in water Map

For example, lower pH values as can be seen in **Figure 6**, which indicate more acidic soils,

may enhance the solubility of various contaminants and heavy metals, which may contaminate water supplies and have an adverse effect on aquatic life. On the other hand, higher pH levels, which indicate more alkaline soils, might affect how readily available vital nutrients are and how aquatic vegetation grows. Through the examination of these soil pH values, the research offers a thorough understanding of the ways in which soil properties interact with parameters related to water quality, providing light on possible sources of pollution and regions in which management actions could be required to preserve or enhance water quality. In order to improve the ecological health and sustainability of the river basins, this analysis encourages the creation of focused strategies for soil and water management.

3.5 Chlorophyll-A

An essential measure of phytoplankton abundance in water bodies is the concentration of chlorophyll, which has a direct impact on the wellbeing of aquatic ecosystems and the likelihood of algal blooms. The Chlorophyll Index was utilized in this work to evaluate the amount and distribution of chlorophyll in the Tigris and Euphrates basins, offering important information about the ecological health and productivity of these water systems. Satellite photography from the Japan Aerospace Exploration Agency's (JAXA) Global Change Observation Mission - Climate (GCOM-C), which is renowned for its great sensitivity to chlorophyll-a and other related pigments, was used to collect the data for chlorophyll concentration.

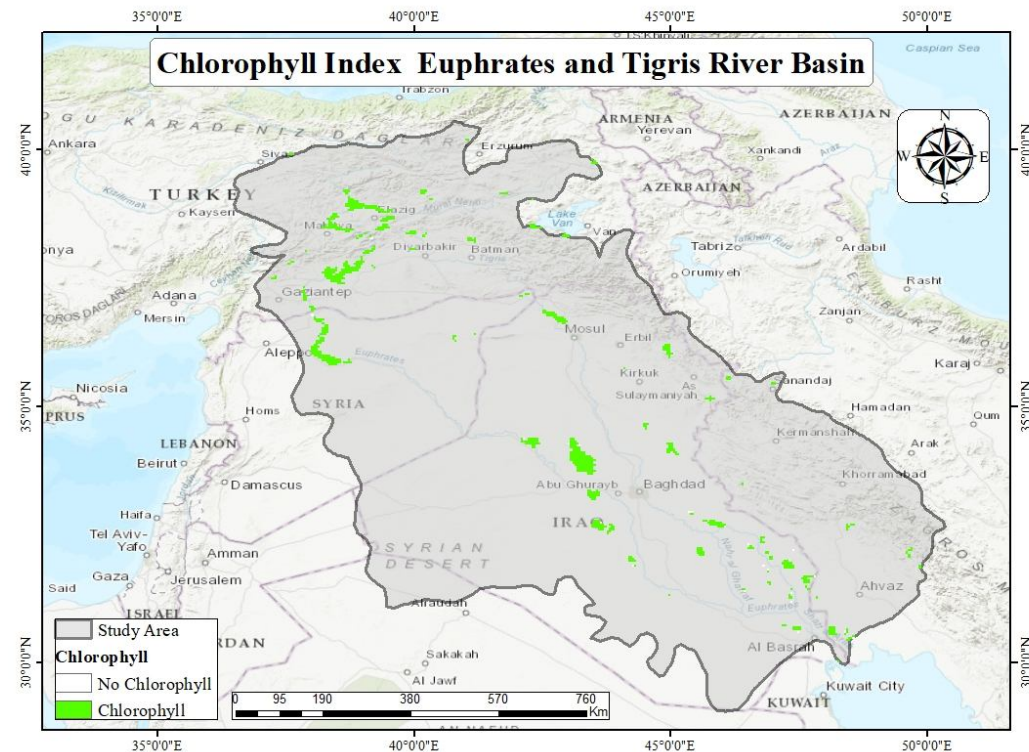


Figure 7: Chlorophyll Index Map

these areas. On the other hand, regions with low to moderate NO_2 levels signify rising pollution, which is the point at which nitrogen compound deposition starts to affect water quality. Nutrient levels in certain locations might gradually rise, which could have an impact on aquatic ecosystems. Elevated levels of NO_2 are typically observed in urban or industrialized areas, as notable nitrogen deposition can aggravate problems such as eutrophication in adjacent water bodies and encourage the spread of nitrogen-dependent diseases. Extremely high NO_2 concentration regions are typically found close to industrial zones or dense metropolitan centers. These areas can have a serious negative influence on water quality, including increased acidity and damaged aquatic life. Comprehending the geographical arrangement of NO_2 in relation to these categories is essential for pinpointing high-risk regions and formulating focused approaches to alleviate its impact on air and water quality.

3.7 Analytical Hierarchy process

By giving each criterion a relative weight, the Analytical Hierarchy Process (AHP) is a structured tool for decision-making that helps assess and rank various criteria. AHP was used in this work to evaluate and categories the water quality in the Tigris and Euphrates basins while taking into account a number of environmental factors, including soil pH, topography, salinity, turbidity, and concentrations of chlorophyll and nitrogen dioxide. A thorough evaluation of these variables was made possible by the AHP framework, which resulted in the creation of an extensive water quality index. (Saaty, 2008).

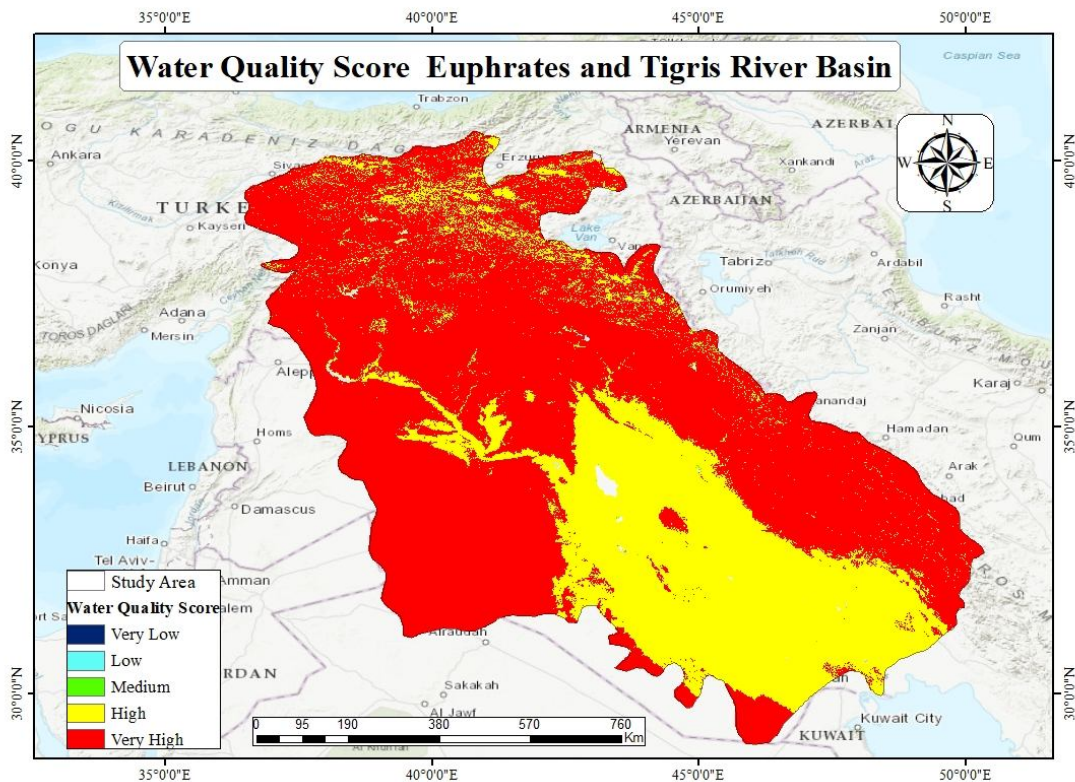


Figure 9: Water Quality Score Map

Five separate groups were identified, as can be seen in **Figure 9**, as a result of the analysis: very low, low, moderate, high, and very high. The "very low" category denotes areas where water quality is seriously harmed, most commonly as a result of high pollution levels and unfavorable environmental circumstances. These classifications represent the general health of the water bodies. On the other hand, "very high" denotes locations with immaculate water quality, where all environmental factors are well within allowable bounds and so promote a robust aquatic ecosystem. The three intermediate categories (low, moderate, and high) represent different levels of water quality and offer a more complex picture of how different basins' water health is distributed geographically.

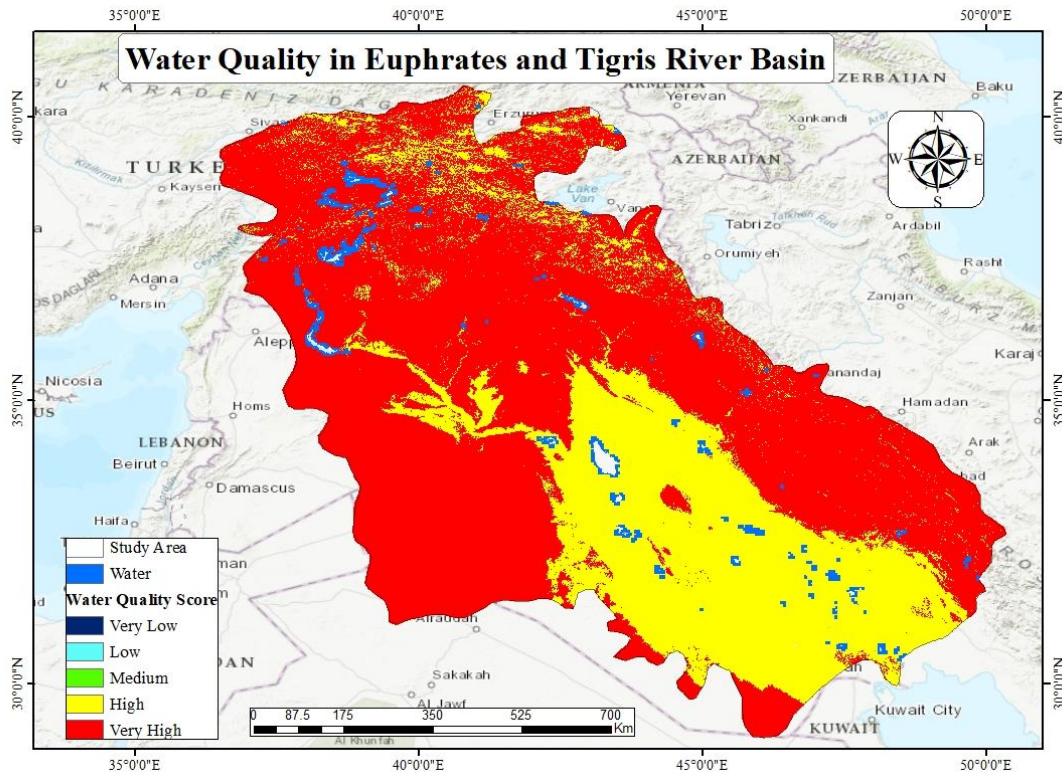


Figure 10: Final Result of Water Quality in Tigris and Euphrates basin

In this case, the use of AHP not only makes it easier to evaluate the water quality clearly and objectively, as in **Figure 10**, but it also aids in determining which areas should be prioritized for environmental management and conservation initiatives. AHP offers decision-makers a strong foundation for creating focused interventions meant to enhance water quality and guarantee the sustainable management of the Tigris and Euphrates basins by combining several datasets and criteria.

4. CONCLUSION

This study highlights the effects of numerous environmental factors on these vital water resources and offers a thorough assessment of the dynamics of water quality in the Tigris and Euphrates basins. Key water quality metrics such as salinity, turbidity, soil pH, nitrogen dioxide (NO₂), and chlorophyll concentration were

assessed by combining remote sensing data, geospatial analysis, and the Analytical Hierarchy Process (AHP). The results showed that there was considerable regional variation in the quality of the water throughout the river basins, with certain areas being more vulnerable to pollution as a result of industrialization, urbanization, and agricultural runoff. The findings highlight how vital it is to keep an eye on the water quality in these river systems, especially in light of the continuous demands from the environment. Certain areas were found to have high salinity, increased turbidity, and notable NO₂ concentrations, all of which could be dangerous for human health and the aquatic ecosystem. The most serious water quality problems can be found in priority regions for intervention thanks to the AHP's classification of water quality into five risk categories. The knowledge gathered from this research highlights the necessity of focused water management plans in order to minimize pollution, lessen the effects of industrial and agricultural operations, and safeguard these essential water supplies. Adopting sustainable methods for managing water resources is essential if we are to meet the demands of an expanding population, agriculture, and the environment. The sustainability and health of the Tigris and Euphrates rivers, which continue to be crucial lifelines for Iraq and the wider region, will require constant observation and policy actions.

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