

## A GIS and SQL Integrated Framework for Analyzing and Comparing Vegetation Indices from Satellite Imagery in Al-Muqdadiyah Area, Iraq

Karam Jassim Mohammed/ Scientific Research Commission  
Baghdad-Iraq

E\_mail: [karam.j.mohammed@src.edu.iq](mailto:karam.j.mohammed@src.edu.iq)

### Abstract:

Vegetation indices are essential tools for assessing and monitoring the variations in vegetation cover over time by using satellite data. This study aims to observe the vegetation cover in the Muqdadiyah area using satellite images from 2016 to 2025. Two images from sentinel 2 dated March 2016 and 2025, with a set of vegetation indices such as (SAVI, MSAVI, NDVI, GNDVI, and TNDVI) were used. Scripts written within a Geographic Information Systems (GIS) environment were utilized to automate the process of extracting these indices, analyzing them spatially and temporally, and comparing the results. A system was also developed to store and subsequently analyze the results using SQL, facilitating efficient data access and querying. The final results indicated that the percentages of vegetation cover, derived from the different indices, showed consistent results. The vegetation cover decreased from approximately 33% in 2016 to about 29% in 2025. This methodology contributes to provide an accurate and flexible tool for monitoring environmental changes in the studied area.

**Keywords:** SQL, GIS, Muqdadiyah, and Vegetation Cover.

### إطار عمل متكامل بين نظم المعلومات الجغرافية وقواعد البيانات SQL لتحليل ومقارنة مؤشرات الغطاء النباتي من صور الأقمار الصناعية في منطقة المقدادية، العراق.

كريم جاسم محمد/ هيئة البحث العلمي. بغداد – العراق

#### الخلاصة

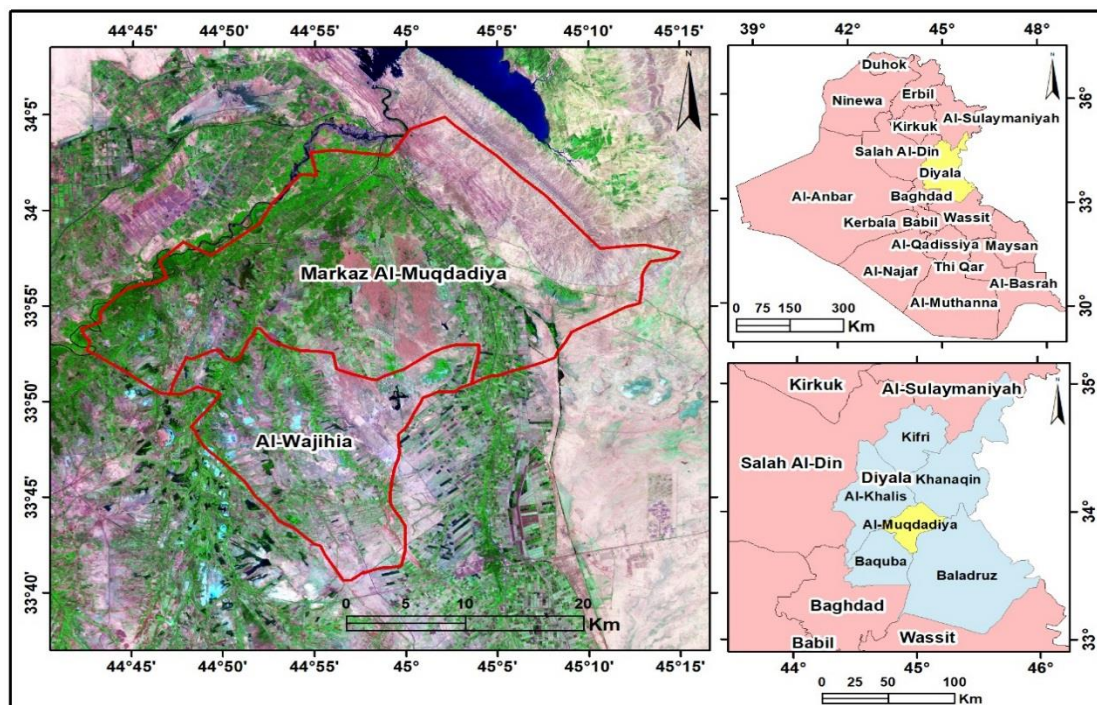
تُعد مؤشرات الغطاء النباتي أدوات أساسية لتقييم ومراقبة التغيرات في الغطاء النباتي بمرور الوقت باستخدام بيانات الأقمار الصناعية. تهدف هذه الدراسة إلى مراقبة الغطاء النباتي في منطقة المقدادية باستخدام صور الأقمار الصناعية من عام 2016 إلى عام 2025. تم استخدام صورتين من سننيل 2 مورختين في مارس 2016 و2025، مع مجموعة من مؤشرات الغطاء النباتي مثل (SAVI وMSAVI وNDVI وGNDVI وTNDVI). تم استخدام البرامج النصية المكتوبة داخل بيئة نظم المعلومات الجغرافية (GIS) لأتمته عملية استخراج هذه المؤشرات وتحليلها مكانياً وزمانياً ومقارنة النتائج. كما تم تطوير نظام لتخزين النتائج وتحليلها لاحقاً باستخدام SQL، مما يسهل الوصول إلى البيانات والاستعلام عنها بكفاءة. أوضحت النتائج النهائية أن نسب الغطاء النباتي، المستمدة من المؤشرات المختلفة، أظهرت نتائج متنسقة. انخفض الغطاء النباتي من حوالي 33% في عام 2016 إلى حوالي 29% في عام 2025. تساهم هذه المنهجية في توفير أداة دقيقة ومرنة لرصد التغيرات البيئية في المنطقة المدروسة.

**الكلمات المفتاحية:** اس كيو ال، نظم المعلومات الجغرافية، المقدادية، الغطاء النباتي.

## Introduction

In the past decade, the rapid expansion and accessibility of remote sensing data have enabled numerous scientific applications, including crop classification, vegetation assessment, forestry analysis, precision farming, urban expansion detection, and landslide risk evaluation. Among these, vegetation mapping represents a fundamental requirement for comprehensive environmental monitoring. Employing remotely sensed imagery provides an efficient and economical alternative to traditional field-based surveys, offering freely available datasets with diverse spatial and spectral resolutions that significantly reduce both cost and time of analysis (Saini, 2023). Remote sensing uses satellite or aerial images to generate a variety of spatial data including metropolitan areas, land use types, vegetated regions, water bodies, and other information about a region's utilities and infrastructures. GIS, on the other hand, offers efficient and useful ways to produce, store, analyze, and display data from remote sensing. In contrast to traditional surveying methods, satellite remote sensing provides a powerful and cost-efficient means for observing land-use dynamics with superior temporal precision (Abood et al., 2024). GIS has emerged as a strong tool for displaying and analyzing Geospatial datasets, in addition to employ these data in decision making in many areas including environmental and engineering fields. GIS is utilized as active tool to develop solutions for water resource problems for evaluating and mapping of water quality, and managing of water resources (Khalaf and Abood, 2024). Remote sensing (RS) techniques are widely utilized for mapping and analyzing vegetation conditions and their temporal variations, primarily through the application of vegetation indices (VI). These indices are favored due to their adaptability, simplicity, and consistency

across different RS platforms. The effectiveness of spectral VIs for large scale monitoring of environmental features has been well established in both terrestrial and aquatic systems. Nevertheless, continued research is necessary to refine these RS-based methodologies and to enhance their applicability across various spatial scales and within diverse freshwater ecosystem context (Gerardo and Lima, 2022). Spectral indices are widely used to improve the extraction of information from raw data, by the minimize the influence of soil background and topographic variations while emphasizing the target features of interest. Numerous vegetation indices (VI) have been developed to evaluate plant health and detect stress conditions. Most of these indices rely on the ratio between reflectance values in the near-infrared and red spectral regions (Chen et al., 2019). The greatest contrast between vegetation and soil occurs within the near-infrared and red spectral regions. Consequently, spectral reflectance measurements obtained from these bands can be utilized to derive various vegetation indices that exhibit strong correlations with agronomic and biophysical parameters associated with plant growth and productivity (Govaerts and Verhulst, 2010). These study objectives employ many spectral indices to monitor and analyze vegetable cover in Al - Muqdadiyah city, as well as to compare their performance over the period from 2016 to 2025. In addition, the results will be stored in a database using the Structured Query Language (SQL). SQL is a powerful language designed to managing and interacting with relational databases. It plays a vital role in supporting data storage, retrieval, and analytical processes within backend systems. Due to its versatility and continuous development, SQL remains an essential tool in data-driven research and applications.



**Figure (1) location of the study area**

#### What's mean SQL:

The SQL language allows you to create table, read from table, update, and delete operations (C-R-U-D operations) to data and database objects.

(SQL) is considered a user-friendly programming, often described as an English-like syntax that simplifies data interaction. Data within SQL databases are organized in tables composed of rows and columns. The language enables users to retrieve and manipulate data from one or multiple tables, including the ability to perform table joins for more complex queries.

SQL supports various operations, commonly known as CRUD functions—Create, Read, Update, and Delete—along with additional logical and analytical tasks. The main SQL command includes:

SELECT- bring back data from table.  
 INSERT-Append new records into tables.

UPDATE- alter existing data within a table.

DELETE- Removes specific records from a table.

CREATE- Generates new database objects such as tables.

ALTER- Alters the structure of existing database objects.

Typically, SQL queries are constructed using essential clauses such as SELECT, FROM, WHERE, GROUP BY, and ORDER BY, which collectively define the data to be extracted, the source tables, the filtering conditions, and the aggregation or sorting methods applied (<https://www.ovhcloud.com>).

#### Materials and methods

In this study, two images of sentinel 2 dated March 2016 and 2025 were used with post grys sql, QGIS Software.

#### The study area

Al-Muqdadiyah is a district in Diyala Governorate, and is considered the

second largest district in the governorate. It is located between (44°45' and 45°15') E and (33°40' and 34°05') N. Its is located to the north of Baghdad, the capital of the Republic of Iraq, approximately 90 kilometers away.

It is also approximately 42 kilometers away from Baqubah, the capital of Diyala Governorate. Muqdadiyah covers an area of approximately 478 km<sup>2</sup> (Al-Khafaji et al., 2021) as shown in Figure 1.

**The used vegetation indices:**

This research utilized five vegetation indices to assess and track vegetation cover dynamics across the study area:

**1. Normalized Difference Vegetation Index (NDVI):**

The NDVI is calculated based on the reflectance characteristics of vegetation in the near-infrared (NIR) and visible red spectral regions. Typically, healthy and dense vegetation absorbs a significant portion of incoming red light while reflecting a higher amount of NIR radiation. In contrast, vegetation that is stressed, sparse, or degraded reflects greater amounts of red light and less NIR energy. NDVI quantitatively represents this spectral contrast by utilizing the ratio between the difference and the sum of the red and NIR reflectance values, as the following equation (Allawai and Ahmed, 2020).

$$\text{NDVI} = \frac{[\text{NIR} - \text{Red}]}{[\text{NIR} + \text{Red}]} \dots\dots\dots (1)$$

Where: NIR and Red are Near Infrared and Red bands of sentinel 2 image respectively.

**2. Green Normalized Difference Vegetation Index (GNDVI):**

The GNDVI is a spectral index particularly sensitive to variations in chlorophyll concentration. It utilizes the green spectralband, generally within the wavelength range of 540 nm to 570 nm, to evaluate vegetation vigor and photosynthetic efficiency. The GNDVI is calculated according to the following equation (Allawai and Ahmed, 2020):

$$\text{GNDVI} = \frac{[\text{NIR} - \text{Green}]}{[\text{NIR} + \text{Green}]} \dots\dots\dots (2)$$

Where: Green and NIR are Green and Near Infrared bands of sentinel 2 image respectively

**3. Soil Adjusted Vegetation Index (SAVI):**

The SAVI is designed to minimize the influence of soil reflectance on vegetation measurements. It incorporates a canopy background adjustment factor, commonly assigned a value of 0.5, which accounts for variations in vegetation density. This index is particularly suitable for regions characterized by relatively sparse or moderately dense vegetation cover. The SAVI is expressed by the following equation: (Indirabai and Nair, 2018).

$$\text{SAVI} = 1.5 \frac{[\text{NIR} - \text{Red}]}{[\text{NIR} + \text{Red} + 0.5]} \dots\dots\dots (3)$$

Where: Red and NIR are Red and Near Infrared bands of sentinel 2 image respectively.

**4. Modified soil adjusted vegetation index (MSAVI):**

The MSAVI is a vegetation index developed as an enhancement of the SAVI model through the modification of the L correction factor. In this formulation, the L value is dynamically reduced for areas with low to medium vegetation density, thereby improving the accuracy of vegetation detection.

The MSAVI adjustment minimizes background noise caused by uncorrected soil reflectance and ground color variations, leading to more reliable estimations of vegetation cover and health (Novando and Arif, 2023). It is calculated by the following formula:

$$\text{MSAVI} = \frac{2\text{NIR} + 1 - \sqrt{(2\text{NIR} + 1)^2 - 8(\text{NIR} - \text{red})}}{2} \dots\dots\dots (4)$$

Where: Red and NIR are Red and Near Infrared bands of sentinel 2 image respectively.

**5. Transformed Normalized Difference Vegetation Index (TNDVI):**

TNDVI is utilized to convert multi-spectral data into single image band which

represents vegetation distribution was computed for imageries using standard algorithm (Shetty and Somashekar, 2013):

$$TNDVI = \frac{\sqrt{[NIR-Red]/[NIR+Red] + 0.5}}{1} \dots\dots\dots (5)$$

Where: Red and NIR are Red and Near Infrared bands of sentinel 2 image respectively

**Results and Discussion:**

In this research, five vegetation indices such as TNDVI, GNDVI, NDVI, SAVI, and MSAVI were applied to monitor and assess vegetation cover dynamics within the study area. The analysis was conducted using two satellite images: Sentinel 2 (2016) and Sentinel 2 (2025). Data processing and analysis were performed using ArcGIS 10.8 software, which facilitated data input, spatial analysis, and visualization of the results. Furthermore, a Spectroradiometer type (FieldSpec3) device was employed to validate the derived vegetation indices and verify their accuracy. The findings demonstrated that various land surface

features in the study area could be effectively distinguished based on their spectral characteristics, particularly in differentiating between bare soil and vegetated areas. Therefore, understanding the spectral behavior of land cover types using spectroradiometer measurements is crucial for accurate results. The results indicated a noticeable decrease in vegetation cover between 2016 and 2025. The vegetation cover proportion, derived from the different indices, showed consistent results across Figures 2–11. Table1, the results confirmed this trend, revealing that vegetation cover decreased from approximately 33% in 2016 to about 29% in 2025. Meanwhile, water bodies decreased slightly from around 4% to 2%, whereas bare land increased significantly from 2016 to 2025 over the same period. In general, the final results concluded that any of these indices can reliably be used to monitor vegetation dynamics within the study area. After that we will save the result in new data base by using sql languages to be more safety and easy. when share information with many user Also, can make marge between two tables without duplicated data.

**Table (1) Area and Percentages of Vegetation Cover in Each Vegetation Index**

Indices	Area (km <sup>2</sup> ) 2016	Percent	Area (km <sup>2</sup> ) 2025	Percent
GNDVI	160	33%	142	30%
MSAVI	162	34%	146	31%
NDVI	159	33%	140	29%
SAVI	159	33%	140	29%
TNDVI	168	35%	148	31%

SQL:

Sql

-- Create the Table

```
CREATE TABLE VegetationCover (
  IndexName VARCHAR(10),
  Area2016 INT,
  Percent2016 DECIMAL(5,2),
  Area2025 INT,
  Percent2025 DECIMAL(5,2));
```

-- Insert the data

```
INSERT INTO VegetationCover
(IndexName, Area2016, Percent2016,
Area2025, Percent2025) VALUES
('GNDVI', 160, 33.00, 142, 30.00),
('MSAVI', 162, 34.00, 146, 31.00),
('NDVI', 159, 33.00, 140, 29.00),
('SAVI', 159, 33.00, 140, 29.00),
('TNDVI', 168, 35.00, 148, 31.00);
```

Figure (3) TNDVI of study area 2025

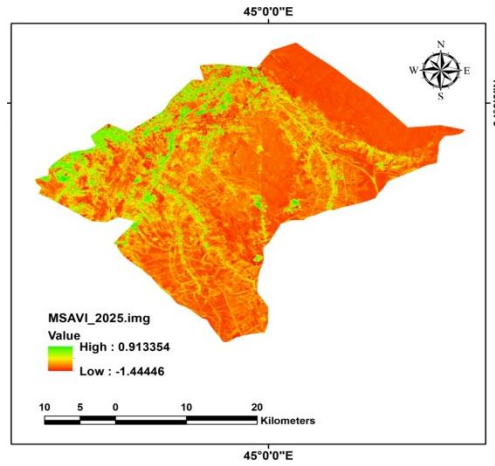


Figure (4) MSAVI of study area 2016

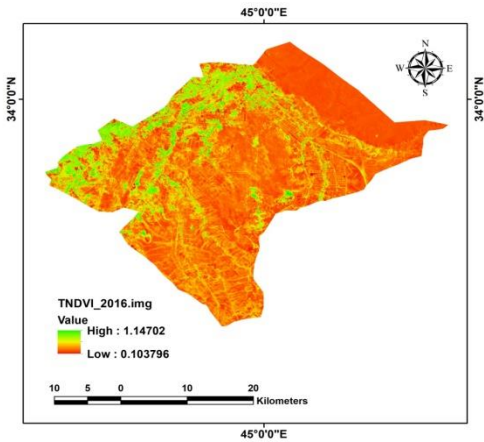
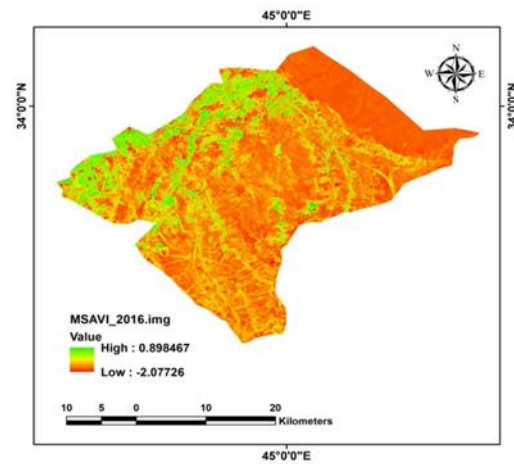
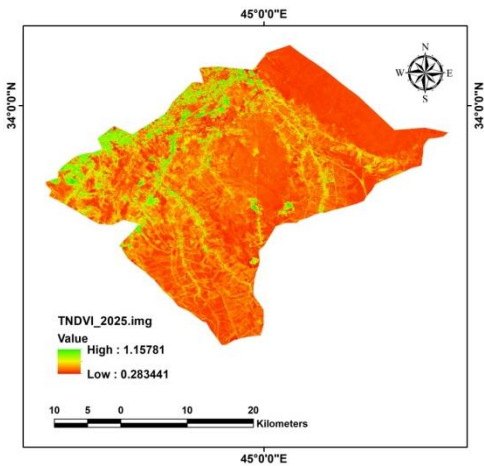


Figure (2) TNDVI of study area 2016

Figure (5) MSAVI of study area 2025



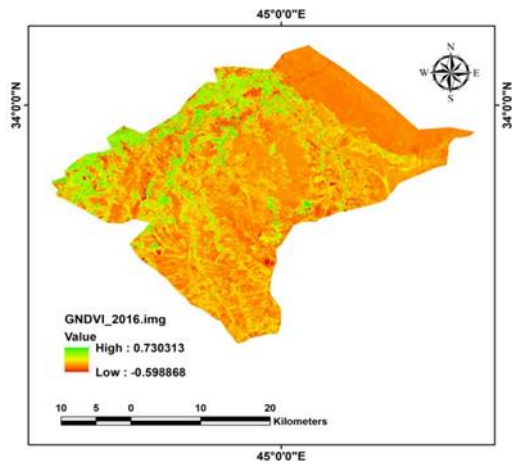


Figure (6) GNDVI of study area 2016

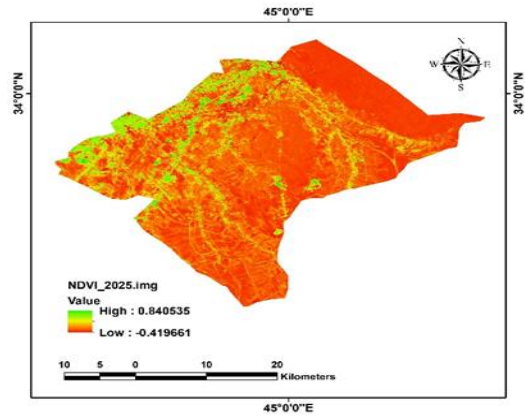


Figure (9) NDVI of study area 2025

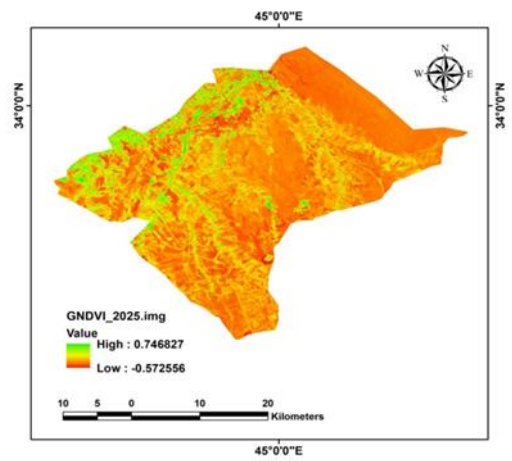


Figure (7) GNDVI of study area 2025

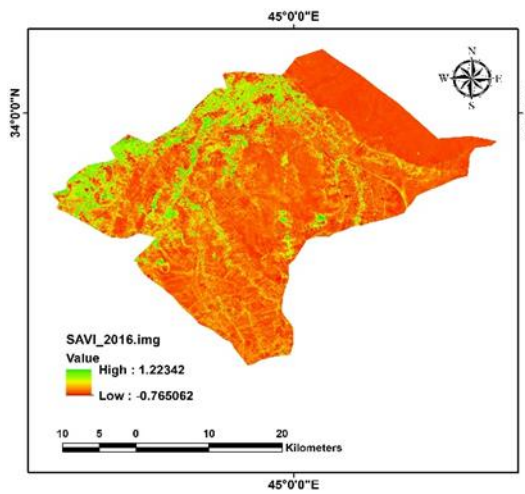


Figure (10) SAVI of study area 2016

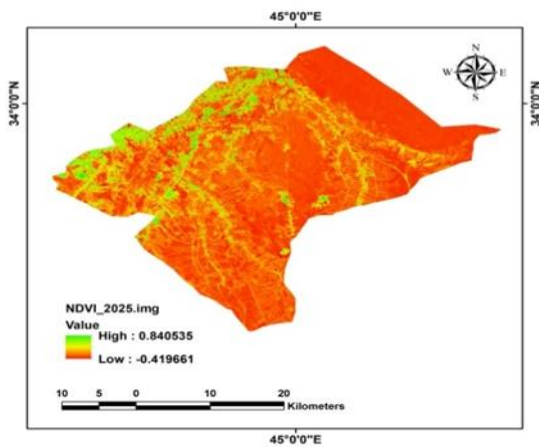


Figure (8) NDVI of study area 2016

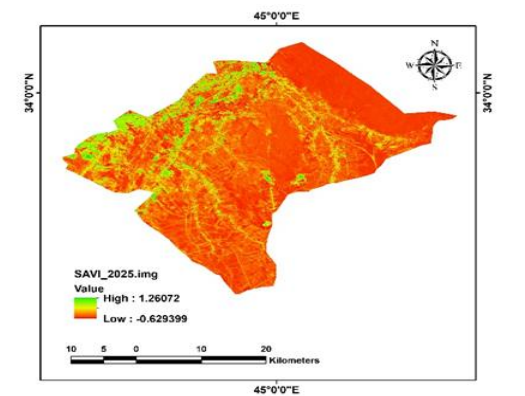


Figure (11) SAVI of study area 2025

## Conclusion

- 1- The vegetation cover showed a noticeable decrease between 2016 and 2025.
- 2- The vegetation cover percentages derived from the vegetation indices (TNDVI, GNDVI, NDVI, SAVI, and MSAVI) were very close to each other.
- 3- Vegetation cover decreased from approximately 30% in 2016 to about 29% in 2025.
- 4- The water bodies decreased from around 4% to 2%, while bare lands increased during the period 2016–2025.
- 5- Any of these indices can reliably be used to monitor vegetation dynamics within the study area.

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