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Monitoring Vegetation Cover in Wasit Governorate, Iraq Using Landsat Imagery and NDVI Analysis (2012–2024)

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Abstract

This study evaluates vegetation cover using the application of Landsat satellite images and the Normalized Difference Vegetation Index (NDVI) in Wasit Governorate, Iraq. We processed the satellite images of 2012, 2016, 2020, and 2024 in order to assess spatial and temporal variations over vegetation coverage. NDVI values were derived from standard preprocessing of Landsat imagery (30 m resolution, including band stacking, clipping the study area, and bracket values through ratios from red and near-infrared spectral bands). The result shows that the vegetation distribution also has prominent spatial variability across the governorate. Vegetation thus is confined to the corridor of the Tigris River and irrigated agricultural lands with moderate NDVI values (comparatively tall shrub cover). By contrast, the western and southern sections of the state have little vegetation because it is semi-arid and lack easy access to water. NDVI > 0.4 is related to regions of high density of agricultural vegetation, and NDVI < 0.2 corresponds to bare land and desert surface. In general, the results show that NDVI extracted from Landsat images presents a useful method to monitor vegetation dynamics and environmental situations in arid and semi-arid areas, such as Wasit..

Keywords: NDVI, Vegetation Cover, Landsat Imagery, Remote Sensing, Semi-arid Environment.

مراقبة الغطاء النباتي في محافظة واسط، العراق باستخدام مرئيات لاندسات وتحليل مؤشر الغطاء النباتي المعياري (NDVI) للفترة (2012–2024)

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الخلاصة

تهدف هذه الدراسة إلى تقييم الغطاء النباتي باستخدام تطبيق صور الأقمار الصناعية لاندسات ومؤشر الغطاء النباتي المعياري (NDVI) في محافظة واسط، العراق. تمت معالجة صور الأقمار الصناعية للأعوام 2012 و2016 و2020 و2024 من أجل تقييم التغيرات المكانية والزمانية في الغطاء النباتي. تم اشتقاق قيم مؤشر NDVI من خلال المعالجة المسبقة القياسية لصور لاندسات ذات الدقة المكانية (30 متر)، والتي تضمنت دمج الحزم الطيفية، وقص منطقة الدراسة، واستخراج القيم باستخدام النسب بين الحزم الطيفية الحمراء وتحت الحمراء القريبة.أظهرت النتائج أن توزيع الغطاء النباتي يمتلك تباينًا مكانيًا واضحًا عبر المحافظة. حيث يتركز الغطاء النباتي على امتداد نهر دجلة والأراضي الزراعية المروية مع قيم NDVIمتوسطة، مما يشير إلى وجود غطاء نباتي كثيف نسبيًا. في المقابل، تُظهر الأجزاء الغربية والجنوبية من المحافظة غطاءً نباتيًا ضعيفًا بسبب طبيعتها شبه الجافة وقلة توفر المياه . تشير قيم NDVI الأكبر من 0.4 إلى مناطق ذات كثافة عالية من الغطاء الزراعي، بينما تمثل القيم الأقل من 0.2 الأراضي الجرداء والأسطح الصحراوية. وبشكل عام، توضح النتائج أن مؤشر NDVI المستخرج من صور لاندسات يُعد أداة فعالة لمراقبة ديناميكية الغطاء النباتي والظروف البيئية في المناطق الجافة وشبه الجافة مثل محافظة واسط.

1. Introduction

The pedagogical approach of researching this aspect is that the vegetation cover has a basic role in maintaining environmental sustainability, ecosystem stability, and agricultural productivity. Different ecological processes, including carbon cycling, soil regulation, water regulation services, and the modulation of climate, are driven by this vegetation. The physiology and morphology of vegetation–irrespective of the specific functional type–respond similarly to environmental disturbances, which can include climate variability (see green colors), land degradation (orange colors, rainfall gradients, etc.), water scarcity (dark blue areas), and human land-use activities, including agriculture (black squares). This points to the need for using vegetation dynamic monitoring to understand environmental change and help with less intense land-use planning. Over the past decades, remote sensing technology has been the most powerful tool for monitoring vegetation dynamics at regional and global scales. Satellites capture Earth's surface data over periods of time and provide important spectral information that can be used to measure the health, density, and distribution of vegetation in space. Remote sensing data can play an important role in understanding the vegetation arrangements over vast areas that are typically hard to access for ground surveys.

Landsat imagery is one of the most prominent satellite datasets commonly used for environmental monitoring applications, thanks to its moderate spatial resolution and long-term historical archive [1, 2]. Since the 1970s, the Landsat program has continuously provided optical remote sensing data for Earth observation that articulated environmental monitoring and land-cover change analysis at local to global scales. Such data have found wide applications in studies of vegetation monitoring, drought assessment, land degradation, and ecosystem management.

The NDVI is one of the more popular vegetation indices that have been derived from satellite data. Normalized difference vegetation index (NDVI) is a common vegetation index used for assessing vegetation presence, health, and density using the difference between the near-infrared (NIR) band and red band to form an expression [3]. Vegetation reflects near-infrared radiation and absorbs red light thanks to biomass content, and thus NDVI is useful for differentiating between vegetated surfaces (areas with vegetation cover) and non-vegetated areas [4]. NDVI is one of the most popularly used indices in studies related to environmental monitoring, vegetation change detection, drought monitoring, land degradation assessment, and agricultural productivity analysis. NDVI time-series analysis has successfully been used to monitor vegetation degradation and environmental stress in semi-arid environments [5, 6].

Recent advances in the analysis of objects on Earth using remote sensing include machine learning and advanced image processing as means of achieving better accuracy in environmental monitoring. This not only facilitates proper interpretation of satellite data but also aids in the identification of land-cover changes [7-9]. There are a variety of machine learning algorithms that have been validated for applications such as land-cover classification and vegetation monitoring, including Random Forest and Support Vector Machine [10-12].

Moreover, with high-resolution multispectral satellite imagery like Sentinel-2, it has been enhanced land-cover mapping and environmental monitoring [13, 14]. In addition, deep learning approaches have recently dominated in remote counting applications to improve vegetation patterns and land-cover detection changes from satellite imagery [15].

Semi-arid regions like Iraq are more at risk of several vegetation degradation hazards such as high temperature and low rainfall, which will impose pressure on water resources. In those regions, irrigation is already an important component, so the stability of the ecosystems and productivity could be influenced in a significant manner by environmental changes. Correctly monitoring plant dynamics in time is still vital to characterize environmental conditions and benefit sustainable land use.

Wasit Governorate, located in eastern Iraq, is one of the most important agricultural regions in Iraq with its vast irrigated land along the Tigris River and extensive semi-arid areas. The distribution of vegetation in the governorate is related to irrigation systems and water availability. The vegetation index of this zone is also probably subject to environmental pressures, such as climate variability or land degradation. Abstract Continuous monitoring of vegetation cover is crucial for agricultural planning and sustainable land-use development, in addition to environmental management in the Wasit Governorate. This study aims to analyze the vegetation cover of Wasit Governorate as determined from Landsat imagery and NDVI analysis. Specifically, this study aims to:

1- NDVI-based classification of vegetation in Wasit Governorate.
2- Spatial variability of plant density.
3- Monitor temporal variations in vegetation cover (2012, 2016, 2020, and 2024).
4- Useful information for environmental monitoring and land management.

2. Theoretical Background

Vegetation indices are mathematical functions of combinations of spectral bands to optimize the observation signals from vegetation observed through a satellite image. Researchers can analyze spectral reflectance characteristics of vegetation or the amount of light reflected off their surfaces by using these indices to measure the presence, health, and density of any vegetative growth.

The most common of these indices is the Normalized Difference Vegetation Index (NDVI), which is extensively used for vegetation monitoring and environmental assessment [3]. Normalized Difference Vegetation Index (NDVI) quantifies the density of vegetation based on its reflection of near-infrared and red spectral bands. Here, the NDVI equation can be written in the form:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

where:

NIR = Near-infrared spectral band

Red = Red spectral band

For Landsat imagery, NDVI is calculated using different spectral bands depending on the satellite. In Landsat-7, the Near Infrared (NIR) band is Band 4 and the Red band is Band 3, while in Landsat-8, the NIR band is Band 5 and the Red band is Band 4.

NDVI has values ranging from −1 to +1. Generally, high values are indices of plant cover/vegetation, and zero values correspond to surfaces like bare soils or urban materials. By definition, bodies of water have negative values (in gross). And so high values of NDVI and healthy bushy vegetation map very well to the levels of barren land, where low values of NDVI correspond with higher barren areas, such as deserts or shrubland. NDVI has been widely used in several environmental variables, such as vegetation monitoring [2,3], drought detection [4], agricultural productivity estimation {Cheng, 2023 #8}[5], and land degradation assessment [6]. Through NDVI time-series analysis, it is able to identify changes in vegetation over a period, thus providing insights regarding the ecosystem dynamics and environmental conditions. NDVI changes are closely connected with climate conditions, precipitation regimes and water availability in semi-arid regions. Some basic NDVI interpretation values are below.

Table 1 – NDVI Classification

NDVI Range	*Vegetation Density*
< 0	Water
0 – 0.2	Bare Soil
0.2 – 0.4	Sparse Vegetation
0.4 – 0.6	Moderate Vegetation
> 0.6	Dense Vegetation

3. Image Processing

Satellite data were extracted from the USGS Earth Explorer platform. To avoid differences resulting from variations between missions, images taken by multiple Landsat missions were used to provide consistency and scientific integrity across the investigation period (2012–2024):

- Landsat-7 ETM+ 2012.
- Landsat-8 OLI in the years 2016, 2020, and 2024.

This is required because Landsat-8 has been operational only since 2013.

Figure -1 Location of Wasit Governorate/Iraq.

3.1 Preprocessing

In order to guarantee data quality and comparability, the following preprocessing pipelines are applied:

1. Radiometric calibration.
2. Atmospheric correction (LaSRC) to convert TOA reflectance to surface reflectance.
3. QA band-based cloud and shadow masking.
4. Clipping images to the study area.
5. Band stacking using ENVI 5.3 .

These steps are crucial in minimizing atmospheric noise that can affect NDVI accuracy.

3.2 Software Environment

Spatial analyses and NDVI calculations were conducted using:

1. SNAP 8.0.0 (preprocessing).
2. ENVI 5.3 (band stacking, analysis).
3. ArcGIS 10.8 (mapping and spatial analytics).

The administrative boundary of Wasit Governorate was obtained from official GIS shapefiles provided by the Iraqi administrative boundary database and used for clipping and spatial analysis of the satellite imagery.

3.3 Temporal Consistency

Satellite images were selected from similar periods of the year to ensure seasonal consistency: October–November for each year studied (2012, 2016, 2020, 2024)

This reduces the seasonal variability but guarantees that NDVI differences in areas between seasons pass measure real vegetation changes rather than seasonal effects.

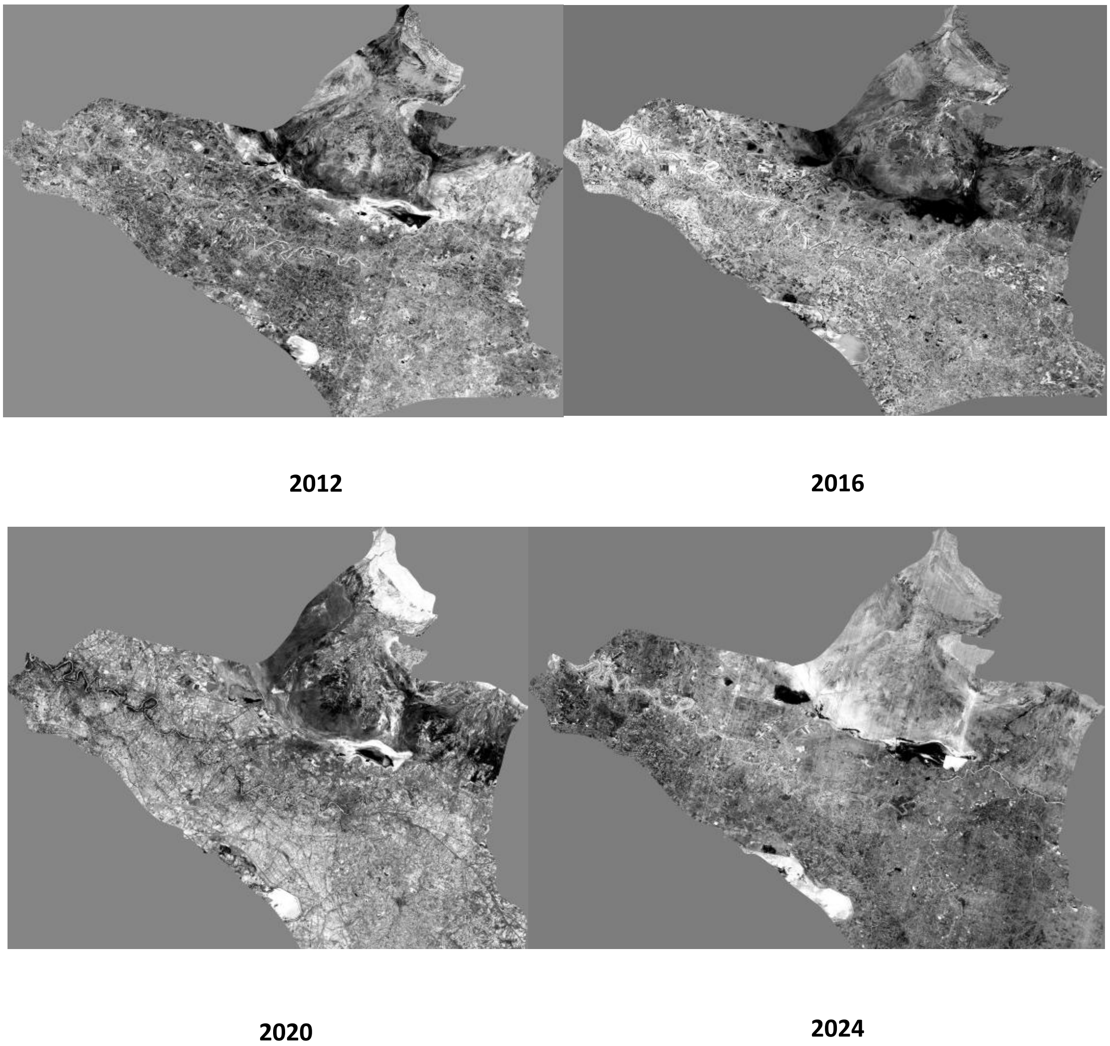

Figure-2 Landsat satellite images were used to derive NDVI maps of Wasit Governorate in October–November (2012, 2016, 2020, and 2024).

3.4. NDVI Calculation

The NDVI was calculated using :

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (2)$$

For Landsat data: NIR = Band 5 (Landsat-8) / Band 4 (Landsat-7).

Red = Band 4 (Landsat-8) / Band 3 (Landsat-7).

To ease the interpretation of the NDVI map, NDVI was designated into vegetation density classes

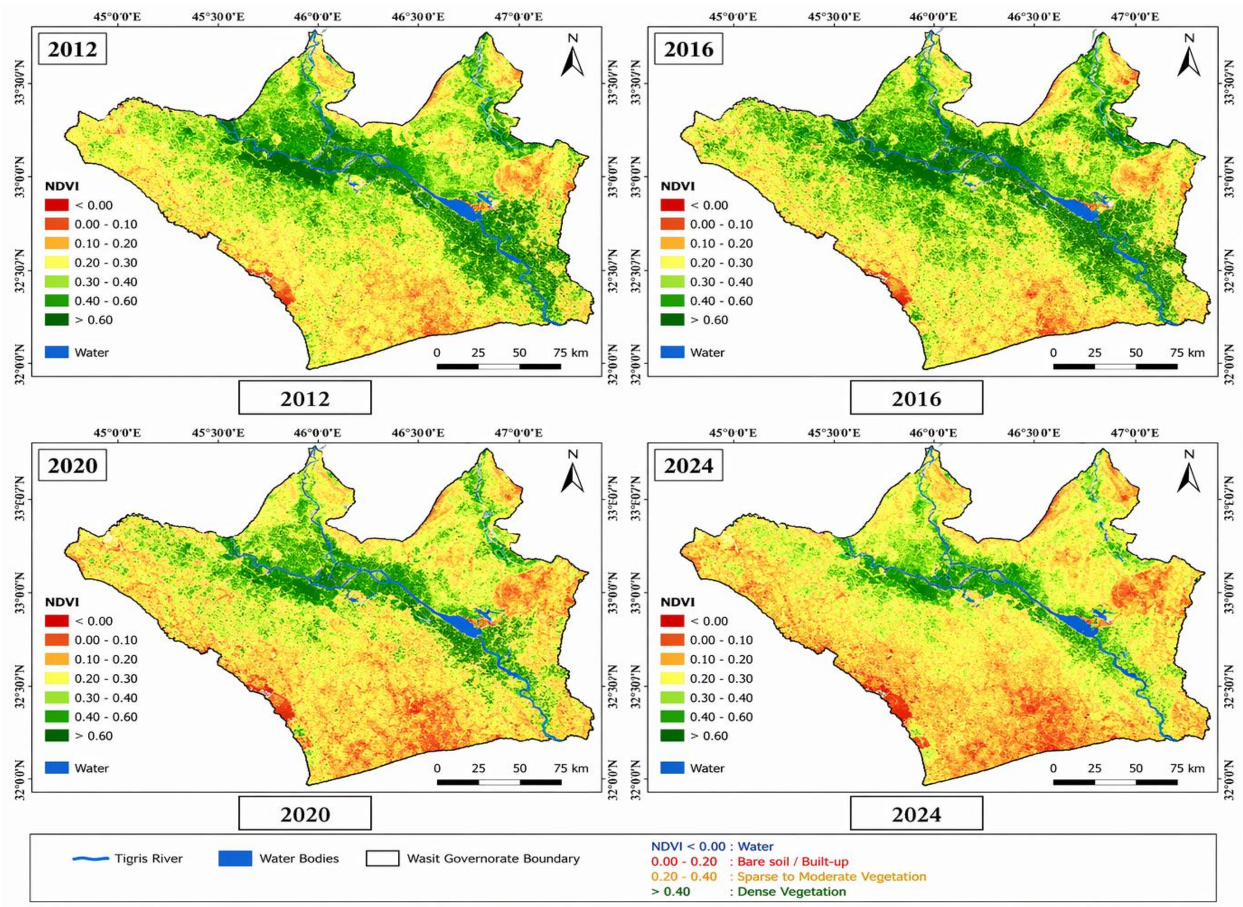

Figure-3 Change detection map showing vegetation increase and decrease between 2012 & 2024 NDVI values.

Table 2 – Mean NDVI Values.

Year	*Mean NDVI*	*Vegetation Condition*
2012	0.34	Sparse Vegetation
2016	0.36	Sparse Vegetation
2020	0.31	Sparse Vegetation
2024	0.29	Sparse Vegetation

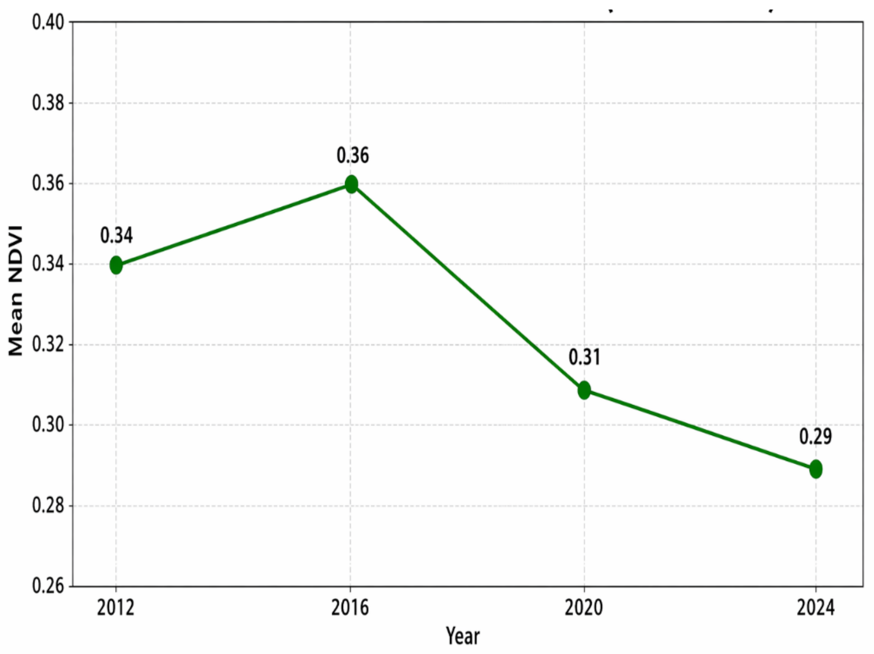

Figure-4 Temporal variation of NDVI values that signify vegetation dynamics between (2012 – 2024).

Table 3 – Vegetation Area Distribution.

Year	*Dense Vegetation(km²)*	*Moderate Vegetation(km²)*	*Sparse Vegetation(km²)*	*Bare Land(km²)*	*Water Bodies(km²)*
2012	2850	4200	5300	4300	350
2016	3120	4380	5040	4100	510
2020	2640	3950	5620	4550	390
2024	2430	3780	5910	4520	510

4. Results and Discussion

NDVI analysis represents spatially and temporally significant changes in vegetation cover across the Wasit Governorate throughout the study phase (2012–2024). The NDVI maps produced illustrate how the locations and distributions of the vegetation are highly impacted by irrigation networks and distance to the Tigris River. The 2012 NDVI map revealed considerable moderate vegetation coverage in vast agricultural zones along the Tigris River corridor (Appendix A, Figure 3). The NDVI values of 0.30 to 0.45 in these zones might indicate irrigated agricultural fields. In contrast, despite the flatter nature of the western and southern portions (based on terrain elevation) of the governorate, the terrain was characterized by low vegetation cover, as represented by NDVI values <0.20, suggesting sparse vegetation or sandy desert surfaces instead. This indicates the potential of NDVI as a proxy for vegetation density and land-cover characteristics in semi-arid environments [3,11].

The NDVI map from 2016 indicates a slight increase in vegetation density when compared to the year 2012. In September to October 2023, some agricultural regions demonstrated NDVI values above the threshold of 0.40, indicating enhanced vegetation growth and crop productivity in that growing season compared to previous months. Other studies are in agreement with NDVI detecting such increases in vegetation density due to the introduction of water sources for irrigation on a landscape level [2,5]. Yet, the NDVI map of 2020 demonstrates some areas with a tremendous decrease in vegetation density in most parts of Wasit Governorate. In most agricultural zones, NDVI values declined to about 0.31, indicating vegetation stress and decreased vegetation cover.

The decrease might be related to some environmental factors like drought, low rainfall, or other land degradation processes in the region. NDVI analysis based on satellite-derived NDVI has previously been shown to provide a reliable indicator of vegetation decline in arid and semi-arid environments [5,6].

The 2024 NDVI map, on the other hand, will also show spatial variability in vegetation conditions. Irrigated Agricultural Lands along the Tigris River still maintain a moderate cover of Vegetation, yet some areas indicate lower NDVI than in preceding years. The average NDVI value for the year 2024 is approximately equal to 0.29, which means that Vegetation Density remains relatively low across all of the governorate over this time period. NDVI classification results indicated that:

1- NDVI > 0,40 means dense vegetation in the agricultural areas.
2- NDVI between 0.20 and 0.40 implies vigorous vegetation cover.
3- Class NDVI < 0.20 = bare surfaces (e.g., desert).

As a result, NDVI temporal analysis showed that density orchestrated moderately in Wasit Governorate 2012–2016 with a gradual downtrend during the years of 2020 and 2024, which reflects an enhancement stressing environmental indirect impact or climate variability on vegetative properties. These findings are similar to Landsat vegetation environmental monitoring studies [1,6].

NDVI-based Vegetation Cover Variation Using Spatiotemporal Analysis for Different Localities of the Wars of Wasit Governorate (2012–2024). Results indicate that vegetation is primarily constrained to within the Tigris River corridor and irrigated agricultural zones, consistent with the premise that water regulates vegetation at semi-arid sites. Thus, we focus on 2012 to 2016, and it is found that when the irrigation is essential, of course, naturally climatic conditions also work out for vegetated area improvement, which recommends an increase in vegetation cover automatically, as clear from Figure 2. The same observations were reported by Nguyen & Pham (2024), who showed water availability and irrigation systems in semi-arid regions have an important influence on vegetation growth as [5].

On the contrary, a large area of the governorate had a noticeable reduction in vegetation density as proven by NDVI maps between 2020 and 2024. This is often associated with environmental factors such as decreased rainfall, longer droughts, and enhanced land degradation processes. The phenomenon is closely associated with climate variability and, therefore, water scarcity, which triggers the degradation of vegetation in arid ecosystems (Li et al., 2023) [7]. Soil moisture change detection analysis provides insight into vegetation loss that mainly occurs in remote areas from irrigation channels. In line with observations from satellite-based environmental monitoring research that established semi-arid systems as highly sensitive to impacts of hydrological variability and land degradation processes [6,12].

Another interesting point is that we find the vegetation has very similar density values close to the irrigation infrastructure. NDVI values at or near irrigation canals and agricultural areas are always greater than (and therefore, greater NDVI values) than the relatively dry surrounding semi-arid regions. This pattern re-emphasizes the crucial part irrigation systems play in supporting vegetation productivity under water-limited environments. Moreover, previous studies demonstrate that satellite images and sophisticated image analysis methods enable the monitoring of land-cover change and environmental status [8–10]. Since their inception, Landsat satellites have been extensively used in monitoring vegetation dynamics and regional environmental changes through remote sensing data that is characterized by long-term reliability [1].

In summary, following are the findings from a study that was conducted to assess the NDVI rooting depth effect on vegetation dynamics and environmental change across semi-arid environments using Landsat data: Integration of satellite image and Geographic Information System (GIS) techniques for monitoring the condition of vegetation provides information on the status of vegetation over wide expanses for potential decision-making towards developing strategies related to environmental management, agricultural planning, and sustainable land-use.

6. Conclusion

In this study, the results of monitoring the vegetation cover changes during 2012–2024 in Wasit Governorate (Iraq) using Landsat-7 and Landsat-8 satellite imagery along with NDVI analysis were presented. The analysis found that vegetation distributions are closely related to irrigation systems and the distance from Tigris river. You can see that the NDVI values were at a higher level in agricultural lands and irrigated areas so on the contrary lower values of NDVI were in desert and semi-arid regions, that generally contain sparse vegetation cover. The results support that NDVI is an useful tool for monitoring vegetation dynamics and environmental conditions in semi-arid. This method can facilitate environmental monitoring, agricultural planning.

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