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Assessing Seasonal Variations of Vegetation Cover Using NDVI in Context Climate Change in Wasit

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Abstract: This study assesses and analyzes the annual and seasonal changes in the Normalized Difference Vegetation Index (NDVI) in Wasit Province, Iraq, between 2020 and 2023. Vegetation cover (VC) variation serves as a key indicator of climate change impacts on ecosystems and agricultural productivity. The research employs satellite-derived NDVI and climate data to detect spatiotemporal changes across the region. Geographically, the Tigris River divides Wasit into two zones: the southern and southwestern parts exhibit higher NDVI values due to abundant water from river branches, whereas the northern and northeastern areas show lower values. A slight improvement in VC was observed in December 2020, likely due to increased Tigris River discharges. Findings indicate a gradual NDVI increase over the study period, with the highest value recorded during summer 2023 (2.94%), highlighting the role of irrigation and modern agricultural practices in enhancing VC beyond the influence of climate factors. Seasonal variations were evident, with summer NDVI values generally exceeding those in winter; the highest winter NDVI was in 2021 (2.40%). Three statistical methods were applied: correlation analysis, linear regression, and ANOVA. Results showed a weak negative correlation between NDVI and precipitation ($r = -0.60$), and a negligible correlation with air temperature ($r = 0.06$). ANOVA confirmed significant differences in NDVI values across the years ($p = 0.0039$), indicating real ecological changes rather than random variation. Using the ARIMA model for forecasting, NDVI is expected to continue a slight upward trend, reaching 0.442 in 2024 and 0.463 in 2025. This suggests a positive vegetation response driven more by improved agricultural and water management practices than by climatic changes.

Keywords: ARIMA model, climate change, GIS,NDVI , satellite imagery.

Introduction

Vegetation cover is a fundamental component of ecosystems, playing a vital role in climate regulation, soil stabilization, and biodiversity support. It also serves as a key indicator of environmental health and the impacts of climate change. Since vegetation cover dynamically changes across seasons in response to climatic factors such as temperature, precipitation, and solar radiation, so that monitoring these changes and understanding their patterns is essential for assessing the impact of climate on ecosystems and developing sustainable resource management strategies. Seasonal vegetation changes is crucial for multiple fields, including predicting environmental changes. Agricultural resource management, assessing the impact of extreme climate events and Protecting ecosystems and biodiversity.

Many studies have emphasized the Seasonal Variations of Vegetation Cover Using NDVI and Climate Data (Piao *et al.*, 2020) when satellite technology enabled large- scale vegetation monitoring. For instance, a recent study in Karbala, Iraq, utilized NDVI from 2000 to 2024 and demonstrated a consistent decline in vegetation cover, strongly correlated with rising temperatures and declining rainfall, further validating NDVI as a key indicator of climate-related vegetation dynamics (Al-maliki *et al.*, 2024) . The greening phenomenon, together with warming, sea-level rise and sea- ice decline, represents highly credible evidence of anthropogenic climate change. Focused on climate change impacts on vegetation in mountainous regions of India and China (Piao *et al.*, 2020). That shown global warming improved vegetation cover at higher altitudes but contributed to its decline in lower areas due to prolonged droughts**.** The studied by (Liu et al. 2020), responses to climate change and human activities from 1982 to 2020 by using Sentinel-2 data to analyze seasonal changes in agricultural regions, demonstrating that agricultural management practices (such as irrigation and fertilization) influenced NDVI values more than climatic factors in some areas (Wanae Gao *et al.*, 2022) . The study used Machine-learning algorithms for sensitivity of vegetation cover (VC) to climate change in the Yarlung Zangbo river basin. The NDVI was predicted to increase by 1.60–4.68% when the temperature increased by 1.5 °C, while it only changed by 0.06–0.24% when the precipitation increased by 10% in the YZRB. Monthly, the vegetation was more sensitive to temperature changes in spring and summer (Cui *et al.*, 2022).

Dynamic Change in NDVI from 2015 to 2021 in Oman. Random forest regression employed to model the relationships between the NDVI and temperature, humidity, rainfall, soil map, geology map. The multiple regression values revealed significant associations between the spatial distributions of the NDVI and the climatic factors. The results revealed that NDVI values were sensitive to heavy rainfall over Jabal Samhan Mountain (Al-kindi, 2023) . The increase in oil extraction, which requires a large amount of fresh water to extract, has multiplied several times in Iraq. This study was by (Hassan A. S., *et al.*, 2018). Decadal analysis of carbon dioxide emissions from various types of fossil fuels in Iraq has greatly affected the natural vegetation cover (Hassan A. S., *et al.*, 2018). Oil extraction operations require the removal of vegetation from the fields, especially since the oil fields are located in agricultural lands, in addition to the spread of pollutants on agriculture, as is the case in the Garraf oil fields (Rukabie *et al.*, 2023) . NDVI used spatially mapped at two times for each year during 2008, 2013, and 2019 in Baghdad used to explore the potential correlations between seasonal NDVI and air temperature during heat land. The result shows that NDVI-derived vegetation growth patterns were highly correlated with their recording during the current growth seasons (Naif *et al.*,2020). Another important studied came from India was deal with forecasting and visualization of NDVI series using two statistical approaches: mean and variance and Regression Integrated Moving Average for forecasting NDVI then compared with observed NDVI data for year 2016-2017 to investigate seasonal impacts on forecast of annual Auto Regression Integrated Moving

Average (ARIMA) based NDVI (Gupta *et al.*, 2019) .

In this study, the NDVI and climatic variables respectively used as dependent and independent variable, which the value of NDVI depends on of rainfall. Therefore, the purpose of this study is to assess and analyze the inter-annual and seasonal variability of vegetation NDVI from 2020 to 2023. Additionally the goals of sustainability developments.

Materials & Methods

Study Area:

Wasit Governorate is located in the south east of Baghdad capital, Iraq. It's lay along the Tigris River about midway between Baghdad and Basra. It is serving as a connecting point between several other provinces. Diyala located to the north, where Baghdad and Diwaniya to the west, Maysan to the south, and Iran to the east show in figure 1. The governorate is strategically important due to its proximity to the Tigris River, which is the primary source of irrigation in the region .The total area, is (17,153 Km^2). Mapped location of Wasit Governorate approximate geographical coordinates are (Latitude: 32.1° N, Longitude: 45.6° E). Wasit has a hot desert climate (BWh) in the Köppen–Geiger climate classification system (Ibrahim *et al.* ,2021) . Most rain falls in the winter. The average annual temperature in Kut is 23.4 °C, and about 138 mm of precipitation falls annually, which has a considerable impact on agricultural production and vegetation cover in the area (Al-obaidey , 2019. Vegetation Cover contains both irrigated and non-irrigated areas, making it an ideal environment for studying seasonal changes in vegetation cover using NDVI, as it allows for an analysis of the effects of irrigation and the impact of climate change on vegetation diversity (Hersbach *et al.*, 2020) .

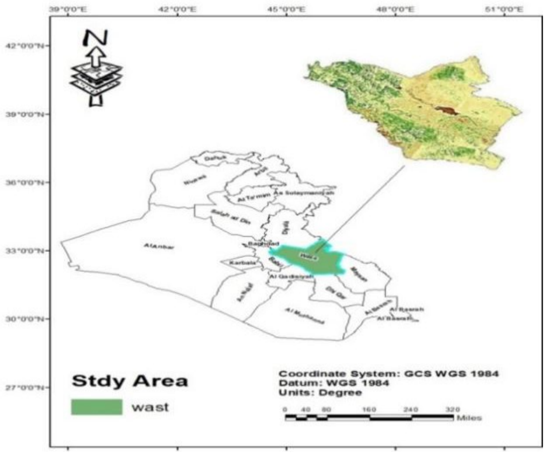


Fig. (1): Map of area studied.

Datasets and Methodology

The ERA5 model is the fifth and most recent generation of European reanalysis generation by the European Centre for Medium-range Weather Forecasts (ECMWF), and is a crucial component of the Copernicus Climate Change ServicesERA5 reanalysis combines in situ observation, satellite data and model forecasts in data assimilation techniques to provide a reliable description of the climate. The ERA5 model produces a 2 m air temperature. Furthermore, monthly ERA5 products of air temperature and total rainfall obtained from the Copernicus climatological data store. However, to investigate the impacts of climate change on various plant species, higher-resolution numerical models are required, and this research study continue to developed in this regard in the future. The model had a resolution of 0.25°× 0.25°, and covered the period from2020 to 2023 that represented reliable platforms such as and local meteorological stations in Wasit. These datasets will provide key insights into the climate conditions in the region (Hersbach *et al.*, 2020).

The analysis of seasonal variations based on NDVI and its response to climate variables in Wasit. This index exhibited as well-known metric for quantifying the health and density of vegetation using sensor data. It is calculate from spectrometric data at two specific bands: red and near infrared. The spectrometric data often sourced from remote sensors, such as satellites. Many studies used this index because of its accuracy. It has a high correlation with the true state of vegetation on the ground. The index is easy to assent: NDVI limit a value between (-1 and 1). An area with nothing growing in it will have an NDVI of zero. NDVI values less than 0 suggest a lack of dry land. An ocean will yield an NDVI of (-1). It calculated from satellite or drone imagery using the formula (1) (Naif *et al.*,2020):

$$NDVI = (NIR - RED) / (NIR + RED) \quad \dots \quad (1)$$

Where: NIR (Near-Infrared band (e.g. TM4) is strongly reflected by healthy vegetation, RED (Visible Red band (e.g.TM3) is absorbed by plants for photosynthesis

The seasonal NDVI for different vegetation types were modeled using two different climatic variables that air temperature and precipitation at time lags of 90 days (season). Climate Impact Analysis Correlation between Climate Variables and NDVI. Correlation analysis (e.g., Pearson or Spearman correlation) performed to quantify the relationship between NDVI values and climate variables (such as temperature and precipitation). That help determine how climate change factors influence seasonal changes in vegetation cover.

Wasit Governorate experiences a semi-arid climate, with annual rainfall rarely exceeding 200 mm, mostly during winter. This limited precipitation impacts water resources, soil quality, and agricultural activity. Rainfall in Iraq follows a seasonal pattern from October to May, peaking in January (Albw-jbianah & hmeesh , 2021) . The Quasi-Biennial Oscillation (QBO) also influences rainfall variability, with its westerly phase increasing precipitation in April and November, and the easterly phase enhancing it in December and January (Al-shamarti *et al.* , 2019).

The high air temperatures in the summer with the low amount of rainfall constitute a challenge for Wasit providence, and this situation has increased with the continuation of climate change. However, this does not prevent the existence of variations in air temperatures, as the average lowest air temperature reached 19°C in the year 2022 and the highest amount of rainfall in the year 2021 (0.001 mm), as shown in Table. 1.

Table (1): Time series for four major cities in Wasit for annual air temperature and precipitation.

Years	Air Temperature (ºC)	Precipitation (mm)
Al Kut Station		
2020	38.47169393	2.48969E-06
2021	19.16790161	0.001068062
2022	15.4475647	0.000846864
2023	31.74043172	6.42179E-05
Badra Station		
2020	37.5297994	1.72104E-06
2021	18.33456828	0.001471403
2022	13.87090454	0.001475747
2023	30.48912964	7.87372E-05
Al Hai Station		
2020	38.75408325	2.66354E-06
2021	19.45468547	0.001119735
2022	15.82809855	0.000602115
2023	32.27819214	3.3221E-05
Al Azizea Station		
2020	38.47169393	2.48969E-06
2021	19.16790161	0.001068062
2022	15.4475647	0.000846864
2023	31.74043172	6.42179E-05

Results & Discussion

3.1 Spatial annual distribution of NDVI for Wasit

The general distribution for annual NDVI for Waist. that divided into two parts, separated by Tigris River. First part located in south and southwest Wasit province that have relatively high NDVI (green shaded). It is scattered and not dense, and this is due to the abundance of water from the streams branching off from the Tigris River, as shown in figure 3. While second part that represented in the north and north east had less NDVI. In December 2020, a slight improvement in vegetation cover was observed, with more green patches appearing, likely due to the increase in water discharges from the Tigris River, which is the main artery that feeds the governorate, and the decrease in evaporation due to the drop in temperature with the presence of few rains showers this season. Despite this relative improvement in the southern part, the northern part still indicates a decrease in NDVI.

When compared these results with, the case of June 2021 shows a slight improvement in vegetation cover, with an increase in green patches, though most areas still exhibit low NDVI levels. Then by December 2021, green areas expand significantly compared to June, reflecting the influence of rainfall in enhancing vegetation density, though some regions remain barren or with sparse vegetation. In June 2022, the slight increase in NDVI continues, with some areas showing increased vegetation density, yet large parts of the region remain in the yellow and light brown range. The case of December 2022, there is a noticeable improvement in vegetation cover compared to previous years, with limited expanded green areas, potentially linked to better climatic conditions or increased rainfall.

June 2023 shows a more significant increase in average NDVI compared to previous years, with newly green-covered areas indicating a gradual improvement in vegetation. while December 2023, the highest NDVI levels were recorded compared to all previous years, with widespread green patches, indicating possible increases in agricultural productivity or improved environmental conditions. A similar pattern was observed in Baghdad, where a long-term NDVI analysis from 1988 to 2022 revealed a steady decline in dense vegetation cover, particularly in summer. The study linked this trend to increased temperatures and reduced rainfall, demonstrating the value of NDVI in assessing urban vegetation under climatic stress (Mahdi & Jasim , 2023) . These results indicate that some climatic factors are moving in a positive direction, leading to improved vegetation cover. However, the most important factors contributing to improved vegetation cover are modern water management and innovative agricultural policies. A study from Khanaqin District in Iraq showed that rising temperatures (from 12.29°C in 2019 to 25.97°C in 2022) and a sharp decline in rainfall (from 469.43 mm to 105.49 mm) resulted in a significant reduction in vegetation area, emphasizing the impact of climatic stress on vegetation loss (Khalaf , 2024).

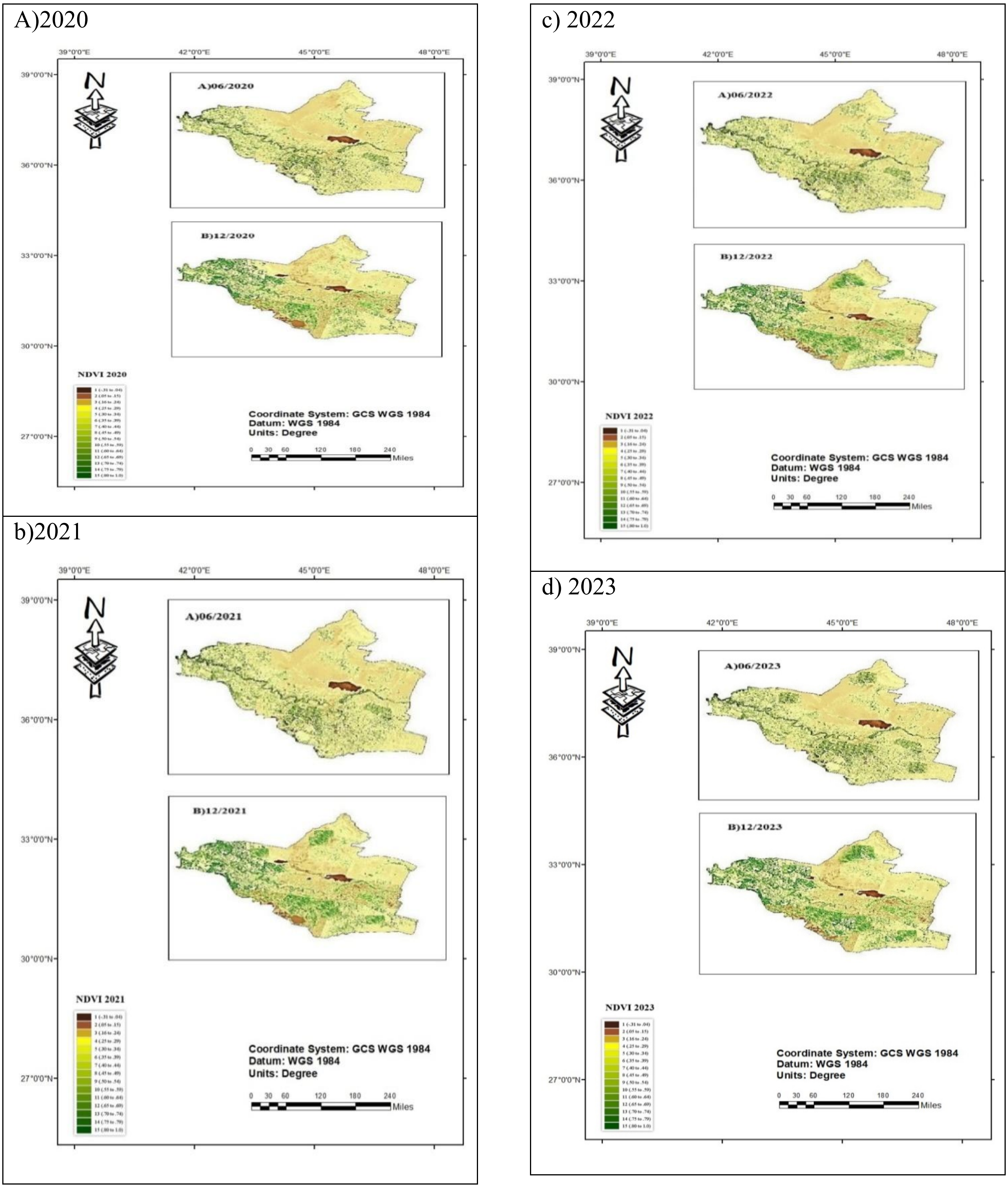
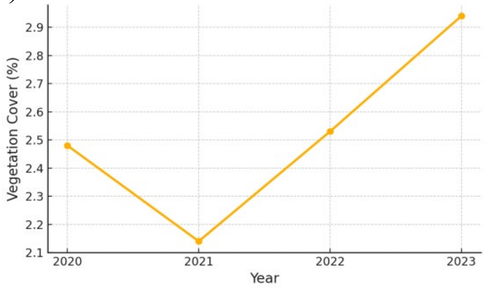


Fig. (2): Spatial variation of NDVI index in a) for (a) 2020, (b) 2021, (c) 2022, and (d) 2023 in Wasit.

Figure .3 analysis reveals a gradual increase in vegetation cover in the summer months (June), with relatively stable or slightly fluctuating cover in the winter months (December). The results indicate a growing trend in summer vegetation, likely due to improved climatic conditions or agricultural practices. However, winter vegetation remains constant, suggesting a less dynamic pattern during this period. This is significant result that climatic factors have less of an impact on the vegetation cover than the agricultural impact, especially irrigation, especially since the nature of the plants in that area is either natural evergreen plants or trees that are more than 2 meters high. This result also matches that although the lowest temperature was in 2022 and the vegetation cover was at its lowest value (figure 3a). on the other hand, the highest precipitation was in 2021, the vegetation cover did not record the highest value in the winter season (figure .3b).

a) Summer VC



b) Winter VC

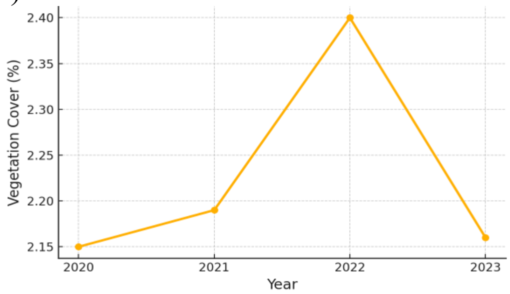


Fig. (3): Summer Vegetation Cover 2020–2023, a) Summer, b) winter

The interesting presentation of the previous result, that founding out in Table 2, which shows the percentages of NDVI practically for each year and season. The highest NDVI was (2.94%) in the summer of 2023, and despite it being a drought year, it constituted the highest value. Therefore, the seasonal variation does not provide a clear idea of the NDVI whereas the highest NDVI for the winter was (2.40 %) in 2021.

Table(2): seasonal NDVI for Vegetation Cover (%) in Wasit province.

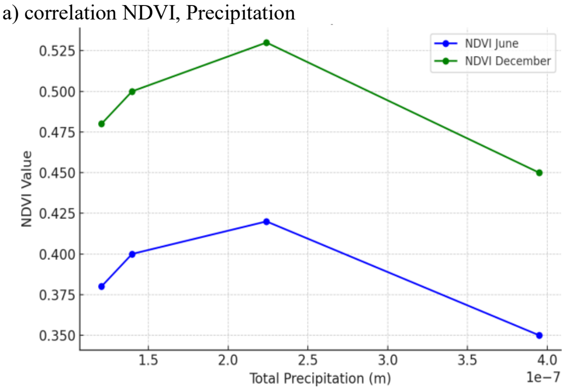
Year	Summer NDVI (%)	Winter NDVI (%)
2020	2.48	2.15
2021	2.14	2.19
2022	2.53	2.40
2023	2.94	2.16

Statistical Methods for Analysis NDVI

In order to verify the results obtained in the first section resorted to statistical methods. Three statistical methods used to achieve this purpose: correlation analysis, Linear Regression Analysis and NOVA.

The correlation analysis between NDVI and Precipitation was negative correlation (-0.60) tends to decrease with increasing precipitation for both winter and summer. In addition, these relationships shown very close behave with NDVI, especially they have same critical point at (2.25 mm). The case of correlation analysis between NDVI and air temperature weak correlation (0.06), that mean air temperature has little to no effect on NDVI, with same citric point (26.9 ºC), as shown in figure 4. These results due to a delayed response of vegetation to precipitation, and a because the VC depend on irrigation by irrigation from streams and rivers much more than depend on precipitation.

a) correlation NDVI, Precipitation



b) Correlation NDVI, Air temperture

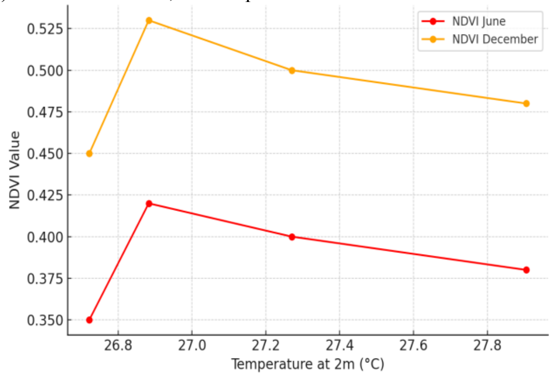
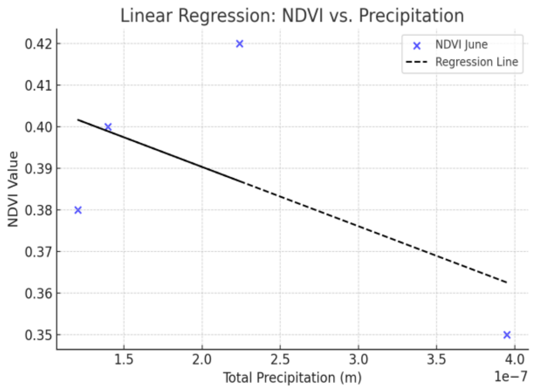


Fig.(4): Correlation analysis for Winter (December, and Summer (June) for Wasit (a) between NDVI and precipitation (m), (b) NDVI and Air Temperature (◦C) for 2020 – 2023. .

Linear regression performed to predict NDVI based on precipitation and air temperature that found out in figure 5: linear Regression Linear Regression Analysis between NDVI and Climate Variables. To further explore the influence of climatic factors on vegetation dynamics, simple linear regression models were constructed to quantify the relationship between NDVI and two key independent variables: precipitation, and air temperature. The objective was to determine the predictive power of each climatic factor on vegetation greenness as measured by NDVI, particularly during the summer season.



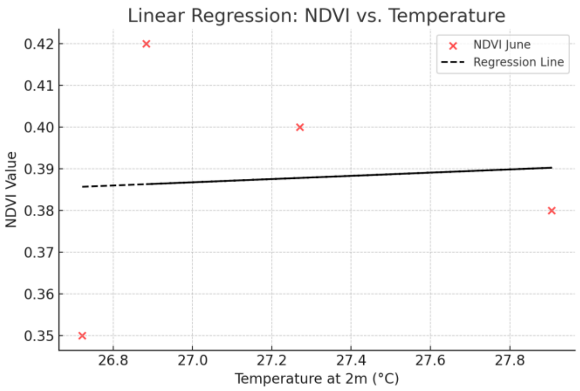


Fig.(5): Linear regression NDVI with Precipitation (left), (b) Linear regression: NDVI with Temperature (Right)

The regression analysis f NDVI with Precipitation revealed a moderate coefficient of determination ($R^2 = 0.356$), indicating that approximately 35.6% of the variability in NDVI could be explained by precipitation levels. However, the model's overall statistical significance was low, with a p-value of 0.403 (F-statistic = 1.106), suggesting that the relationship between NDVI and precipitation is not statistically significant at the 95% confidence level. Despite the negative slope coefficient (-1.426×10^5), which implies an inverse relationship between precipitation and NDVI, this result should be interpreted with caution. A possible explanation lies in the non-linear or delayed response of vegetation to rainfall, especially in arid regions like Wasit, where excessive or poorly distributed rainfall may lead to runoff or flooding, thereby limiting effective soil moisture absorption. The regression model for air temperature yielded an extremely low R^2 value of 0.005, indicating virtually no explanatory power. Furthermore, the p-value of 0.932 confirms the absence of a statistically significant relationship between temperature and NDVI during the summer period. These suggests that air temperature, within the observed range, is not a dominant factor controlling vegetation growth in this region, which aligns with previous studies in arid climates where vegetation is primarily water-limited rather than air temperature-limited. These findings align with a large-scale study in the Yarlung Zangbo River Basin, which showed that a 1.5°C increase in temperature caused a 1.60–4.68% increase in NDVI, whereas a 10% increase in precipitation only caused a 0.06–0.24% change. This suggests that temperature influences vegetation growth more significantly than precipitation in certain climates, though the response varies by region and vegetation type (Cui *et al.*, 2022). A related study in Basra found that dense vegetation cover declined from 4.8% in 1990 to 1.0% in 2024, while land surface temperatures increased significantly. This supports the observation that higher temperatures often correspond with vegetation loss, especially in arid regions (Al-Bahadli , *et al.*, 2025).

Interpretation and Implications for Linear regression. These findings support the hypothesis that precipitation plays a more influential, albeit complex, role in determining vegetation cover compared to temperature in semi-arid environments. However, the low sample size (n = 4 years) limits the robustness and generalizability of the regression outcomes. It is therefore recommended to: Expand the temporal scope of the study to include more years of data. Employ non-linear or multivariate models (e.g., polynomial regression or machine learning algorithms) to capture the potential delayed or threshold-based vegetation responses. Incorporate additional variables such as soil moisture, evapotranspiration, land use change, and irrigation patterns for a more comprehensive analysis. Table 3.

Relationship	R^2 Value	P-Value	Interpretation
NDVI vs Precipitation	0.356	0.403	Not significant, moderate negative correlation
NDVI vs Temperature	0.005	0.932	Very weak and non-significant relationship

The interpretation of ANOVA used as statistically verify whether the observed changes in vegetation cover (NDVI). across the years are significant, a one-way Analysis of Variance (ANOVA) test was conducted for the NDVI values from 2020 to 2023. The test yielded an F-statistic of 20.75 with a corresponding p-value of 0.0039, which is well below the standard significance level ($\alpha = 0.05$). These results indicate that there is a statistically significant difference in NDVI values between the years studied, confirming that the changes in vegetation cover are not due to random variation. This result is consistent with prior assessments conducted in southern Oman, where NDVI-based analysis from 2015 to 2021 identified statistically significant seasonal and spatial shifts in vegetation linked to climate variability. The study emphasized the utility of NDVI and regression models in long-term environmental monitoring (Al-Kindi *et al.*, 2023). The consistent upward trend in NDVI, especially in December of each year, supports the hypothesis that environmental conditions or agricultural practices have gradually improved over time.

Forecasting and visualization of NDVI Time Series

Drought is a recurring and periodic climate phenomenon that occurs because of rainfall falling below its average for a long or short period. This leads to a decrease for water running in rivers. This leads to a decrease in water in drains, a decrease in soil moisture, and a decline in vegetation cover and agricultural land. What concerns us about the concept of drought is the climate changes that have occurred in recent years, which have had a significant and effective impact on our study. Climate changes result from a water deficit caused by evaporation rates on the amount of rainfall, leaving insufficient moisture for the growth of agricultural crops and food production. The resulting consequences are usually a general deterioration of the ecosystem, leading to drought and desertification due to insufficient production to meet demand. Rainfall is insufficient to sustain agricultural activity. To prove

Currently, Annual ARIMA based NDVI forecast is implemented using MODIS NDVI time series pixel drilling. A time-series model (ARIMA) was used to forecast NDVI for the upcoming for two years. The results shown in figure. 5 that forecasting value for NDVI for 2024 was (0.442), while the forecasting value NDVI for 2025 was (0.463). The trend suggests a slight increase in NDVI over the next two years. This result was compatible with the studied for forecasting over India.

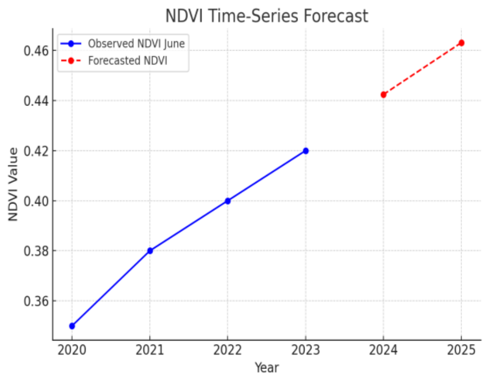


Fig. (6): NDVI Time-Series Forecast:

Conclusions

The spatial distribution for annual NDVI for Wasit divided into two parts, separated by Tigris River. South and southwest Wasit province that have relatively high NDVI, while the north part shown low percentage of NDVI. In December 2020, a slight improvement in vegetation cover was observed, likely due to the increase in water discharges from the Tigris River. The highest NDVI was (2.94%) in the summer of 2023, and despite it being a drought year. Therefore, the seasonal variation does not provide a clear idea of the NDVI whereas the highest NDVI for the winter was (2.40 %) in 2021. Similar findings were observed in Thi-Qar Governorate, where vegetation cover dropped by nearly 80% from 1990 to 2022 due to decreased rainfall and increasing desertification, reinforcing the critical need for adaptive resource management strategies in southern Iraq (Al-saad *et al.*, 2023).

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Conflicts of interest

The authors declare that there is no conflict of interest related to this research work, in accordance with the requirements and standards of academic publishing.

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تقييم التغيرات الموسمية في الغطاء النباتي باستخدام مؤشر NDVI في سياق التغير المناخي في واسط

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المستخلص: تهدف هذه الدراسة إلى تقييم وتحليل التغيرات السنوية والفصلية في مؤشر الفرق المعياري للنباتات (NDVI) في محافظة واسط، العراق، خلال الفترة من 2020 إلى 2023. يُعدّ التغير في الغطاء النباتي مؤشرًا حيويًا لتأثيرات التغير المناخي على النظم البيئية والإنتاج الزراعي. استخدمت الدراسة بيانات NDVI المستمدة من الأقمار الصناعية إلى جانب بيانات مناخية للكشف عن التغيرات المكانية والزمانية في المنطقة. تقسّم نهر دجلة محافظة واسط إلى منطقتين: الجزء الجنوبي والجنوبي الغربي أظهرا قيماً أعلى لـ NDVI بسبب وفرة المياه القادمة من فروع النهر، بينما سجل الجزء الشمالي والشمالي الشرقي قيماً أقل. وُثق تحسن طفيف في الغطاء النباتي في كانون الاول 2020، يُعزى على الأرجح إلى زيادة تصريف المياه من نهر دجلة. أظهرت النتائج زيادة تدريجية في NDVI خلال فترة الدراسة، وسُجلت أعلى قيمة في صيف عام 2023 (2.94%)، مما يعكس الدور الكبير للري والممارسات الزراعية الحديثة في تعزيز الغطاء النباتي، متجاوزًا تأثير العوامل المناخية. لوحظت أيضًا فروقات موسمية، إذ تجاوزت قيم NDVI في الصيف نظيراتها في الشتاء، مع تسجيل أعلى NDVI شتوي عام 2021 (2.40%). استخدمت الدراسة ثلاث طرق إحصائية: تحليل الارتباط، والانحدار الخطي، واختبار التباين (ANOVA). أظهرت النتائج وجود علاقة سلبية ضعيفة بين NDVI والهطول المطري ($r = -0.60$)، وعلاقة شبه معدومة مع درجة حرارة الهواء ($r = 0.06$). وأكد اختبار ANOVA وجود فروقات معنوية بين السنوات ($p = 0.0039$)، مما يشير إلى تغيّرات حقيقية في الغطاء النباتي. وأظهر التنبؤ باستخدام نموذج ARIMA استمرار الزيادة الطفيفة في NDVI خلال عامي 2024 (0.442) و2025 (0.463)، مما يعكس استجابة إيجابية للغطاء النباتي ناجمة عن تحسين إدارة الموارد المائية والممارسات الزراعية، أكثر من كونها نتيجة لتحسن مناخي مباشر.

الكلمات المفتاحية: NDVI، التغير المناخي، نظم المعلومات الجغرافية .