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Correlation analysis of NDVI with remote sensing-based vegetation indices for sesame crop monitoring

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Abstract

Accurate assessment of crop growth using remote sensing is crucial for precision agriculture and sustainable crop management. The Normalized Difference Vegetation Index (NDVI) is widely used to assess vegetation vigor; however, its effectiveness can vary depending on soil background, canopy structure, and crop growth stage. In the present study, NDVI was correlated with several remote sensing-based vegetation indices, including the Soil Adjusted Vegetation Index (SAVI), Enhanced Vegetation Index (EVI), Leaf Area Index (LAI), Difference Vegetation Index (DVI), Green Difference Vegetation Index (GDVI), Transformed Difference Vegetation Index (TDVI), and Renormalized Difference Vegetation Index (RDVI), to evaluate their suitability for monitoring sesame crop growth.

Regression analysis revealed positive relationships between NDVI and all selected vegetation indices, with coefficients of determination (R^2) ranging from 0.580 to 0.845. The strongest correlation was observed between NDVI and DVI ($R^2 = 0.845$), followed closely by EVI ($R^2 = 0.841$) and SAVI ($R^2 = 0.802$), indicating their high sensitivity to vegetation vigor and biomass. LAI also showed a strong association with NDVI ($R^2 = 0.788$), supporting the use of NDVI as a reliable indicator of leaf area development in sesame. Moderate to strong correlations were recorded for GDVI ($R^2 = 0.748$) and TDVI ($R^2 = 0.745$), whereas the weakest relationship was observed with RDVI ($R^2 = 0.580$).

Keywords: Correlation analysis, NDVI, precision agriculture, remote sensing, sesame crop, vegetation indices

1. Introduction

Vegetation indices derived from satellite remote sensing data play a vital role in monitoring crop growth, assessing vegetation health, and estimating biophysical parameters. Among these indices, the Normalized Difference Vegetation Index (NDVI) is extensively used due to its simplicity and effectiveness in capturing vegetation greenness and biomass. NDVI is sensitive to chlorophyll content and canopy structure, making it suitable for crop growth monitoring over large areas. NDVI is influenced by soil background effects and saturation at high biomass levels, particularly during peak vegetative growth. To overcome these limitations, several alternative vegetation indices such as SAVI, EVI, LAI, DVI, GDVI, TDVI, and RDVI have been developed. Each index incorporates different mathematical formulations to account for soil reflectance, atmospheric effects, and canopy density.

Correlation analysis between NDVI and other vegetation indices provides insight into their mutual relationships and helps identify indices that respond similarly to crop growth dynamics. Such analysis is crucial for selecting suitable indices for crop-specific monitoring, minimizing redundancy, and enhancing the interpretation of remote sensing data. This study focuses on evaluating the correlation between NDVI and multiple remote sensing-based vegetation indices for the sesame crop grown under summer season conditions.

1.1 Objectives of the study

1. To evaluate the relationship between NDVI and other remote sensing-based vegetation indices (SAVI, EVI, LAI, DVI, GDVI, TDVI, and RDVI) for the sesame crop.
2. To identify the most suitable vegetation indices correlated with NDVI for monitoring the sesame crop condition.

2. Materials and Methods

2.1 Study area

The experiment was conducted at the Instructional Farm, College of Agricultural Engineering and Technology, Junagadh

Agricultural University, Junagadh (Fig.1). The latitude and longitude of the study area are 21°28'59.19" N to 21°29'02.54" N (North latitude) and 70°26'09.83" E to 70°26'10.45" E (East longitude).



Fig 1: Location map of the study area

2.2 Data Collection and Software Used

Remote sensing analysis was performed using Sentinel-2A satellite imagery and QGIS 3.16 to derive NDVI and other vegetation indices. Index values were extracted from the study

area for different growth stages and used to develop scatter plots and linear regression models. Correlation analysis was performed using the coefficient of determination (R^2) to assess the relationships among vegetation indices.

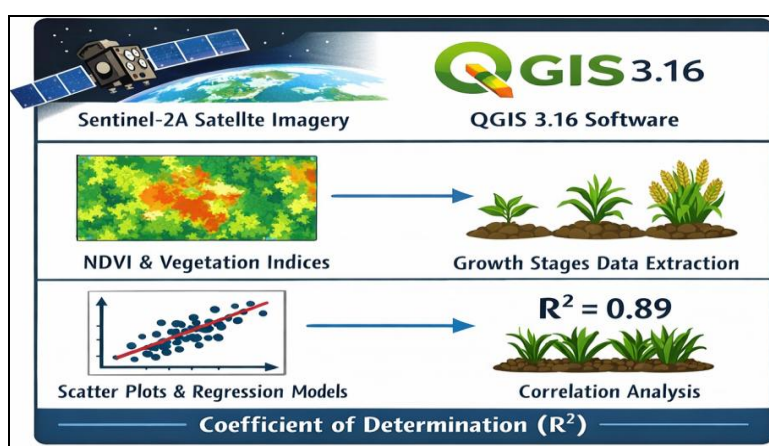


Fig 2: Software Framework for Data Analysis

Normalized Difference Vegetation Index (NDVI)

“The NDVI, introduced in 1974 by Rouse and colleagues, was computed according to the following expression:”

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

“In vegetation, chlorophyll absorbs radiation mainly in the visible wavelengths, while high reflectance in the near-infrared region is influenced by leaf structure and water content. Therefore, NDVI is widely correlated with different vegetation parameters, including biomass, productivity, and canopy quantity.”

NDVI ranges from -1 to +1, with +1 indicating healthy vegetation cover, lower values representing stressed vegetation, negative values representing open water or high moisture content, and a 0.1 value, indicating bare soil.

2.3 Soil adjusted vegetation index (SAVI)

The soil-adjusted vegetation index (SAVI) is a vegetation index that accounts for and minimizes the effect of soil background conditions. SAVI is a means of monitoring the density and

vigour of green vegetation growth using the spectral reflectivity of solar radiation. SAVI was computed by using the following formula (Huete, 1988) ^[5]

$$SAVI = \frac{(NIR - R)(1 + L)}{NIR + R + L} \quad (2)$$

Where L is the correction factor whose values range from 0 (high vegetation cover) to 1 (low vegetation). The value of L = 0.5 was used in this study. The index had been designed to correct high soil reflectance in arid regions. Its value ranges between 0 (a very high vegetation cover) to 1 (a very low vegetation cover).

2.4 Enhanced Vegetation Index (EVI)

“The Enhanced Vegetation Index (EVI) is an advanced vegetation indicator that, like NDVI, is used for quantifying vegetation greenness (Huete *et al.*, 2002) ^[4]. It was developed to improve sensitivity in dense vegetation and enhance monitoring accuracy by reducing atmospheric effects and decoupling background canopy effects. EVI was computed using the equation suggested by Hatfield and Prueger (2010) ^[3].

$$EVI = G \times \frac{(NIR - R)}{(NIR + C1 \cdot R - C2 \cdot B + L)} \quad (3)$$

The EVI includes an 'L' factor to account for canopy background effects, along with 'C' coefficients that correct for atmospheric resistance, and incorporates information from the blue band (B). These improvements enable the index to be calculated as a ratio of red (R) and near-infrared (NIR) reflectance while minimizing background interference, atmospheric noise, and saturation issues. For vegetation pixels, EVI values generally vary between 0 and 1."

2.5 Leaf Area Index (LAI)

The index is used for quantifying leaf area index, nitrogen concentration, and photosynthetic efficiency in agriculture. This index is used to estimate foliage cover and to forecast crop growth and yield. LAI is computed using the following formula (Boegg et al. 2002) [2]:

$$LAI = (3.618 \cdot EVI - 0.118) \quad (4)$$

LAI values typically range from approximately 0 to 3.5. However, when the scene contains clouds and other bright features that produce saturated pixels, the LAI values can exceed 3.5. Ideally, clouds and bright features are masked out from the scene before creating an LAI image.

2.6 Difference Vegetation Index (DVI)

This index utilizes linear combinations of the red and photographic infrared bands for vegetation monitoring. It is capable of differentiating vegetation from soil; however, it does not consider variations between reflectance and radiance resulting from atmospheric conditions or shadow effects. The Difference Vegetation Index (DVI) was calculated using the empirical equation proposed by Tucker (1979) [11]."

$$DVI = NIR - RED \quad (5)$$

This index indicates the presence of healthy green vegetation. However, under dense canopy conditions, it may saturate when the leaf area index (LAI) is high. The index values vary between -1 and 1, with typical green vegetation generally falling within the range of 0.2 to 0.8.

2.7 Green Difference Vegetation Index (GDVI)

This index uses the aerial colour-infrared photography for determining in-season nitrogen requirements of corn. This index was initially developed using colour-infrared photography to estimate the nitrogen requirement of corn. GDVI was computed

by using the following formula (Sripada et al., 2006) [10]:

$$GDVI = NIR - Green \quad (6)$$

One of the primary shortcomings of the NDVI is that it is sensitive to atmospheric interference, soil reflectance, cloud cover, and canopy shadows. Indices have thus been developed that help address some of these shortcomings.

2.8 Transformed Difference Vegetation Index (TDVI)

The index is particularly useful for assessing vegetation cover in urban environments. It avoids saturation issues observed in NDVI and SAVI and exhibits excellent linear behavior in response to variations in vegetation cover. TDVI is computed by using the following formula (Bannari et al. 2002) [1]:

$$TDVI = 1.5 \times \frac{(NIR - Red)}{(NIR^2 + Red + 0.5)} \quad (7)$$

2.9 Renormalized Difference Vegetation Index (RDVI)

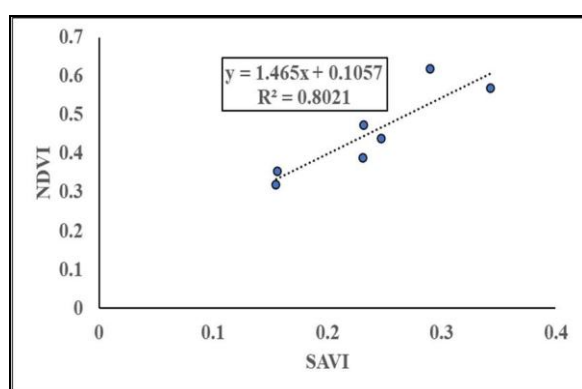
This index measures the PAR absorbed by vegetation from bidirectional reflectance measurements. The index highlights healthy vegetation using the difference between red and near-infrared bands together with NDVI, and it shows minimal sensitivity to soil effects and sun viewing geometry. RDVI is computed by using the following formula (Roujean and Breon, 1995) [8]:

$$RDVI = \frac{NIR - Red}{\sqrt{NIR \cdot Red}} \quad (8)$$

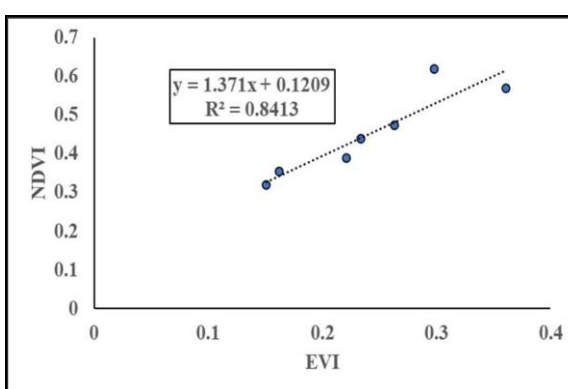
3. Results and Discussion

3.1 Correlation between NDVI and Remote Sensing-based Vegetation Indices

The collected data were analyzed using a regression model to examine the correlation between different variables (Parmar and Gontia, 2019 [7]. The Normalized Difference Vegetation Index (NDVI) was analyzed in relation to other remote sensing-based vegetation indices such as SAVI, EVI, LAI, DVI, GDVI, TDVI, and RDVI to evaluate crop growth and vegetation conditions. Examining the correlation among these indices helps determine which indicators best represent canopy structure and moisture status. Earlier research has also indicated that NDVI shows consistent relationships with several vegetation indices, making it a useful parameter for assessing crop health and aiding irrigation management decisions (Parmar & Gontia, 2016; Rouse et al., 1974) [6].



(a) NDVI and SAVI



(b) NDVI and EVI

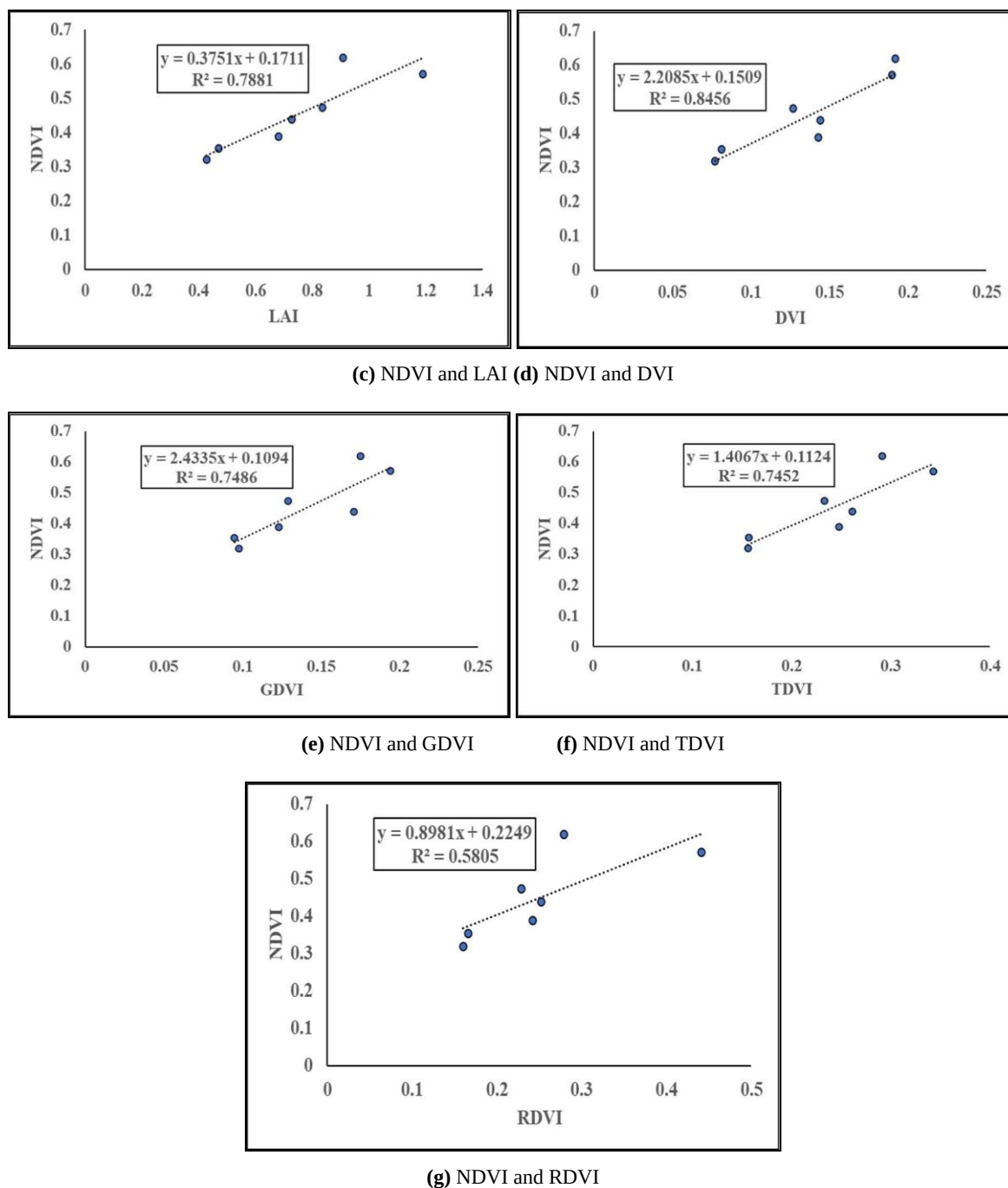


Fig 3: Relationship of NDVI with SAVI, EVI, LAI, DVI, GDVI, TDVI and RDVI

Table 1: Coefficient of determination (R^2) values between NDVI and Remote Sensing Vegetation Indices for the Sesame crop

Sr. No.	Relationship of NDVI (y) with vegetation indices (x)	Relationship	R ²
1	SAVI	$y = 1.465x + 0.1057$	0.802
2	EVI	$y = 1.371x + 0.1209$	0.841
3	LAI	$y = 0.3751x + 0.1711$	0.788
4	DVI	$y = 2.2085x + 0.1509$	0.845
5	GDVI	$y = 2.4335x + 0.1094$	0.748
6	TDVI	$y = 1.4067x + 0.1124$	0.745
7	RDVI	$y = 0.8981x + 0.2249$	0.580

Fig. shows the correlation of NDVI with Remote Sensing Vegetation Indices SAVI, EVI, LAI, DVI, GDVI, TDVI, and RDVI, respectively, where y indicates NDVI, and the x-axis indicates remote sensing vegetation indices.

3.2 Interpretation of Correlation Results

Table 1. shows the coefficient of determination (R^2) values

ranged from 0.580 to 0.845, indicating moderate to strong correlations between NDVI and other vegetation indices.

- The highest correlation ($R^2 = 0.845$) was observed between NDVI and DVI, suggesting that DVI responds similarly to changes in vegetation biomass and canopy density.
- EVI ($R^2 = 0.841$) and SAVI ($R^2 = 0.802$) also showed strong relationships with NDVI, highlighting their

effectiveness in representing vegetation vigor while accounting for soil and atmospheric influences.

- LAI ($R^2 = 0.788$) exhibited a strong correlation, confirming that NDVI is a reliable proxy for leaf area development in the sesame crop.
- GDVI ($R^2 = 0.748$) and TDVI ($R^2 = 0.745$) showed moderate to strong correlations, indicating their sensitivity to green biomass.
- Lowest correlation ($R^2 = 0.580$) was found between NDVI and RDVI, possibly due to differences in mathematical transformation and sensitivity at higher biomass levels.

4. Conclusion

The correlation analysis indicated that NDVI exhibited moderate to strong relationships with all selected vegetation indices used for monitoring sesame crop growth. Among them, DVI, EVI, and SAVI showed the strongest associations with NDVI, highlighting their effectiveness in capturing variations in vegetation biomass and canopy condition. LAI also demonstrated a strong relationship, supporting the reliability of NDVI as an indicator of leaf area development. Although GDVI and TDVI exhibited comparatively lower correlations, they were still responsive to changes in green biomass. RDVI showed the weakest association with NDVI, which may be attributed to its reduced sensitivity at higher biomass levels. Overall, the consistent positive relationships observed across all vegetation indices confirm that NDVI is a robust and dependable index for assessing sesame crop growth and overall crop condition.

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