



ISSN: 0067-2904

Modified Vegetation Detection Index Using Different-Spectral Signature

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Received: 24/3/2021

Accepted: 11/6/2021

Abstract

The Normalization Difference Vegetation Index (NDVI), for many years, was widely used in remote sensing for the detection of vegetation land cover. This index uses red channel radiances (i.e., 0.66 μm reflectance) and near-IR channel (i.e., 0.86 μm reflectance). In the heavy chlorophyll absorption area, the red channel is located, while in the high reflectance plateau of vegetation canopies, the Near-IR channel is situated. Senses of channels (Red & Near- IR) read variance depths over vegetation canopies. In the present study, a further index for vegetation identification is proposed. The normalized difference vegetation shortwave index (NDVSI) is defined as the difference between the cubic bands of Near- IR and Shortwave infrared radiation (SWIR) divided by their sums. The radiances or reflectances are included in this index from the Near-IR channel and WSIR2 channel (2.1 μm). The NDVSI is less sensitive to atmospheric effects as compared to NDVI. By comparing the one NDVSI index with the two indexes (NDVI, SAVI) of vegetation cover, good correlations were found between NDVI and NDVSI ($R^2=0.917$) and between SAVI and NDVSI ($R^2=0.809$). Accordingly, the proposed index can be taken into consideration as an independent vegetation index

Keywords: vegetation index; NDVI; reflectance spectrum; remote sensing.

مؤشر كشف الغطاء النباتي المعدل باستخدام البصمة الطيفية

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الخلاصة

تم استخدام مؤشر الغطاء النباتي (NDVI) على نطاق واسع لاستشعار الغطاء النباتي عن بُعد لسنوات عديدة. يستخدم هذا المؤشر إشعاع القناة الحمراء (أي انعكاسات تبلغ حوالي 0.66 مايكرومتر) وقناة بالقرب من الأشعة تحت الحمراء (أي حوالي 0.86 مايكرومتر) تقع القناة الحمراء في منطقة امتصاص الكلوروفيل القوية، بينما تقع القناة القريبة من الأشعة تحت الحمراء في هضبة الانعكاس العالي لمظلات الغطاء النباتي، تستشعر القناتان (الحمراء و الأشعة تحت الحمراء) أعماق مختلفة جدًا من خلال مظلات الغطاء النباتي. في هذه المقالة، تم اقتراح مؤشر آخر للكشف عن الغطاء النباتي. يُعرّف مؤشر الموجة القصيرة للغطاء النباتي (NDVSI) على أنه الفرق بين النطاقات المكعبة (NIR)³ و (SWIR) مقسومًا على مجموعها. يستخدم هذا المؤشر إشعاعات أو انعكاسات من قناة قريبة من الأشعة تحت الحمراء وقناة WSIR2 (أي حوالي 2.1

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مايكرومتر). NDVI أقل حساسية للتأثيرات الجوية من NDVI، بمقارنة مؤشر NDVI مع المؤشرين (NDVI و SAVI) للغطاء النباتي، تم العثور على ارتباط جيد بين (مؤشر NDV ومؤشر NDVI)؛ أي ان معامل الارتباط ($R^2=0.917$) ونتيجة العلاقة بين مؤشر SAVI ومؤشر NDVI ($R^2=0.809$). يمكن اعتبار NDVI كمؤشر مستقل إلى جانب NDVI التقليدي.

1. Introduction

The physical properties of soil, water, and vegetation in terrestrial environments are revealed by the spectral structure of radiant flux emitted from the Earth's surface [1]. Remote sensing techniques, models, and indices are used to convert spectral data into a system that can be easily understood [2]. From the spectral vegetation curve, it is found the reflectance in the visible bands is relatively poor, as the leaf pigments absorb the majority of light [3]. The blue and red wavelengths of chlorophyll strongly absorb energy and reflect greenish wavelengths. Due to the cellular structure of the leaves and the particular spongy mesophyll, the reflectivity in the near-infrared (NIR) band is higher as compared to the visible band. For that reason, the vigorous vegetation is green. The high NIR reflectance and generally low visible reflectance can therefore readily distinguish healthy vegetation, whereas the reflectance of the infrared wavelengths of the shortwave is associated with water content and structural vegetation. Water shows absorption bands of 1.45, 1.95, and 2.50 μm . The reflectivity of leaves usually rises beyond these absorption bands, in the SWIR band, as the water content in the leaf decreases, which is shown in Figure (1) [3,4,5].

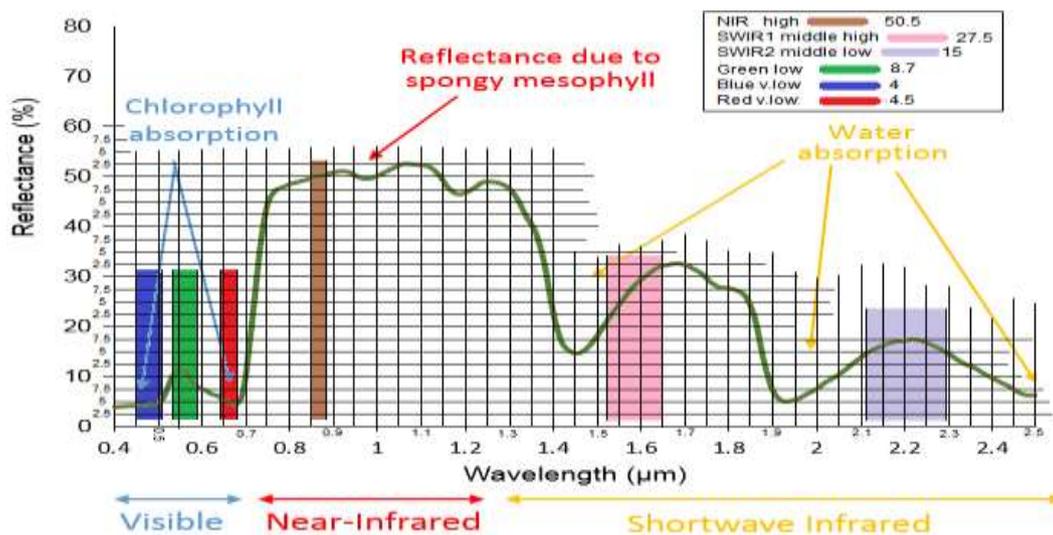


Figure 1- The spectral vegetation curve

In the past two decades, the Normalized Difference Vegetation Index (NDVI) has been the most commonly used index for vegetation remote sensing. It is equivalent to $(\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$, in which RED represents the red channel radiance, nearly 0.66 μm , and NIR represents the radiance of a near-IR channel, nearly 0.86 μm (in reflectance units) [6]. Due to high chlorophyll levels absorption of plant tissues in red and high reflectance in NIR, the two bands contain a lot of information about vegetation. One of the most popular indicators used is the soil-adjusted vegetation index (SAVI), which is a vegetation index that seeks for decreasing the influences on bright soil by means of soil-brightness correction factor. It is frequently utilized in arid areas in which vegetation coverage is decreased. $\text{SAVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red} + L) \times (1 + L)$; the L value varies: $L=1$ for uncovered green vegetation zones; $L=0.5$ for modest green vegetation zones; and $L=0$ for lot of green vegetation zones [7,8]. On the other hand, some scientists tried to focus on the characteristics of the absorption of the red band, while overlooking the simply saturated characteristic and

usage of blue and green groups [9]. Although the blue channel has vegetation reflectance behavior similar to the red band, it has rarely been used in remote sensing as a vegetation indicator. The same applies to the green band, even though numerous researches have shown that it is better related to vegetation constraints [10]. The information obtained from vegetation indices varies due to spectrally similar features. Although many different VIs have been formulated, most are sensitive to atmospheric influences. The present work aims to try replacing the Red NDVI band into a band other than the green and blue bands. This band (SWIR2, around 2.1 μm) is employed to create a state-of-the-art vegetation index, called here the Normalized Difference Vegetation Shortwave Index (NDVSI), which can be defined as the difference between normalized cubic bands (NIR^3) and (SWIR^3) divided by their sums. In addition, we compare the proposed NDVSI index with two commonly used indexes (NDVI and SAVI).

1.1 Related work

In this section we review some of the studies in which the WSIR band is used to detect the vegetation.

Huo *et al.* (2021) proposed the Normalized Distance Red & SWIR (NDRS) index based on the linear relationship between the red and SWIR bands to early detect forest stress. This index identified stressed forests with accuracies from 0.80 to 0.91. These accuracies are high compared to the NDVI and other indices [11].

Özbay *et al.* (2017) developed a vegetation index algorithms using reflectance/radiance data in the VNIR (Visible Near Infrared) band using the hyperspectral images and SWIR (Short Wave Infrared) band for the purpose of vegetation detection. The effectiveness and accuracy of the proposed method were tested on hyperspectral data taken from different places on different dates of the year. Test results showed that vegetation regions in hyperspectral images can be detected successfully [12].

1.2 Problem Statement

Variation of the information obtained from vegetation indicators still remains a challenge especially in heterogeneously covered and rural areas, such as the study area, due to spectrally similar features.

1.2 Satellite Imagery Acquisition

In our work, Landsat-8 satellite images were used due to their low cost, particularly for the direction covered. Another advantage of Landsat 8 images is ownership, which enables academia and donor and federal agencies to exchange information legally. Two satellite images that have the date of 18/02/2017 were analysed. The images were taken during the same season (summer season), were not highly affected by the atmosphere (scattering and absorption), and were clouds free. The images were collected from the database of USGS Earth Explorer [13,14, 15], as shown in Figure (2).



Figure 2-The database of USGS Earth Explorer

1.3 Study area

The area of the present study is set in Baghdad, with considerable parts in Abu Ghraib and Yusufiya regions. It is located within the coordinates of Lat:33°18'34'' N, Lon:44°04'02''E, as shown in Figure (3).

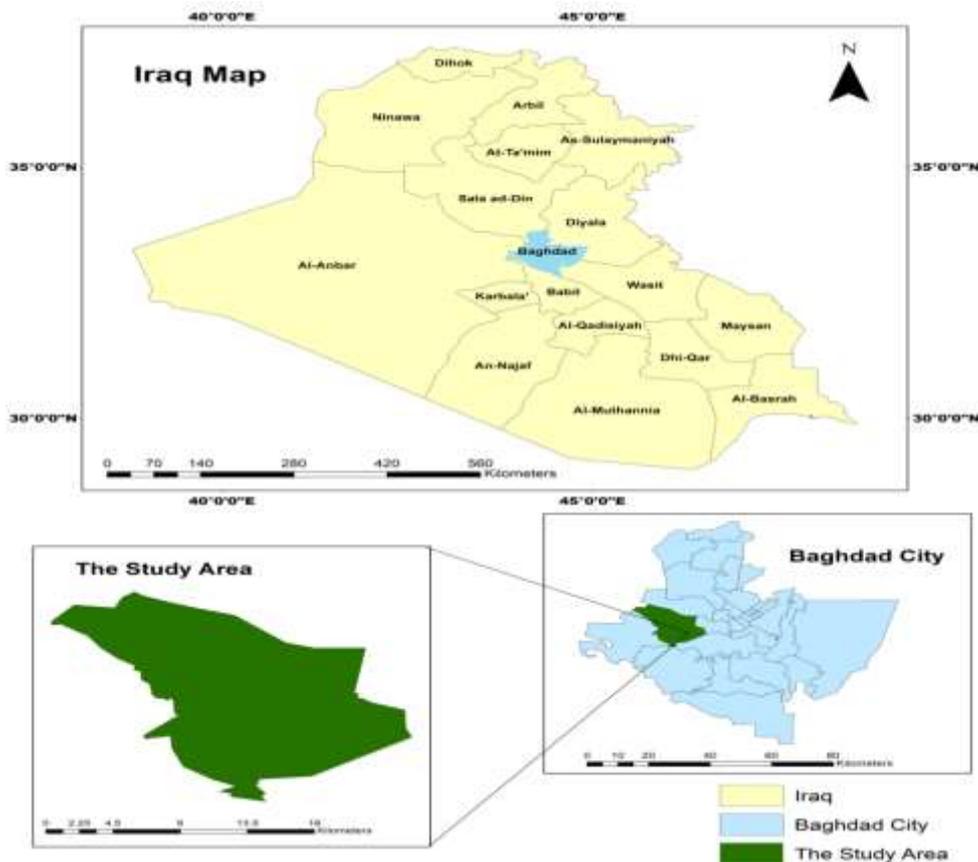


Figure 3-The study area

2. Methodology

One of the furthestmost significant biophysical indicators of soil attrition is the vegetation coverage. This can be calculated by means of vegetation categories resulting from the images of satellite [16]. Hyperspectral vegetation analysis is still focused on multi-spectral indices used as reference data or contemporary data. In this research, different classes of vegetation indices that were applied to the study area have been selected due to the dominance of its vegetation cover. The measured indexes are: (1) the conventional ratio index because it is the most conventional used index [17, 18]; (2) the corrected and modified conventional indices, such as the SAVI index; and (3) the proposed indicator NDVSI. The three determined indexes are determined using the following equations:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad \text{where } (0 < NDV < 1) \quad (1)$$

NDVI less than or equal to 0.1 refers to barren areas of rock, sand, or snow. Reasonable amounts are expressed by shrubs and grassland (0.2 - 0.3), whereas temperate and tropical rainforests are indicated by high value (0.6 - 0.8). The bare ground is symbolized by NDVI values that are near to zero, and water bodies are represented by negative NDVI values [16,19].

$$SAVI = \frac{(NIR - RED)}{(NIR + RED + L)} * (1 + L) \quad \text{where } L = 0.5 \quad (2)$$

$$NDVSI = \frac{(NIR)^3 - (SWIR2)^3}{(NIR)^3 + (SWIR2)^3} \quad \text{where } (0 < NDVSI < 1) \quad (3)$$

This formula was determined as a result of shortwave infrared spectral reflectance examination using the NDVI index equation as a criterion for determining vegetation cover, as shown in Table 1.

Table 1-The shortwave infrared spectral reflectance examination

Band	NIR	SWIR1	Index=(Bi) ⁿ -(Bj) ⁿ /(Bi) ⁿ +(Bj) ⁿ		
			Linear	Square	Triple
Reflectance	50.5	27.5	0.294872	0.542568	0.721938
Band	NIR	SWIR2	Index=(Bi) ⁿ -(Bj) ⁿ /(Bi) ⁿ +(Bj) ⁿ		
			Linear	Square	Triple
Reflectance	50.5	15	0.541	0.837	0.948

3. Results and Discussion

This part focuses on the comparisons between the vegetation indexes in the ability to detect the vegetation.

3.1 Results

The determined linear correlation coefficients between NDVI index values (as a reference for vegetation detection) and the vegetation indexes values were determined using Landsat-8 satellite image (Dated (18/2/2017), Path169, Row 37 and the Coordinates system UTM_ zone 38N, Top=3789615, Left=245985, Right=478515, and Bottom=3553185) for the selected study area (see Figures 4, 5 and 6).

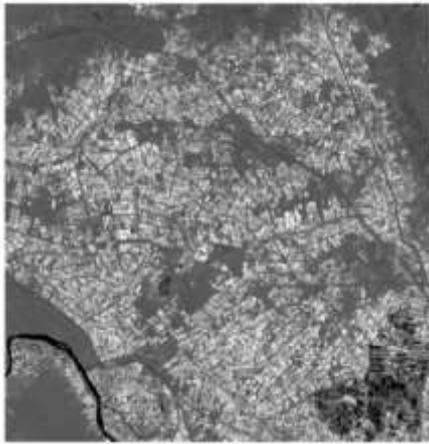


Figure 4-The vegetation cover uses the NDVI index SAVI index

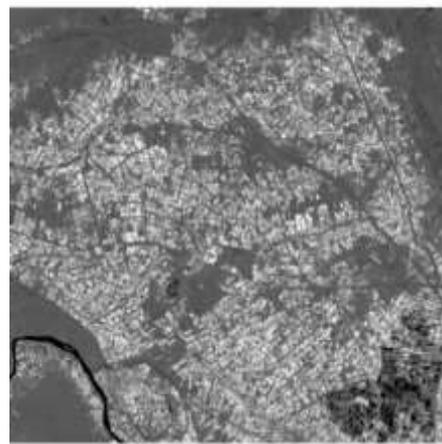


Figure 5-The vegetation cover use

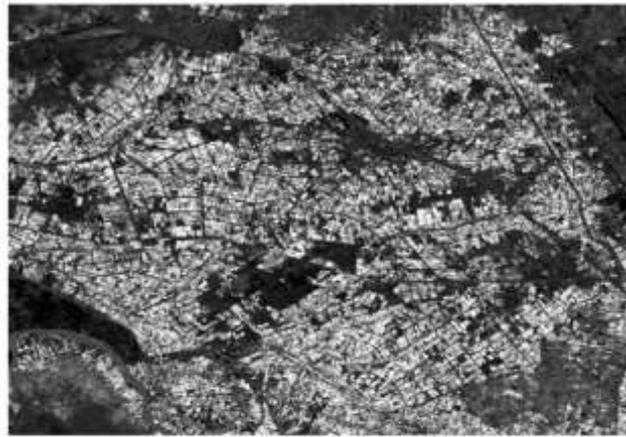


Figure 6 - The vegetation cover use NDVSI index

3.2 Relationship between NDVI index and SAVI index

The indexes NDVI and SAVI are among the most used indicators of vegetation cover worldwide. They were compared to assess their ability to detect vegetation cover [20, 21, 22]. Table 2 shows the range of vegetation (NDVI) for different land cover classes. In this study both indexes (NDVI & SAVI) are calculated for certain vegetation areas in the Landsat image (shown in Figures 4 & 5); they were compared using the scatter plot. The result of this analysis is shown in Figure 7, and the determined correlation (R^2) coefficient between NDVI & SAVI was to be equal to $= 0.8838$.

Table 2-The NDVI classification range [23]

Class	NDVI
Water	-0.28-0.015
Build-Up	0.015-0.14
Barren Land	0.14-0.18
Shrub and Grassland	0.18-0.27
Sparse Vegetation	0.27-0.36
Dense Vegetation	0.36-0.74

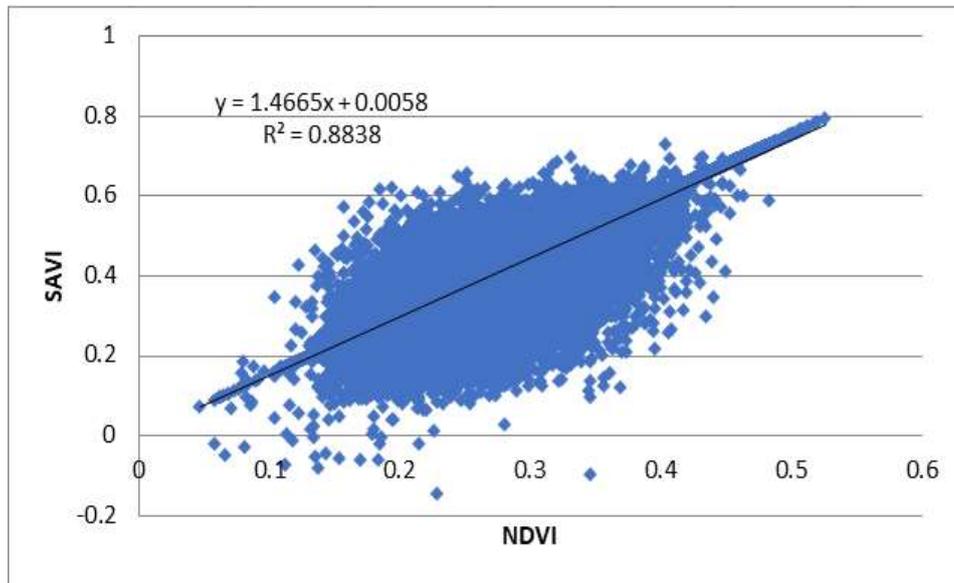


Figure 7-The correlation between NDVI index and SAVI index

3.3 Relationship between NDVI index and NDVSI index

Also, the relation NDVSI (defined by equation 3) and NDVI (equation 1) was determined and analyzed using the scatter plot method. The results indicated that the sensitivity of the NDVI index is lower than the NDVSI index for detecting the vegetation., strong positive correlation coefficient between both indexes is found ($R^2 = 0.9173$) as shown in Figure 8.

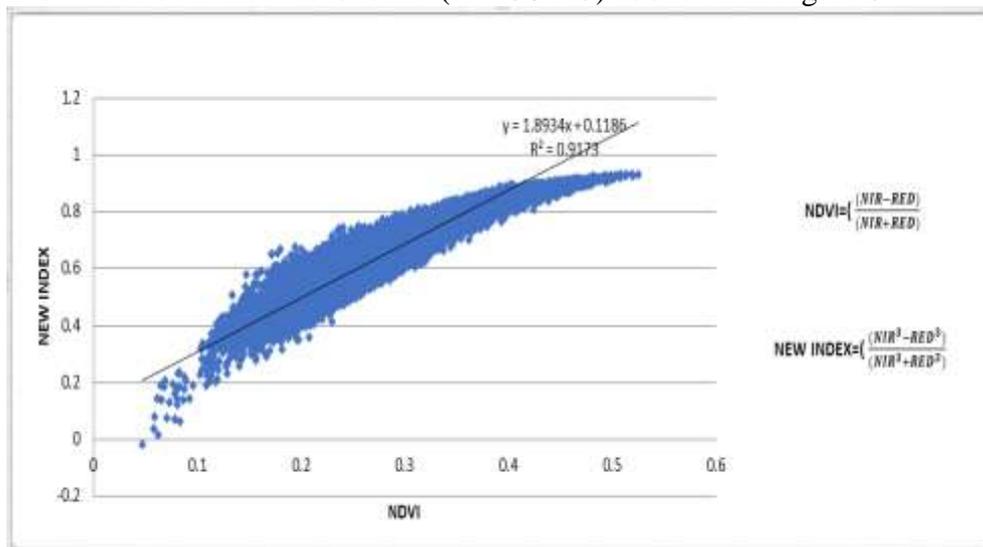


Figure 8-The correlation between NDVI index and NDVSI index

3.4 Relationship between SAVI index and NDVSI index

From the relation, NDVSI (defined by equation 3) and SAVI (equation 2) the correlation coefficient between the SAVI index and NDVSI index is ($R^2 = 0.8093$, as shown in Figure 9). It is worth noting that this obtained correlation value is very asymptotic to the correlation coefficient between NDVI index and SAVI index ($R^2 = 0.8093$)

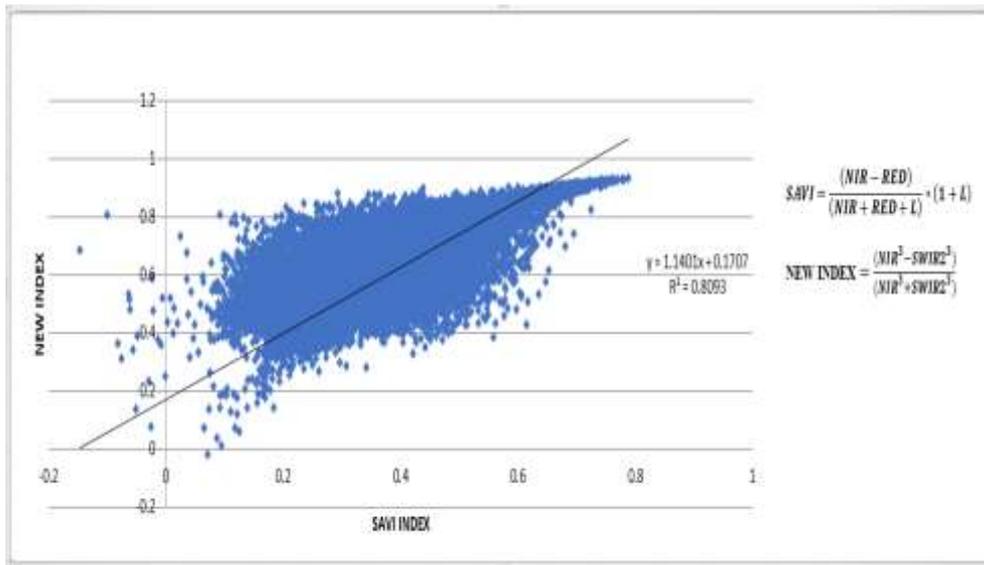


Figure 9- The correlation between SAVI index and NDVSI index

3.5 Verification

As a verification stage, the above stages were carried out on the Al-Mada'en region, which is located around the southeast of Baghdad (Lat: 33°05'48'' N, Lon:44°26'40''E) as shown in Figure 10.

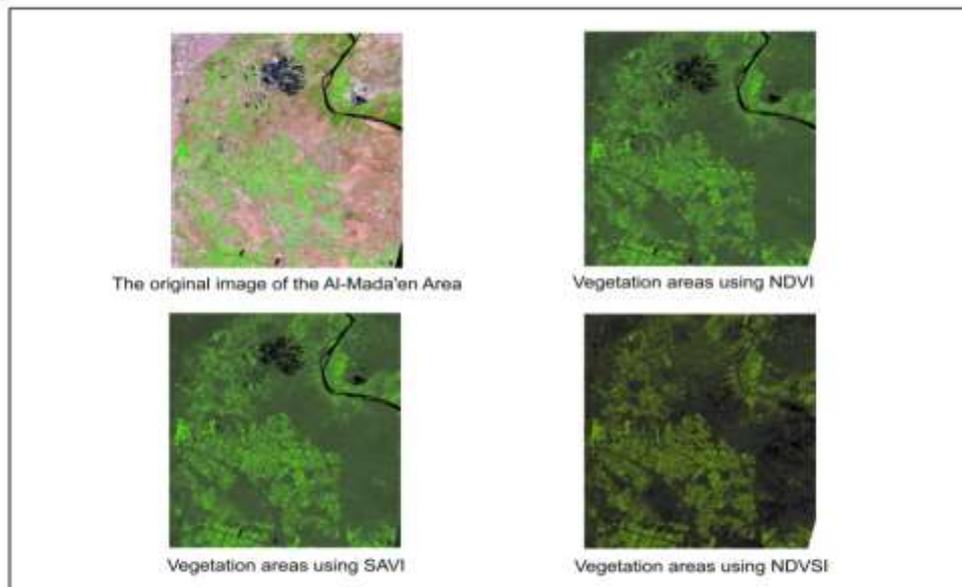


Figure 10 - Al- Al-Mada'en area

The results showed that the correlation coefficient NDVI index and NDVSI index is ($R^2=0.9122$) and that the correlation coefficient SAVI index and NDVSI index is ($R^2=0.9122$).

Table 3-Levels of vegetation cover for the study areas

Region: Abu-Ghraib				Region: Mada'en		
Index →	NDVI	SAVI	NDVSI	NDVI	SAVI	NDVSI
Mean	0.26501	0.39443	0.62037	0.23610	0.35414	0.55893

STDEV	0.05965	0.09296	0.11785	0.06297	0.09445	0.13774
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From the results shown in Table 3, it is clear that the level of vegetation in Abu-Ghraib is a little bit higher than that in Al-Mada'en.

The results also showed that The NDVSI index has a high correlation coefficient with NDVI (as shown in Figures 7, 8, and 9), and that replacing the Red band with the WSIR2 band in the NDVI contributes new information about vegetation, which was not previously available in visible and near-infrared measurements because WSIR2 bands reflected radiance patterns related to leaf water content; water does not absorb this part of the electromagnetic spectrum. , thus the NDVSI index is resistant to atmospheric effects, distinguishing it from NDVI, SAVI indexes.

4. Conclusions

The red band is replaced in the NDVI equation with the SWIR2 band ($\sim 1.24 - 2.2\mu\text{m}$) and amplification the dynamic band of the proposed NDVSI index to power 3, as shown in formula(3) based on the test values of spectral bands reflectivity shown in Table (1). The initial results showed that the sensitivity of the NDVSI index to detect vegetation cover is higher compared to the NDVI index, SAVI index, which developed a basis for improving NDVI and reducing soil impacts. The signature of vegetation canopies in the WSIR2 channel differs significantly from that of the red channel. So the NDVSI can be considered as a stand-alone vegetation index. Since different environments have complex and variable characteristics, it is recommended the proposed VI test should be done through a comprehensive study and analysis taking into account along with the consideration of the existing of VI benefits and limitations.

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