Journal of Physics: Conference Series

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Study of vegetation cover distribution using DVI, PVI, WDVI indices with 2D-space plot

To cite this article: Taghreed A H Naji 2018 *J. Phys.: Conf. Ser.* **1003** 012083

Study of vegetation cover distribution using DVI, PVI, WDVI indices with 2D-space plot

Taghreed A H Naji

Department of Physics, College of Education for Pure Sciences/ Ibn- Al-Haithem, University of Baghdad, Baghdad ,Iraq

Taghreednaji1972@gmail.com

Abstract. The present work aims to study the effect of using vegetation indices technique on image segmentation for subdividing an image into the homogeneous regions. Three of these vegetation indices technique has been adopted (i.e. Difference Vegetation-Index (DVI), Perpendicular Vegetation Index (PVI) and Weighted Difference Vegetation Index (WDVI)) for detecting and monitoring vegetation distribution and healthiness. Image binarization method being followed the implementation of the indices to isolating the vegetation areas from the image background. The separated agriculture regions from other land use regions and their percentages are presented for two years (2001 and 2002) of the (ETM+) scenes. The counted areas resulted from 2D-space plot technique and the separated vegetated areas resulted from the using of the vegetation indices are also presented. The separated agriculture regions from the implementation of the DVI-index have proved better than other used indices. Because it showed better coincident approximately with 2D-space plot segmentation.

Keyword. Image segmentation, vegetation indices, image binarization technique.

1. Introduction

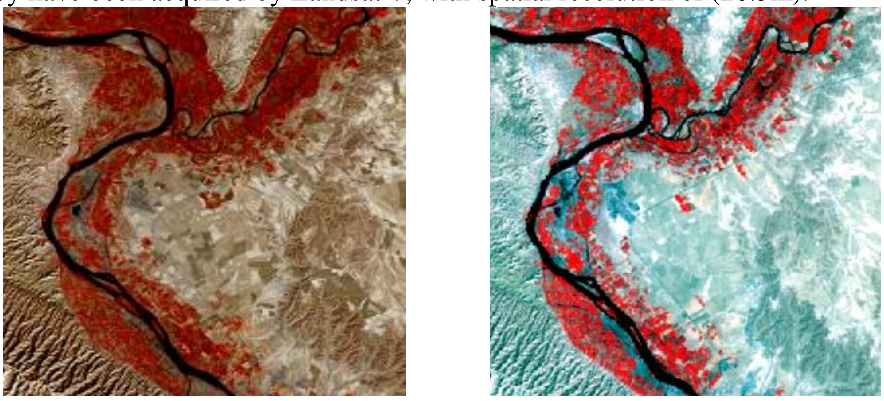
Multispectral scanning measurements are used for predicting and assessing vegetative characteristics. Such as; plant leaf area, total biomass, chlorophyll content, plant height and plant stress by vegetation indices [1]. It is a number value that is generated by some algebraic combination of remotely sensed spectral bands to estimate the vegetation amount for image pixel. It is a measurement of vegetation greenness or health on remote sensing images, it has been developed to use for environmental monitoring. Vegetation absorption for energy spectral bands is very high in visible and invisible bands from 0.4 µm to 0.7 µm and 1.3 µm to 2.5 µm, due to the presence of chlorophyll pigment and water in the vegetation leaves, so the vegetation appear very dark. While in (0.7-1.3) µm bands, Vegetation appear very brighter and scattering for light, due to the internal structure of vegetation leaves cells. Vegetation indices will yield high values for this bands [2].

In this research, three vegetation indices are adopted to be implemented, as Difference Vegetation Index (DVI), Perpendicular Vegetation Index (PVI) and Weighted Difference Vegetation Index (WDVI) indices. The 2D-space segmentation has been utilized for the purpose of comparison with vegetation indices results. This method based on dividing the Near Infrared “NIR” and Red “R” diagram into two regions (vegetation and non-vegetation areas) corresponding to their reflectance values.

2. Materials and methods

2.1 The available data

The region of interest (ROI) has been chosen and used in this work is Al Fit’ha situated north Salah al-Den province, cover (130 km2), upper left point lat. 35° 17' 14.70" N, long. 43° 22' 51.22" E, lower right point lat. 35° 09' 49.16" N, long. 43° 29' 40.19" E. As it is obvious, the area involves the junction region between the Tigris and the Lower Al-Zab Rivers which contains different types of Landcover classes. Images in ‘figure 1’ show this ROI; the available images were two temporally ETM+ exposure at 2001, and 2002. They have been acquired by Landsat-7, with spatial resolution of (28.5m).



a b

Figure 1. a-First Time (2001) the original scene, b- Second Time (2002), at the same size, with resolution of (28.5m).

2.2 Detection and separation of vegetation areas

The vegetation indices are developed by the world food monitoring organizations to assist future drought warning system [3]. There are many functionally information of vegetation indices, while some provide biophysical content. They have been grouped into four types including slope based, distance based, orthogonal transformation and plant water sensitive vegetation indices depend on spectral bands combination [4].

Vegetation indices have been computed via arrays arithmetic the details of these indices, as their equations mentioned for DVI, PVI and WDVI indices.

The DVI- index is a slope based group, and was obtained by subtracting the red reflectance from the near-infrared reflectance. It is simpler than NDVI-index but it is prone to measurement errors in the Near Infrared (NIR) and Red (R) bands because it is not normalized by their sum. This index as computationally easier than PVI-index. The range of this index is infinite and the index is given ‘as in equation (1)’ [5]:

$$DVI = NIR - R \tag{1}$$

The PVI-index is a distance based group, and was designed to assume that the perpendicular space of the pixel from the soil line is linearly depended on the vegetation area; it attempts to eliminate difference in soil background, applicable for arid and semiarid regions. The higher PVI -index values indicate to the effect of brighter soil background, at the expense of incomplete vegetation. This allows creating different slopes for soil lines. PVI-index is affected by atmospheric fluctuations and it given different data, so atmospheric correction should been performed on the data before implemented this index. The range of this index is -1 → +1, given 'as in equation (2)' [2]:

$$PVI = (\sin(a) \times NIR) - (\cos(a) \times R) \quad (2)$$

Where: (a) is the angle between the soil line and the NIR axis.

WDVI-index has been used to overcome high PVI values, which due to the brighter soil background. This index is based on distance too, and it assumes that the ratio between NIR and Red reflectance of bare soil is constant. WDVI- index has mathematically simpler from PVI-index, but it has an infinite range. Like PVI-index, it is very affected by atmospheric fluctuations. This index is given 'as in equation (3)' [6 and 2]:

$$WDVI = NIR - (g \times R) \quad (3)$$

Where: (g) is the slope of the soil line.

The 2D- space plot technique for image segmentation has been adopted to surmount the mutation in segmented areas, by identify the threshold values locally which depended on image features reflectance. This method is separated the vegetation and non-vegetation regions on the space diagram between the Near-Infrared (NIR) and Red (R) spectral bands.

In order to identify pixels most likely contain significant vegetation, a simple threshold values may be implemented to the vegetation indices. Selection of threshold values depended on the pixel values in the vegetation indices images. The vegetated areas appear green when viewed as logically binary images. To monitor the vegetation covers, the following percentage and area's counting relationships are implemented:

$$\rho_v = (N_v/N_t) \times 100 \quad (4)$$

$$A_t = N_t \times R^2 \quad (5)$$

$$A_v = A_t \times \rho_v \quad (6)$$

Where:

P_v = is the percentage of vegetation class.

N_v = is the number of pixels within the vegetation class.

N_t = is the total number of pixels within the processed image.

A_t = is the total area of image, measured by square kilometer.

A_v = is the area of vegetation class, measured by square kilometer.

R^2 = is resolution of the satellite image data; i.e. (28.5 × 28.5 m2) for the Landsat (ETM+) data.

There are many of change detection algorithms; one of the most common algorithms which used in this research is "Image Differencing". This algorithm involves subtracting each digital number (DN) value of first time image from that of the second time image and adding a specific positive constant to avoid negative values. The subtraction results produced three levels of information: positive and negative values in area of feature changes, and zero values in area of no changes; mathematically:

$$CD\ (i,j) = DN_2\ (i,j) - DN_1\ (i,j) + C \quad (7)$$

Where:

CD (i, j): is the produced image of changes.

DN1 (i, j): the first time image.

DN2 (i, j): the second time image.

C: is a positive constant ranging from (0 to 255) for 8- bit image.

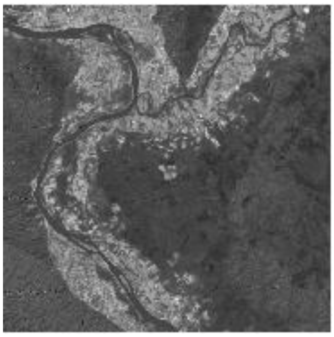
(i, j): row's and column's number, respectively.

3. Results and discussion

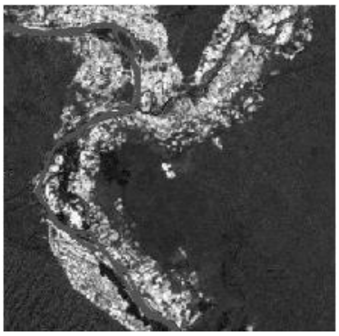
Many vegetation indices have been developed and used for exploring vegetated areas. Three of them have been adopted in this research to detect the vegetation covers for the ROI satellite images. These images are used to illustrate the effect of performing these indices, are shown in 'figure 1', false color scenes (Band2, Band3, and Band4) are combined, by smaller size extracted temporal.

Three indices formula have been used to exploring the vegetated regions on these images, shown in 'figure 2'. The vegetation cover of the ROI using DVI- index was 25.64 km2 at 2001 and 26.91 km2 at 2002 (i.e. 19.72 and 20.70%, respectively). The ROI is decreased in the surface of vegetation from 24.70 to 26.94 km^2 between 2001 and 2002 (i.e. 19 and 20.72%, respectively) using PVI- index. The WDVI-index has been found to be more sensitive than the PVI-index. This index was used to minimize the effect of soil reflectance variation. The change of vegetated area showed decreases in the surface of vegetation from 24.87 to 27.56 km^2 at the periods 2001 and 2002, (i.e. 19.13 and 21.20%, respectively). The differences between the percentage areas of vegetated areas using different vegetation indices due to the utilized threshold assigned for each differences.

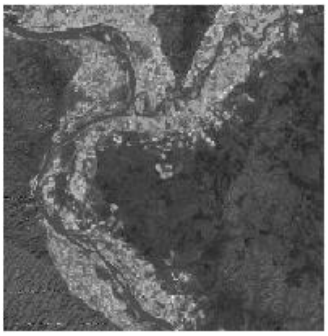
To split the vegetation regions from other land cover classes, different suitable threshold have been used (i.e. all pixels < threshold have been assigned to represent background (non-vegetation cover), while those ≥ threshold have been regarded as to represent the vegetation cover), the splitting or slicing results are demonstrated in 'figure 3'.



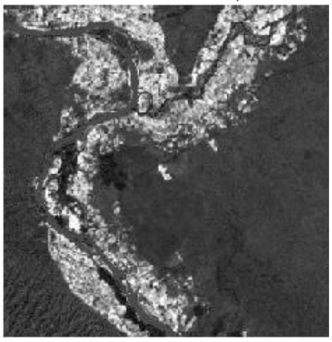
DVI First Time, 2001



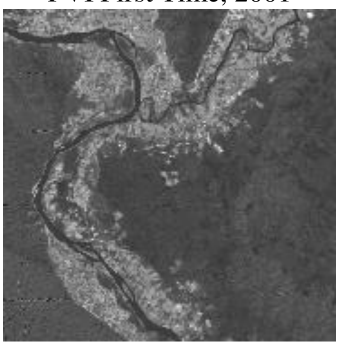
DVI Second Time, 2002



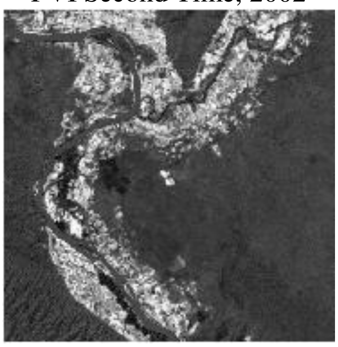
PVI First Time, 2001



PVI Second Time, 2002



WDVI First Time, 2001



WDVI Second Time, 2002

Figure 2. The vegetation indices effects on the multi-temporal images (2001 and 2002)

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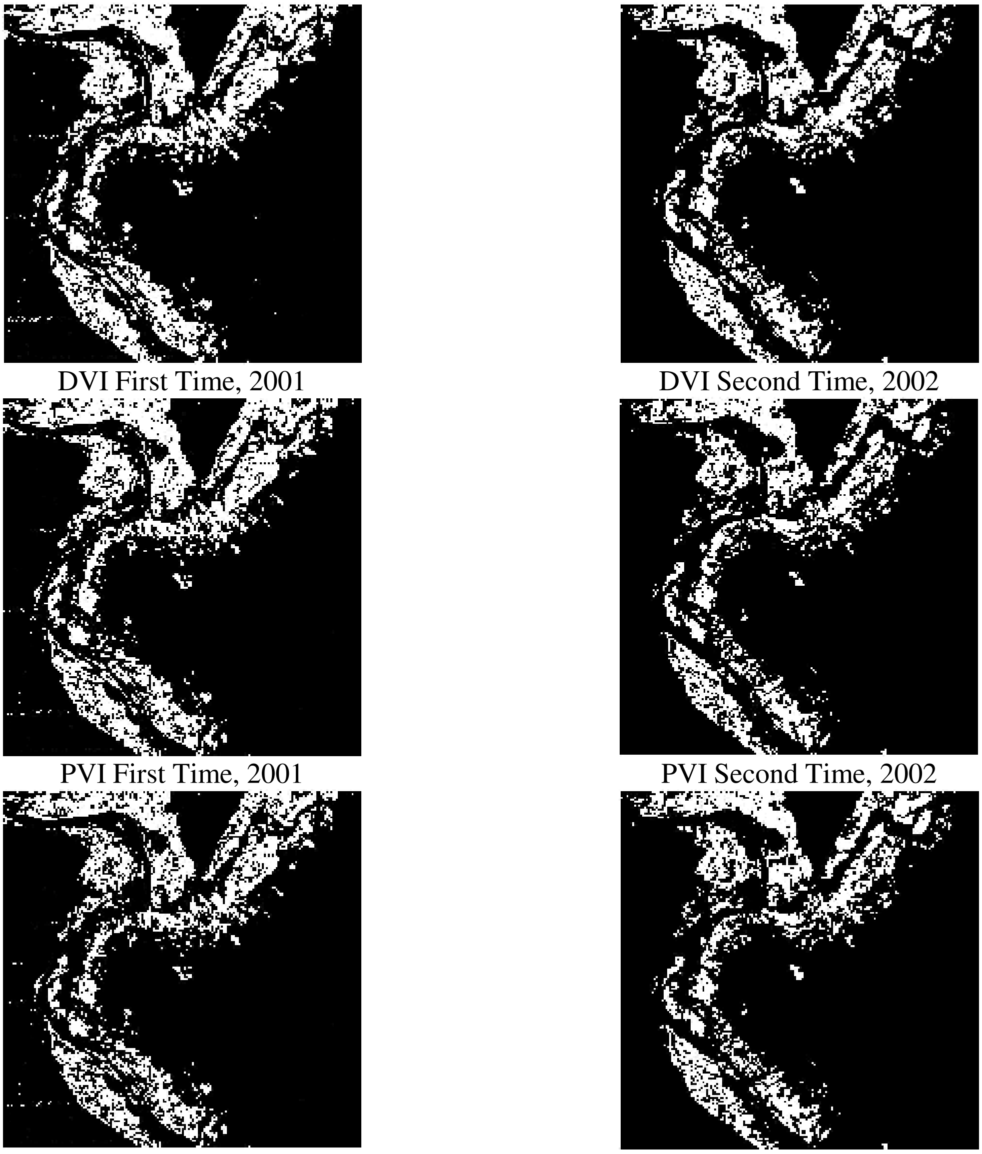

Figure 3. Vegetation layers, binaries by decided threshold (given in table 1)

To compare the implementation of the vegetation indices with 2D-space plot segmenting results, 'figure 4' shows the studied areas as to consist either vegetated and non-vegetated regions, coloring them into green (for vegetated areas), and blue (non-vegetated areas). (Table 1) presents the percentage area of the vegetated covers within the processed images, show right column of 'figure 4'. Two dimension space diagram is plotted by projecting the thresholded colored images on them, shown in the left column of 'figure 4'.

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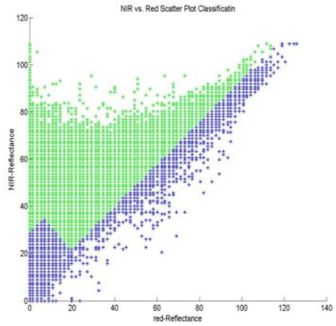
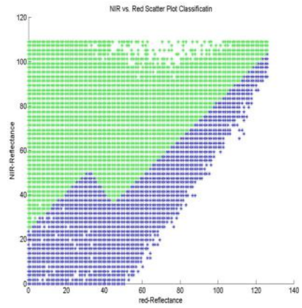
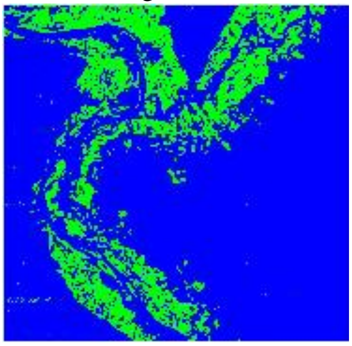
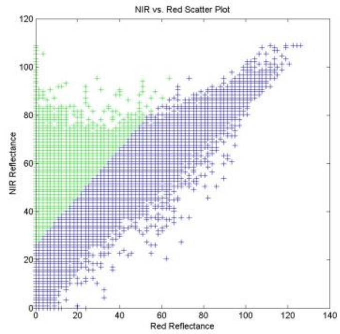


2D-space plot method for First -Time image (2001)

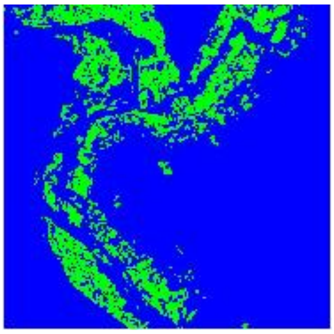


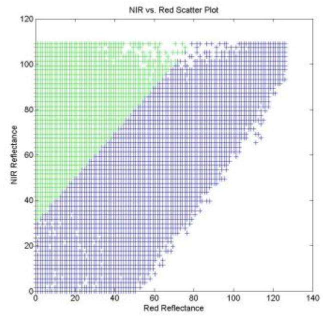
2D-space plot method for Second -Time image (2002)



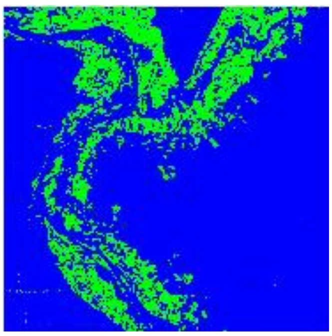


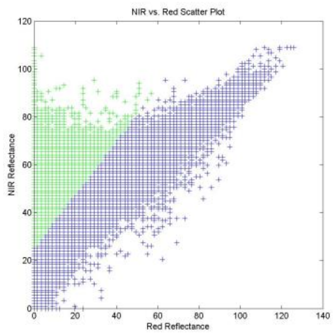
DVI First Time, 2001



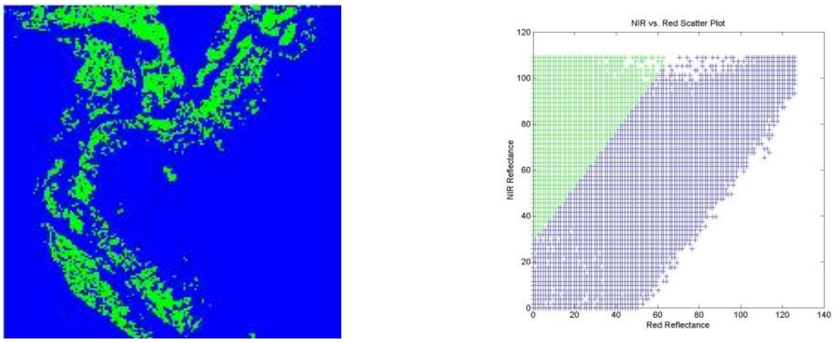


DVI Second Time, 2002

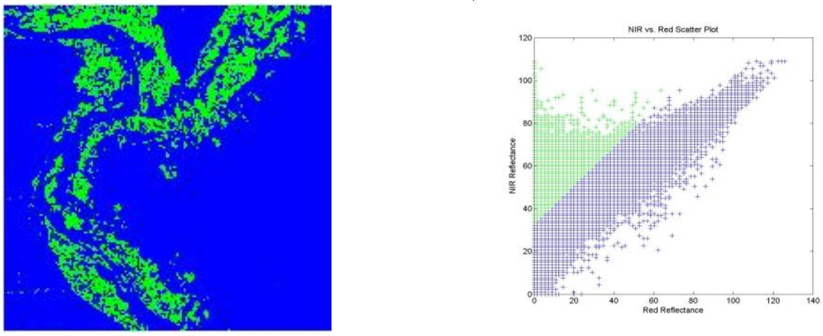




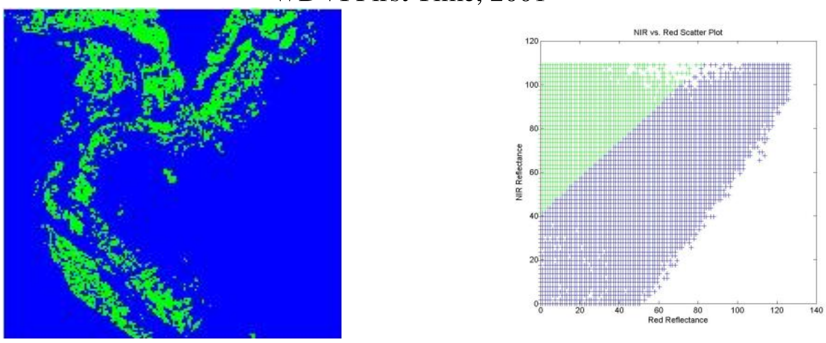
PVI First Time, 2001



PVI Second Time, 2002



WDVI First Time, 2001



WDVI Second Time, 2002

Figure 4. Thresholded images and their 2D-space plots, produced by projecting the values of thresholded images on the original 2D-space plots

Table 1. List of threshold values, and percentage vegetation coverage for vegetation indices images (First, and Second Time)

Index	First Time (2001)			Second Time (2002)		
	Threshold	**%Percentage**	**Area km2**	**Threshold**	**%Percentage**	**Area km2**
DVI	115	19.72	25.64	110	21.72	27.94
PVI	120	19	24.70	110	21.70	27.91
WDVI	115	19.13	24.87	110	20.20	26.56

In this research, 'as in equation (7)' has been utilized to discriminate the changes in vegetated areas for the period 2001 to 2002, as illustrated in 'figure 5'. Image differencing algorithm has been applied on previous images before and after utilizing the vegetation indices to detect the changes in vegetation areas.

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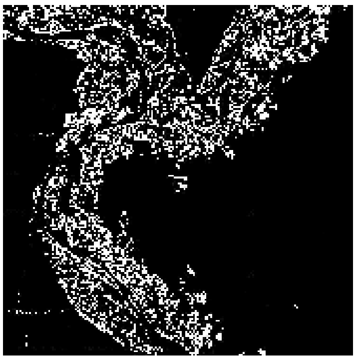
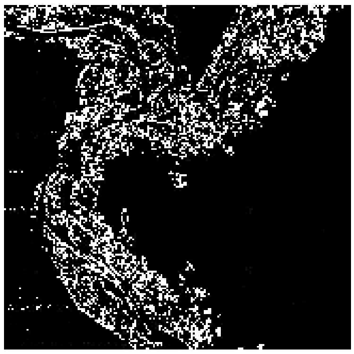
The changes in the vegetation areas with the percentage variations, with and without implementing vegetation indices, are listed in (table 2).

This study has been performed and built using ArcGIS10.3, ENVI 4.5 software's and MATLAB R2013a language.

Table 2. Vegetation changes during period 2001 to 2002, utilizing vegetation indices

The vegetation cover in the entire study area without implementing vegetation indices was 201.67 km^2 representing 155.13%.		
Implementing Vegetation Indices	**%Percentage**	**Area km^2**
DVI	13.92	17.80
PVI	13.62	17.41
WDVI	12.26	16.24


DVI layer


PVI layer

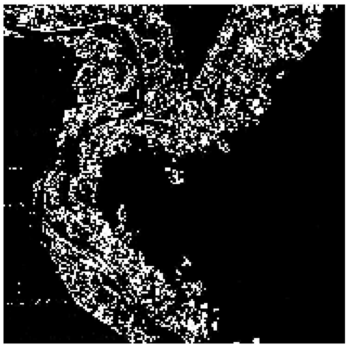

WDVI layer

Figure 5: Vegetation layers changes, using differencing images method

4. Conclusion

Vegetation index must be applicable as good indicator of vegetated cover, and have overcome the undesirable influence of soil background and other effects. Because the vegetation exhibits higher reflectance in NIR band and strong absorption (low reflectance) in R band. In this work, different indices for vegetation have been implemented to differentiate vegetated areas using multispectral temporal scenes to study of vegetation cover density and distribution; these were (DVI, PVI and WDVI). For detecting vegetation changes the vegetation index and 2D-space plot technique can be compared. The differences between vegetated areas, using different vegetation indices, have been interpreted due to the utilized threshold assigned for each of them. Generally, the implementation of indices yield brighter grey levels for the healthy vegetated areas, and darker grays for other parts of land cover. However, any deficient result may be referred to spectrally and reflectively affected scenes. As listed in tabulated results, the vegetated areas are mostly less in the first time (2001); this may be caused by the effect of climatic; annual rainfall, evaporation and irrigation, or agriculture policy. As it has been noticed in 'figure 4', the (DVI) index showed better performance than others, because it showed better coincident approximately with 2D-space plot segmentation technique. The research results can be more conformable to fact, when they were depended on field measurements of the study area for detecting vegetation areas and assessing its case.

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