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Implementation of remote sensing for vegetation studying using vegetation indices and automatic feature space plot

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Abstract

Remote sensing techniques play an important role for monitoring vegetation growth and health, as well as others Landcover and Landuse. Image segmentation techniques are the most important tools, usually used to differentiate between the Earth's surface features. One of the most common techniques to isolating the vegetated area from other land use regions is by utilizing the vegetation indices.

In this research, different vegetation indices will be utilized for detecting and monitoring vegetation greenness, healthiness, and wetness.

A new adaptive technique for image segmentation has been introduced in this research is automatic feature space plot, this based on partitioning the feature space plot between the visible Red and Near-Infrared remotely sensed bands. The multi temporal Enhanced-Thematic-Mapper plus (ETM+) available scenes have been used to cover the studied areas, in two successive years (2001 and 2002). This feature space plot segmentation method divided the reflectance diagram in two regions; these were vegetation and no-vegetation.

A variety of indices formulas have also been used to globalize the vegetation patches, three of these vegetation indices have been adopted (i.e. RVI, NDVI and IPVI). The "NDVI" has higher recognized vegetated areas than other adopted indices of the amount of vegetation (ripe vegetation). Image binarization method being followed the implementation of the indices to isolating the vegetation areas from the image background. The isolated vegetated areas and their percentages are presented in tables to show the agriculture regions in two multi temporal scenes. The changes at these agriculture areas have also been computed and presented visually on the form of images, and numerically by listing them in tables (in km^2). The counted areas resulted from the automatic feature space plot method and the isolated vegetated areas resulted from the implementation of the vegetation indices are also presented.

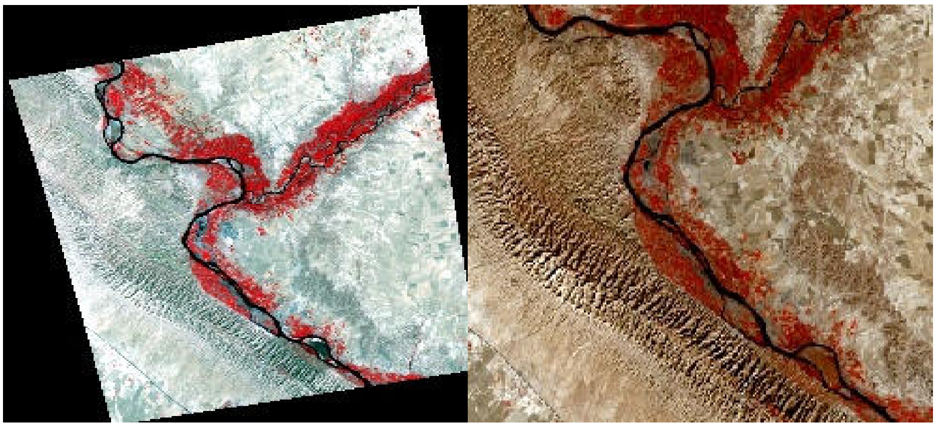
Keyword Image segmentation, feature space plot segmentation, vegetation indices, image binarization, change detection technique.

1. Introduction

The application of remote sensing technology in agriculture has become one of elementary means in monitoring growth of main crops, production prediction and soil moisture content etc,. Much of the Earths land surface has an uppermost cover of vegetation which intercepts electromagnetic radiation transmitted through the atmosphere. Satellite images obtained over land surface invariably contain areas of vegetation cover. The Earth observation satellites are in routine use for a broad range of agricultural applications. In developed countries these producers are often sophisticated because they profit agricultural and meteorological information. Remote sensing techniques played an important role in crop identification and production estimation, disease and stress detection, soil and water resources characterization [David et al., 2003]. Several studies have been published to cover the use of the classification methods, demonstrating the vegetation indices concept, and change detection to monitoring vegetation healthy with other land cover, and tried to find the distribution of vegetation from soil background [Richardson, and Wiegand, (1977)]. In 1960's, scientists have extracted and modeled various vegetation indices VIs using remotely sensed data. With increasing population pressure throughout the world the need for increased vegetation agriculture becomes crucial. Vegetation surveys are presently conducted throughout the world in order to gather information and statistics of vegetated regions. This information of data is most important for the implementation of effective management decisions. There is a definite need for improved management for vegetated regions. To implement this, it is first necessary to obtain reliable data not only the types, but also the quality, quantity and locations of these regions. Satellite remote sensing technology becomes an important factor in improving the present systems of acquiring and generating these vegetated region data. Vegetation survey is needed for planning and allocation of the limited regions to different sectors of the economy [Fadhil, 2006]. Under this subject, four methods have been employed here on two multi-temporal Landsat ETM+ images exposure at 2001, and 2002; these are: automatic feature space plot, vegetation indices, locating vegetation using threshold values and vegetation change detection, to discriminate vegetated regions, and determining the change detection in vegetation coverage during this period, with extract its percentage areas.

2. Sample of Test Scene

The region of interest has been chosen and used in this work is Al Fit'ha situated north Salah al- Den province, cover (130 km^2), 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 sensor, with spatial. Total area of sets images are (130 Km^2).



a b

Figure 1. a-First Time (2001) (size 660×556 pixels) the original scene, b- Second Time (2002) Geo-corrected scene (size 946×1008 pixels) resolution of (28.5m).

3. The automatic feature space plot method

A new segmentation method has been adopted to surmount the mutation in segmented areas, by identify the threshold values locally which depended on image features. This method is performed automatically to separate the vegetation and non vegetation regions on the feature space plot between the Near-Infrared (*NIR*) and Red (*R*) spectral bands.

The steps of automatic feature space plot algorithm are stated as the followings points:

1- Compute the minimum and maximum distance from extremes points of the feature space plot, defined as equation:

$$Distance = \sqrt{R^2(x) + NIR^2(y)} \quad ..(1)$$

2- Calculate the straight line pass through the extremes points by the equation of the best fit line, given by:

$$NIR\ (y) = m\,R(x) + b \quad ....(2)$$

3- Select the threshold value for down and up the straight line, depending on the experimental results of the searcher, the best threshold value is suggested for (T$_1$= 10). The restricted area between down and up this line represents the bare land region can be determine, using:

$$y_{up} = mx + b + T$$

$$..........…(3)$$

$$y_{down} = mx + b - T$$

4. Vegetation Indices

Vegetation indices provide a very simple yet elegant method for extracting the green plant quantity signal from complex canopy spectrum. Often computed as differences, ratios, or linear combinations of reflected light in visible and NIR wavebands, VIs exploits the basic differences between soil and plant spectra. Indices such as the ratio vegetation index (RVI) and normalized difference vegetation index (NDVI), perform exceptionally well when management goals require a quantitative means for tracking green biomass or LAI through the season

It is a number that is generated by some algebraic combination of remotely sensed spectral bands to estimate the amount of vegetation in a given image pixel. There is fairly good empirical evidence that they can [Terrill, 1994]. It is a measurement of vegetation greenness or health, it has been developed to enhancing the visibility of healthy vegetation on satellite images, it has now used as a key tool for environmental monitoring.

Vegetation indices show a strong correlation with many agronomic and biophysical plant parameters. Nearly all of the commonly used vegetation indices (VIs) are only concerned with red-near-infrared space. Indices such as the ratio vegetation index (RVI) (or simple VI) and normalized difference vegetation index (NDVI), perform exceptionally well when management goals require a quantitative means for tracking green biomass or leaf area index through the season or for detecting uneven patterns of growth within a field [Harrison et al., 2000; Jensen, 2000].

In this research, three vegetation indices are adopted to be implemented, listed at the following:

4.1. Ratio Vegetation Index (RVI):

The RVI Index is a simply vegetation index. This index gives general information about vegetation properties, it is sensitive to optical properties of the soil background, and it is useful for discernment between soil and vegetation areas. Many other indices have been created to give more detailed and organized information than this index, regarding the vegetative activity (health) of certain regions [Sandison, 1999]. Ratio images give a measure of the difference in reflectance of the same surface for two separate portions (bands) of the electromagnetic spectrum. They are often used to expose hidden information, particularly when there is an inverse relationship between two spectral responses to the same earth surface. They are therefore used in geological mineral differentiation as well as for discriminating vegetated from non vegetated regions. If two different regions have the same spectral response in two electromagnetic bands, then the ratio provides little additional information to that gained from examining the region by using one band along. Ratioing is particularly useful in vegetation detection because of the high spectral absorption in the "R", and high reflectance in the "NIR" region. The (NIR/R) ratio produces a high pixel value when vegetation is present but a low value for any other region when vegetation is not present [Gibson et al., 2000].

The value of the ratio will be greater for increasing amounts of healthy green vegetation. This is because vegetation reflects more strongly in the NIR than in the red visible. The values for "NIR" and "Red" bands are average values for the reflectance curves at those wavelength intervals. Sometime the (G/R) ratio is used, but it is not as effective because the difference between the responses of vegetation in the green visible band (G) is not as great as in the infrared. This index has a range of 0→∞, the dark and bright extremes of the gray scale represent pixels with the greatest difference in reflectivity between the two spectral bands. Different types of vegetation and soil may have different index values, given by [Sabins, 2007]:

$$RVI = NIR/R \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where: NIR: is the near-infrared reflectance, and R is the red reflectance

4.2. Normalized Difference Vegetation Index (NDVI):

The most common form of vegetation index is the Normalized Difference Vegetation Index (NDVI). It takes the (NIR - R) difference and normalizes it to help balance out the effects of uneven illumination such as the shadows of clouds or hills. The pixel-by-pixel basis subtracts the value of the *"R"* band from the value of the *"NIR"* band and divides by their sum. It performs exceptionally well when management goals require a quantitative means for tracking green biomass or leaf area index through the season or for detecting uneven patterns of growth within a field [Charles et al., 1983]. It is significantly correlated with change in crop biomass during growth stages. And can be used as a surrogate for estimating the fractional amount of photosynthetically active radiation absorbed by crop canopy for potential use in photosynthesis [Paul et al., 2003]. NDVI on the pixel scale may include signal from both the vegetation canopy and the background surface. One can expect a maximum NDVI value for a fully vegetated canopy covering the ground (greenness during the period), and a minimum NDVI value for a pure background surface where there is no vegetation cover. Usually, NDVI is above 0.70 for green leaves of healthy plants. It produces an index value ranging between -1(no vegetation) → +1 (complete healthy green vegetation cover). Atmospheric corrections may be implemented to the images before computation of NDVI for vegetation analysis [Qina et al, 2005].

Drought is one of the conditions affecting vegetation that can be sensitively measured by NDVI calculations. It has been accepted as a surrogate for primary production and has served as a good measure of seasonal vegetation changes, even at coarse scales [Freund, 2005]. This index is given by:

$$NDVI = (NIR - R)/(NIR + R) \ldots\ldots(5)$$

RVI and NDVI are functionally equivalent and related to each other by:

$$NDVI = (RVI - 1)/(RVI + 1) \ldots\ldots.(6)$$

4.3. Infra-Red Percentage Vegetation Index (IPVI):

The subtraction of the red band value in the numerator was irrelevant, by using the NDVI. The Infrared Percentage Vegetation Index (IPVI) was proposed as method for improving calculation speed. This index and NDVI are functionally equivalent [Pavelka, 2005].This index is computationally faster than the NDVI and scales data in percentages. It eliminates negative numbers, and output data ranges from zero to one, red radiance subtraction in the numerator of NDVI was irrelevant. This index is effectively the same as NDVI and may be preferred with large data sets or slow computers [Al-Banna, 2004]. The range of this index is 0 → +1, given by:

$$IPVI = NIR/(NIR + R) \ldots\ldots(7)$$

Another formula IPVI:

$$IPVI = (NDVI + 1)/2 \ldots\ldots\ldots(8)$$

5. Locating Vegetation via the Threshold Values

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 white when viewed as logically binary images. To monitor the vegetation covers, the following percentage and area's counting relationships are implemented:

$$\rho_v = \left(\frac{N_v}{N_t}\right) \times 100 \ldots\ldots\ldots.(9)$$

$$A_t = N_t \times R^2 \ldots\ldots\ldots\ldots..(10)$$

$$A_v = A_t \times \rho_v \ldots\ldots\ldots\ldots\ldots..(11)$$

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. ($28.5 \times 28.5\ m^2$) for the Landsat (ETM+) data.

6. Vegetation Change Detection Algorithm

Change detection is an important application of remote sensing in environmental areas. It may mean different things to different users, depending on the details of change required. In general change detection is a process of identifying differences in the state of object or phenomena by observing them at different time. The fundamental assumption of digital change detection is that; there exit a difference in the spectral response of digit number (DN) of two images for the same area [Musaoglu et al., 2000]. The reliability of the process may also strongly affected by multi environmental factors that might change between dates. Furthermore, there are many other factors influencing changes between two different data imagery; like atmospheric effects, wind, soil moisture condition, and lake level [Quinn, 2001].

The change detection procedures should involve the following steps according to [AL Samaraey, 2003];

1. Data acquiring by the same sensor.
2. Similar spatial resolution.

3. The same geographic area and day time exposure.
4. Preprocessing including minimize sun angle and seasonal differences.
5. Precise spatial registration for the various data within similar (image or map as to references [Lillesand, 2008].
6. Two images should be matching to make them in the same size with respect to all features.
7. To compute change detection we can use one or more of the change detection algorithms.

The subject of change detection algorithms based on analysis of several important factors. First, the analyst must know the biophysical characteristics of the studied area. Second, it is important to know the required registration accuracy [Musaoglu et al., 2000]. In fact, 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 (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 or radiance change, and zero values in area of no change; mathematically:

$$CD\ (i,j) = DN_2\ (i,j) - DN_1\ (i,j)\ + C \text{......(12)}$$

where:

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

DN_1 (i, j): the first time image.

DN_2 (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.

In this research, equation 14 has been utilized to discriminate the changes in vegetated areas for the period 2001 to 2002. The results are viewed by Landsat-7, ETM+ sensor. Image differencing algorithm has been applied on previous images before utilizing the vegetation indices. Image differencing method is, also, implemented to detect the changes in vegetation areas, after utilizing the vegetation indices. The methodology has been utilized to detect the vegetated areas and change of vegetation coverage during this period, which illustrated on block diagram shown in Figure 2.

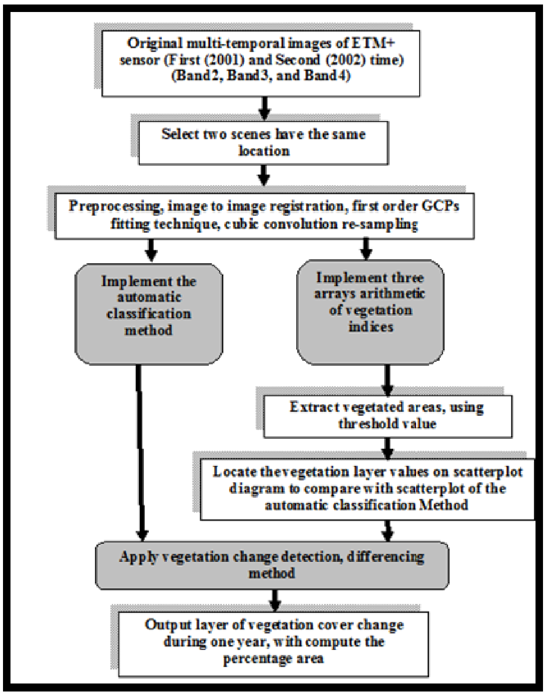


Figure 2. Block diagram of the vegetation change detection process, followed in this Research

7. Results and discussions

After the correction and matching process, three of vegetation indices, as fairly good empirical evidences were implemented on the multi-temporal Landsat ETM+ images. These images are geometrically corrected in the World Geodetic System 1984 datum “WGS84”, and Universal Transverse Mercator projection (Zone 38 North) “UTM N38” using the first order (linear) of polynomial function and cubic convolution registration resampling. The Root Mean Square (RMS) error of the image-to-map registration was between 0.05 and 0.85 pixels. As appear in table 1, number of Ground Control Points “GCPs” used to correct the second images was 6.

The sample of satellite images used to illustrate the effect of performing these methods, are shown in figure 3. False color scenes (Band2, Band3, and Band4) are combined, and then followed by smaller size extracted temporal (R and NIR) bands.

Table 1. Second time registration parameters

Total (RMS) Error = 0.502 meter

GCP No.	Base Image First Time, 2001		Warp Image Second Time, 2002		Error (meter)		RMS Error
	X	Y	X(meter)	Y(meter)	X	Y	(meter
1	166.3300	23.3300	529.5000	363.5000	-0.48	0.10	0.49
2	286.3300	301.5000	307.6700	301.3300	-0.03	-0.04	0.05
3	115.3300	351.5000	339.6700	539.3300	0.82	0.24	0.85
4	156.3300	32.3300	383.5000	596.3300	-0.31	-0.16	0.35
5	136.3300	217.3300	254.3300	280.3300	0.45	-0.02	0.45
6	42.3300	23.3300	529.5000	443.3300	-0.44	-0.12	0.46

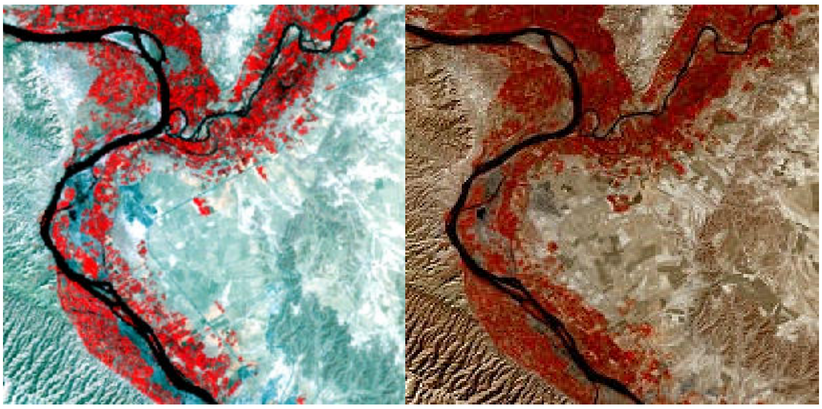
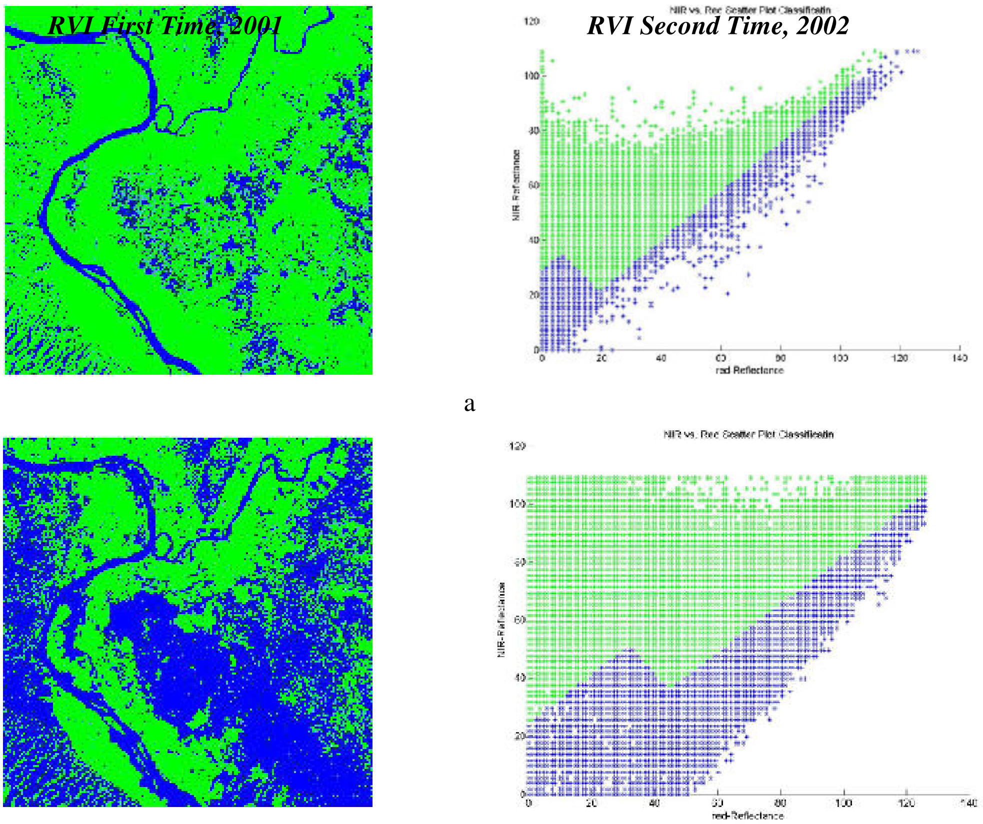

First-Time (400×400) Second-Time (400×400)

Figure 3. Extracted the original and Geo-corrected scenes in figure (1) at the same size.

In automatic method, the bare land region is located automatically on feature space plot diagram, using (T = 10). Figure 4 demonstrates the resulted segmented images, using the automatic feature space plot segmentation method, coloring them into green for vegetated areas, and blue for non-vegetated areas. This method showed enhanced results, because they have based on physical base treatment (i.e. amount of absorption by the Red band, and the amount of reflection on the NIR band). The superiority of the automatic segmentation technique may be argued to the assumption that the bare land line is defined correctly (i.e. linearly). Moreover, the automatic technique can be implemented, faster and more adequate on new scenes.

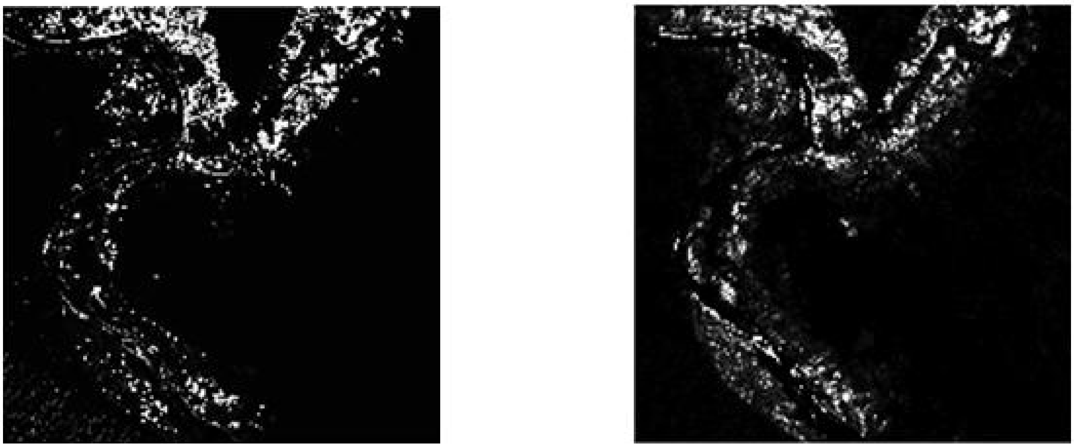


a

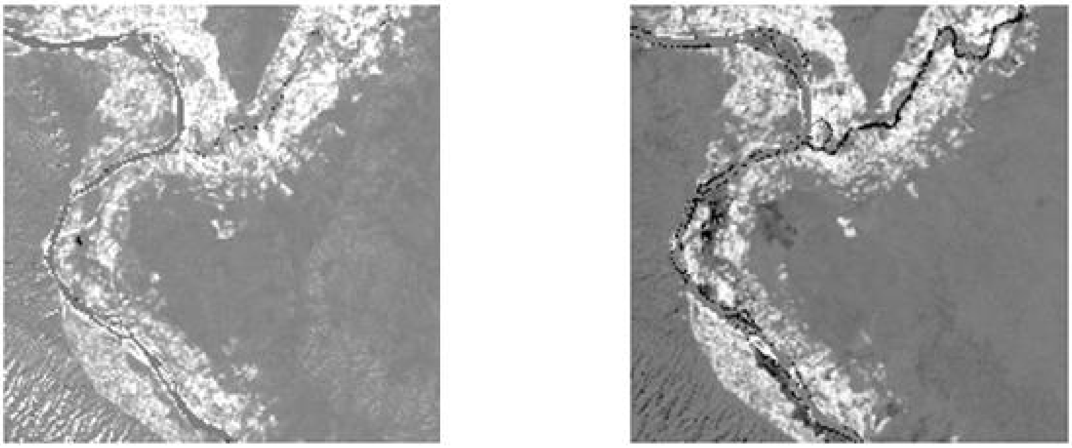
b

Figure 4. a & b Thresholded images (First -Time (2001) & Second -Time image (2002)) and their feature space plot

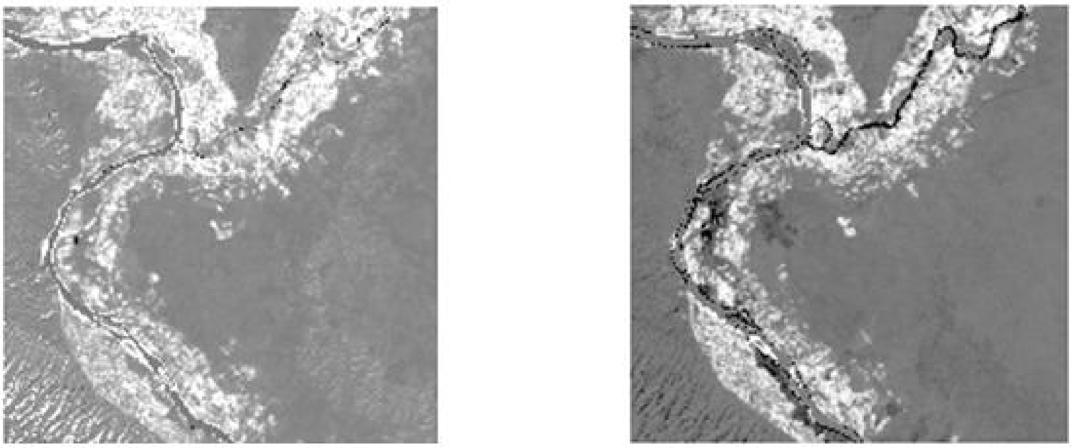
Three vegetation indices formula have been computed via arrays arithmetic to exploring the vegetated regions on the temporal images, shown in figure 5. In (RVI) index, the vegetation cover in the entire study area was 16.06 km^2 in the year 2001, while it decreased to 13.65 km^2 in the year 2002, and they forms 12.35 and 10.50%, respectively. The vegetation cover of the studied area in (NDVI) index was 25.89 km2 in the year 2001, and 27.82 km2 at 2002; it is representing 19.92 and 21.40%, respectively of the total studied area. The decreasing in the surface of vegetation during the studied period in (IPVI) index; i.e. from 25.80 to 27.30 km2 between 2001 and 2002 (representing 19.90 and 21%, respectively).



RVI First Time, 2001 ***RVI Second Time, 2002***



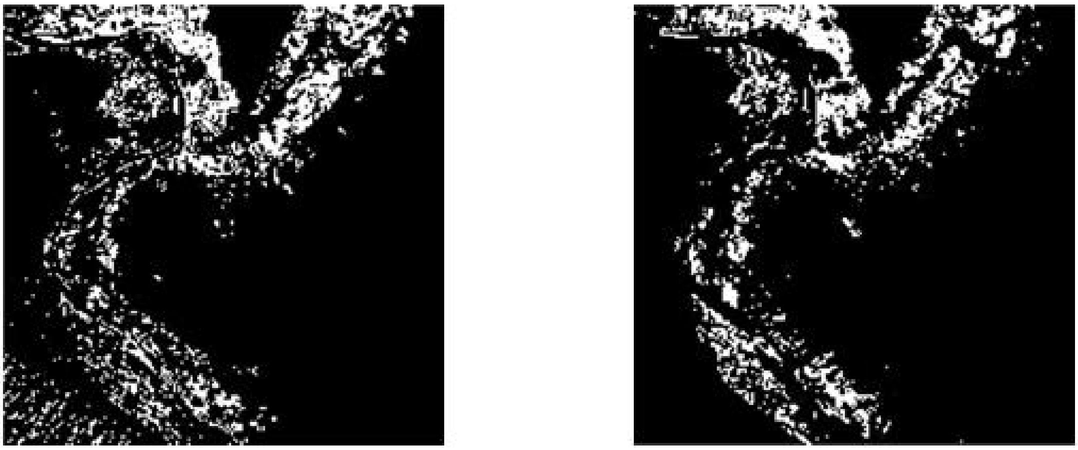
NDVI First Time, 2001 ***NDVI Second Time, 2002***



IPVI First Time, 2001 IPVI Second Time, 2002

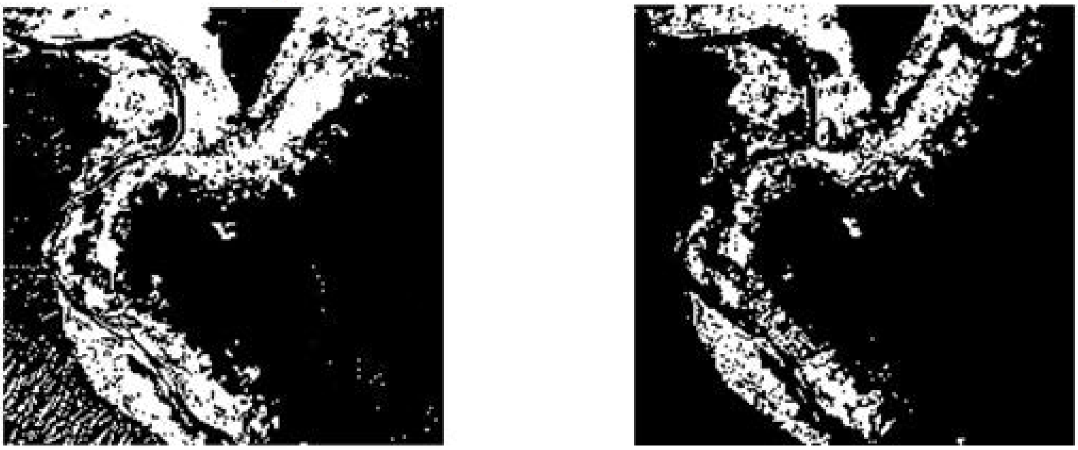
Figure 5. The vegetation indices effects on the multi-temporal images (2001 and 2002)

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, while those ≥ threshold have been regarded as to represent the vegetation cover), the splitting or slicing results are demonstrated in figure 6.



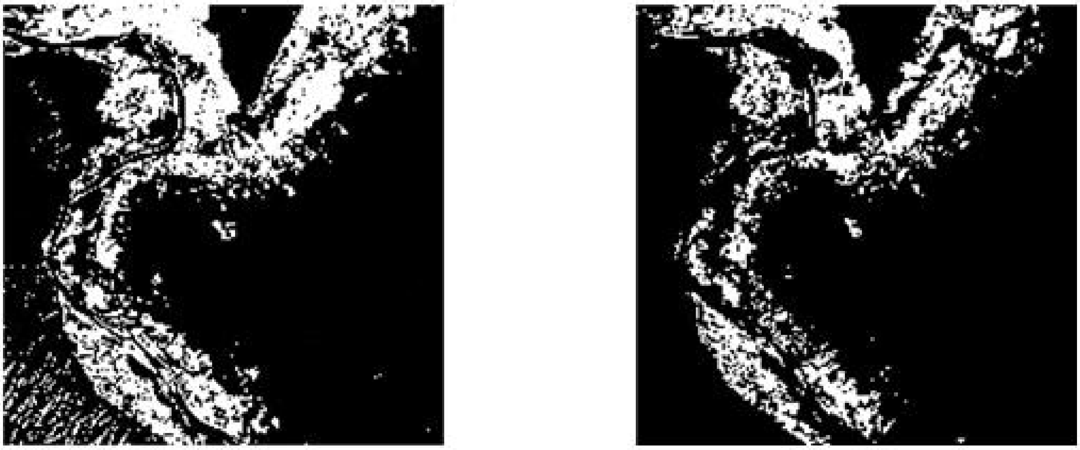
RVI First Time, 2001

RVI Second Time, 2002



NDVI First Time, 2001

NDVI Second Time, 2002



IPVI First Time, 2001

IPVI Second Time, 2002

Figure 6. Vegetation layers, binaries by decided threshold (given in table 4-10)

For the purpose of comparison between the automatic feature space plot segmentation and the vegetation indices results, Tables 2 & 3 present the percentage area of the vegetated and non vegetated covers within the processed images. It should be noted in table 2 that; the total area of both temporally viewed sets of images was (130 Km^2), consisting vegetation cover about (108.35 km^2) in year (2001), and (60.32 km^2) in year (2002), it cover (83.35) and (46.4)%, respectively, using automatic feature space plot segmentation method.

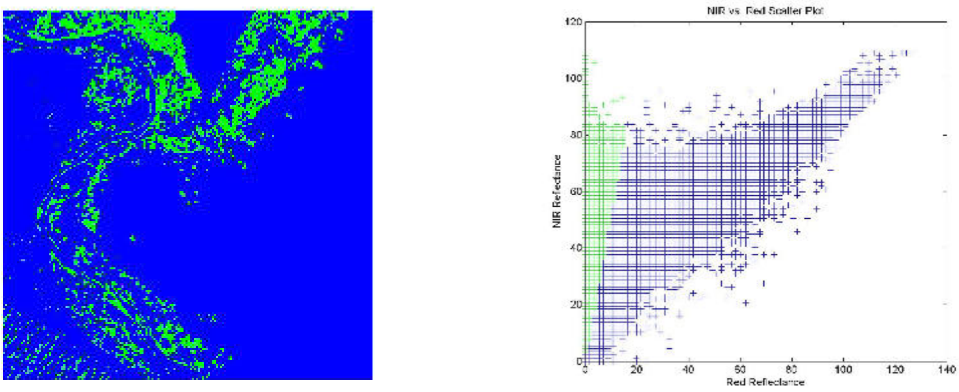
Table 2. The percentage areas for vegetation and non-vegetation segmented regions in two multi-temporal Landsat ETM+ images using automatically method

Data & Size	**%Percentage**	**Area (km^2)**	**%Percentage**	**Area (km^2)**
First Time [400 400]	83,35	108,43	16,73	21,8
Second Time [400 400	46,4%	60,32	53,81%	69,96

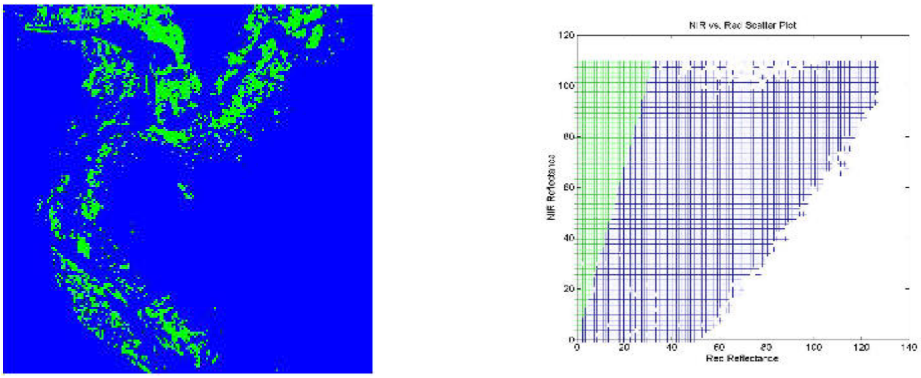
To compare the implementation of the vegetation indices with the automatic feature space plot segmentation results, figure 6 shows the studied areas as to consist either vegetated and non-vegetated regions, coloring them into green (for vegetated areas), and blue (non-vegetated areas), see right column of figure 7. Feature space plot diagrams then plotted by projecting the thresholded colored images on them, shown in the left column of figure 7.

Table 3. List of threshold values, and percentage vegetation coverage for vegetation indices images (First, and Second Time)

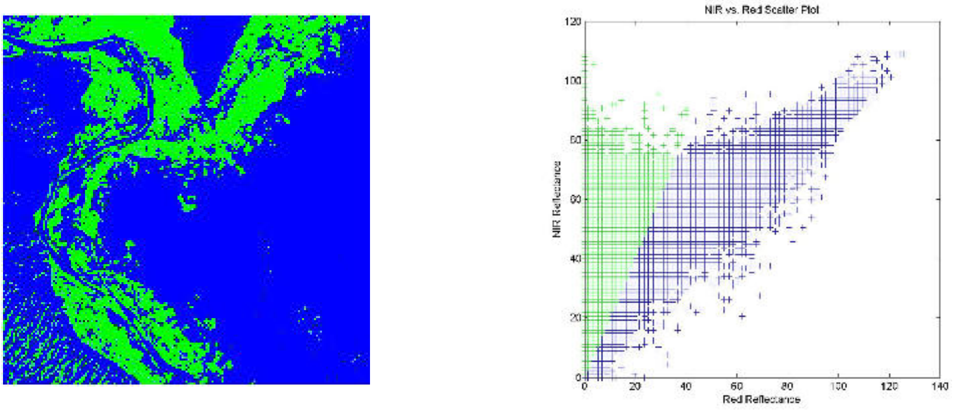
Index	**First Time (2001)**			**Second Time (2002)**		
	Threshold	**%Percentage**	**Area km2**	**Threshold**	**%Percentage**	**Area km2**
RVI	10	12.35	16.06	35	10.50	13.65
NDVI	180	19.92	25.89	145	21.40	27.82
IPVI	180	19.90	25.80	140	21	27.30



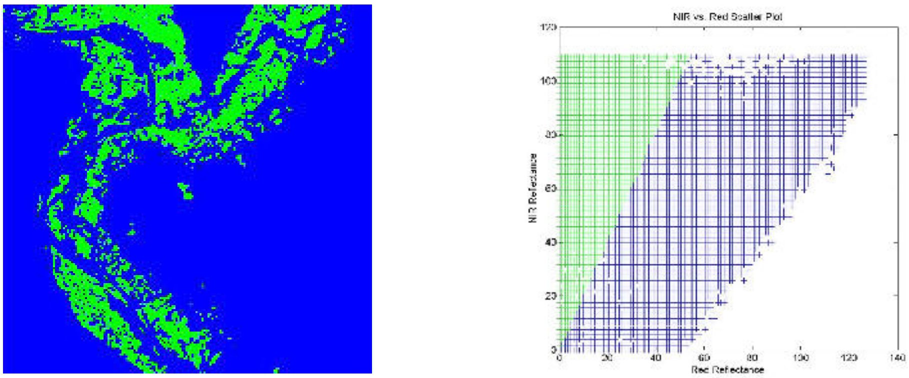
RVI First Time, 2001



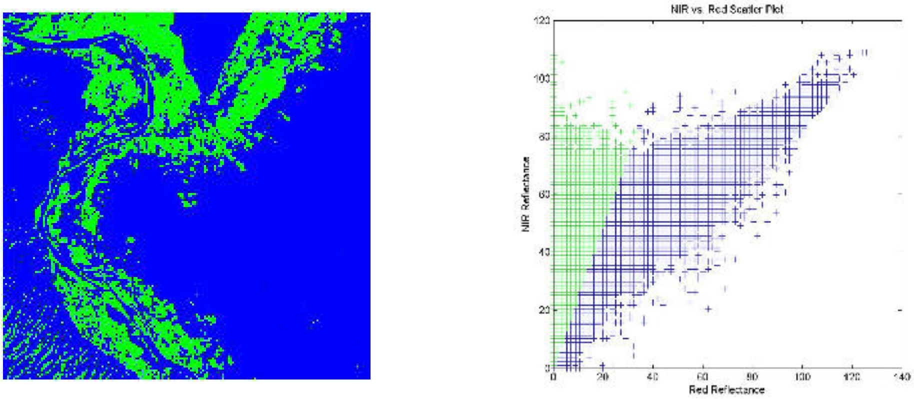
RVI Second Time, 2002



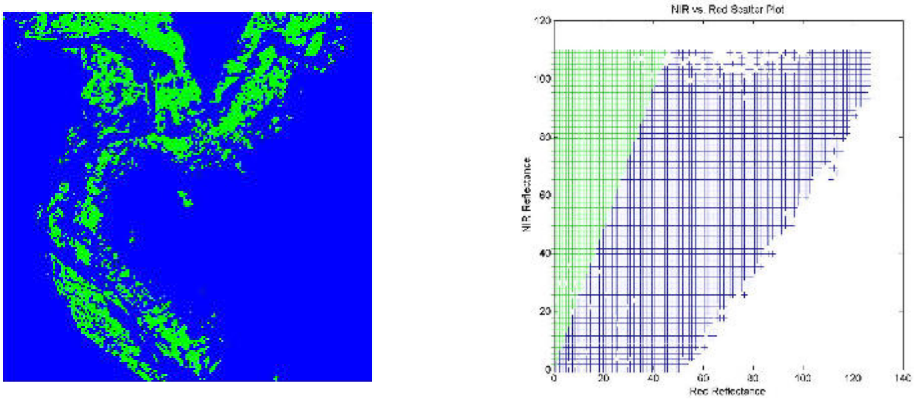
NDVI First Time, 2001



NDVI Second Time, 2002



IPVI First Time, 2001



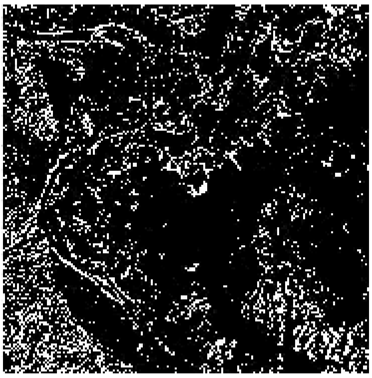
IPVI Second Time, 2002

Figure 7. Thresholded images and their feature space plot s, produced by projecting the values of thresholded images on the original feature space plots

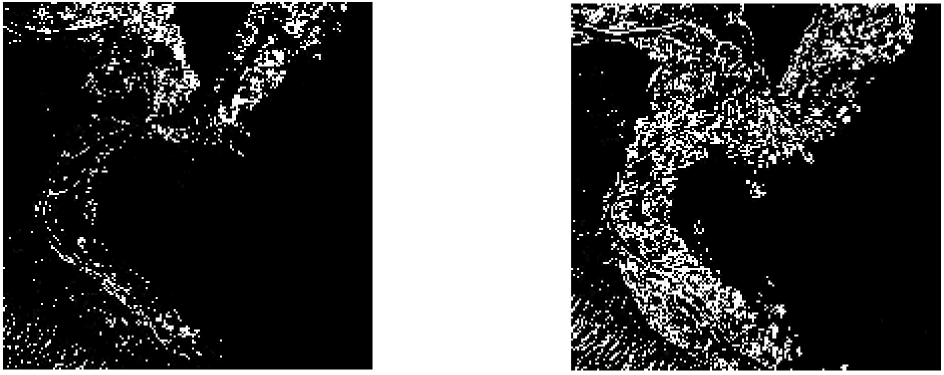
The changes in the vegetation areas have been computed, using differencing method between the thresholded images in figure 6 (Image (2002) - Image (2001)), as illustrated in figure 8. The changes in the vegetation areas with percentage variations, with and without implementing vegetation indices, are listed in table 4. This study was performed using 64-bit computer platform of core 2 Due 2.2 GHz processor and MATLAB version 2013 from the results of applying the vegetation indices and automatic feature space plot methods.

Table 4. 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**
RVI	8.36	10.87
NDVI	14.23	18.50
IPVI	14	18.20

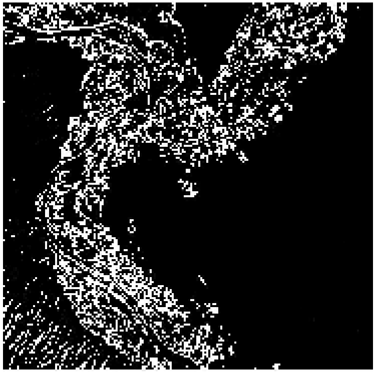


Change detection between First, and Second Time layers



Change detection of RVI layer

Change detection of NDVI layer



Change detection of IPVI layer

Figure 8. The changes in vegetation layers, using differencing images method

8. Conclusions

The monitoring of the vegetation health and land cover changes is one of the most applications of remote sensing. The methods have been attacked by segmenting remotely sensed scenes, using a purely statistics dependent criteria. A new automatic feature space plot method has been introduced, in this research, depending on the relationships between the amount of reflectance in the NIR band, and the amount of absorption in the Red band. The resulted segmented images using this new segmentation technique have been sliced into two layers according to the number of decided classes (i.e. only 2-classes (vegetation and non vegetation) were decided), by optimum threshold values which depended on image spectrum on the feature space plot. The variation between results of automatic feature space plot segmentation method refers to the mechanism of selection of position for bare land line in the feature space plot.

The ideal vegetation index must be applicable as good indicator of vegetated areas, and have enhanced vegetation characteristics while minimizing 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 research, different indices for vegetation have been adopted and used to differentiate vegetated areas from other land cover regions; these were (RVI, NDVI, IPVI). The (NDVI) yields higher recognized vegetated cover distribution than other vegetation indices, because this index related to the amount of vegetation detected by this index. 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. The differencing image and statistical characteristics have been implemented to delineate and calculate the areas of changes in agriculture land

However, any inadequate result may be referred to the viewing conditions; i.e. environmental effects (spectrally and reflectively affected scenes). As listed in tabulated results, the vegetated areas are mostly decreased; this may be caused by the amount of rainfall, irrigation, or agriculture policy.

The research recommends using endmember extraction techniques can help to differentiate between similar classes for the germinated vegetation healthy and wet soil.

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