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Spatio temporal analysis of vegetation by vegetation indices from multi-dates satellite images: Application to a semi arid area in ALGERIA

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Abstract

The vegetation index is considered a good indicator of vegetation behavior and can contribute to explain the evolution of vegetation. Hence the problem of our research: to what extent the analysis of the spatial and temporal evolution of vegetation index on a semi-arid region, allows us to understand its evolution and its relationship with the phenomenon of urbanization?

The objectives of the study is to analyze the spatio-temporal variations of the vegetation dynamics from a series of available multi-dates satellite images (MSS, LANDSAT ETM +) covering the Laghouat city which is a semi arid area of Algeria (from 1987 to 2006) and to describe the context of overall vegetation indices (NDVI, SAVI, TSAVI) to make a comparative study of fourths vegetation indices, to choose the best index according to the study area using.

There are two approaches that reduce the specific contribution of the ground so that the sensitivity of the index for the vegetation: One is based on a modified formulation of the normalized difference vegetation index (NDVI) differentiation respective contributions of red and near infrared bands i.e. SAVI index. On comparing the (NDVI) index with (TVI) which is designed to eliminate negative values and stabilize the variance, we note a clear description of the spectral behavior of vegetation by (TVI) according to its spectral spreading of vegetation histogram which is more important than the (NDVI).

As for the (SAVI) index designed for low vegetation cover by chlorophyll is used to reduce the spectral contribution of soil best suited to the semi-arid region.

We note an improvement in spectral spreading vegetation compared to the NDVI and TVI, thus improving the description of the vegetation index SAVI. By adopting the adjusted vegetation index SAVI ground and classifying

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thematic images as following: the 1987 blue, green 2001 and the 2006 red and superposition of three layers, one obtains a thematic map representing the vegetation change from 1987 to 2006. The choice of these three dates specifically related to the fact that the analysis is sensitive to vegetation season (vegetation different from one season to another). To make a comparative study one must choose images, the acquisition dates of which are very close (the same month). This diachronic study (spatio-temporal) allows us the analysis of the rate/rhythm of the extension and the distribution of vegetation.

Keywords: Semi arid , vegetation Index, remote sensing image, vegetation dynamic

1. Introduction

Most remote sensing satellite sensors offer multispectral images besides panchromatic images. This multispectral information is extremely valuable to detect various objects in the image. Nearly all plants need sunlight to survive, using chlorophyll to convert radiant energy from the sun into organic energy. Chlorophyll exhibits unique absorption characteristics, absorbing wavelengths around the visible red band (645 µm) while being transparent to wavelengths in the near-infrared (700 µm). These characteristics of chlorophyll are commonly used to design indices to estimate the local vegetation density in multispectral satellite or airborne imagery.

Assessing and monitoring the state of the earth surface is a key requirement for global change research. Classifying and mapping vegetation is an important technical task for managing natural resources as vegetation provides a base for all living beings and plays an essential role in affecting global climate change.

Previous studies have compared vegetation indices based on various criteria [1-3]; yet no clear winner has emerged. In some experiments, the NDVI outperforms all other indices; for others it is less successful. It is clear that, despite many attempts to develop alternatives, the NDVI remains one of the most effective indicators of vegetation density.

Since its introduction, the NDVI has been used in a wide variety of studies including those on global vegetation [4, 5], crop estimation and vegetation growth [6-8], land cover [9-11] and climate [12-14].

Vegetation mapping also presents valuable information for understanding the natural and man-made environments through quantifying vegetation cover from local to global scales at a given time point or over a continuous period.

ETM+ of Landsat images were used a long time to analyze the dynamics of the vegetation. These images have the advantage of a space good resolution and a large cover temporal [15, 16], we can find an excellent survey about vegetation method extraction in [21].

The objectives of the study is to analyze the spatio-temporal variations of the vegetation dynamics from a series of available multi-dates satellite images (MSS, LANDSAT ETM +) covering the Laghouat city which is a semi arid area of Algeria (from 1987 to 2006) and to describe the context of overall vegetation indices (NDVI, SAVI, TSAVI) to make a comparative study of fourths vegetation indices, to choose the best index according to the study area using. We note an improvement in spectral spreading vegetation compared to the NDVI and TVI, thus improving the description of the vegetation index SAVI.

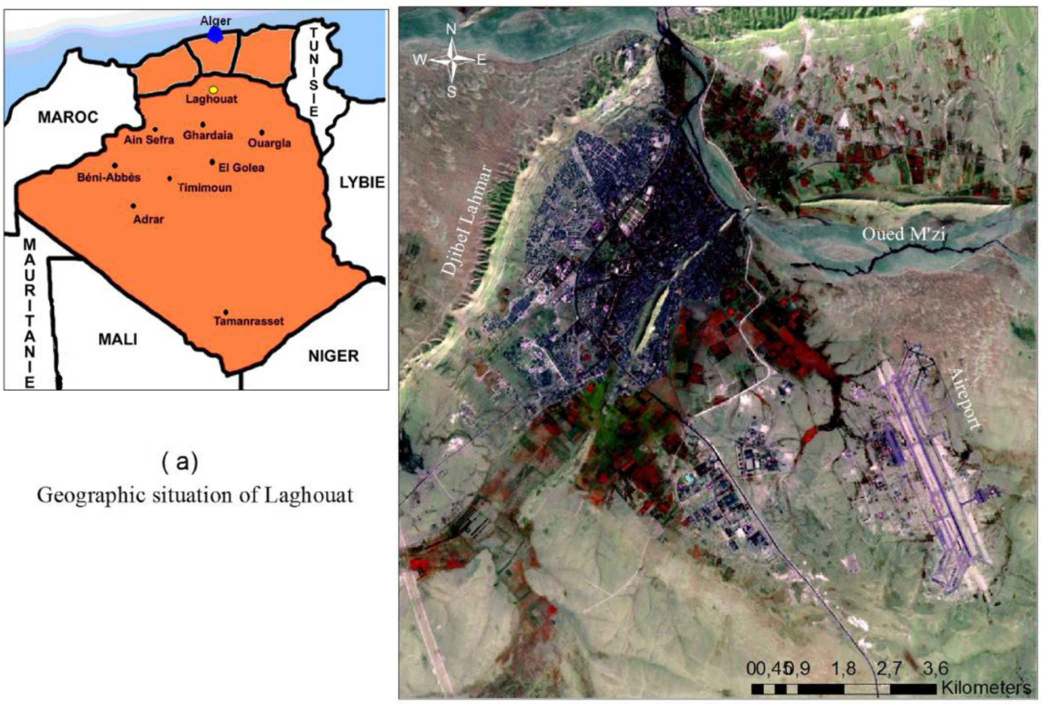
By adopting the adjusted vegetation index SAVI ground and classifying thematic images as following: the 1987 blue, green 2001 and the 2006 red and superposition of three layers, one obtains a thematic map representing the vegetation change from 1987 to 2006. The choice of these three dates specifically related to the fact that the analysis is sensitive to vegetation season (vegetation different from one season to another). To make a comparative study one must choose images, the acquisition dates of which are very close (the same month).

This diachronic study (spatio-temporal) allows us the analysis of the rate/rhythm of the extension and the distribution of vegetation.

2. Study area

Laghouat is an oasis city located at approximately at 400 km south of Algiers, to 751 m of altitude and with latitude of 33,799° N and a longitude of 2,882 ° E. It is an oasis built on the boards of the Wadi M'zi, the largest Wadi of the south of Saharian Atlas, limited to the south by a broad pastoral zone which extends until Bordj of Tilghemt covering a surface of 400 km^2, Fig.1.

Oasians systems in Algeria, and particularly in Laghouat, underwent major and accelerated changes since the decade 1950. Certain periods and events of the history marked in a particular and notable way this evolution : forced sedentarisation of the wandering populations in the end of decade 50 and at beginning of the decade 60, discovered of hydrocarbons , sedentary conditions of the Nineties, the demographic growth of the population, the urban extension of the various agglomerations..., such are the principal aspects of the multiple changes of oasian space. During these transformations, the oasian environment has rocked towards a configuration of a complex urban morphology and a structure always not answering to architectural and urbanistic standards.



(a)
Geographic situation of Laghouat

(b) SPOT image of Laghouat (from Scientific project ISIS of CNES(n°22)

Fig.1 Geographic situation of study area

3. Materials and Methods

3.1. Materials

The satellite images used for this study are: one Thematic Mapper (TM) and two Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images with a resolution of 30 meters acquired respectively in: April 11 1987, April 2 2001, April 16 2006 and were acquired at one favorable time of the year, April. Each spectral band was downloaded from data base of the GLCF (Total Land Cover Facility) of the University of Maryland and combined in false color composite to have an idea of the general information contained in the various channels. The high resolution of the sensor especially ETM+ (30m) is well suited for determining land cover, vegetation type and health, and geologic characteristics. Table 1 shows spectral characteristics of the used images.

Table 1. Landsat 7 Enhanced Thematic Mapper Plus (ETM+) sensor

Bands	Wavelength (µm)	Resolution (m)	Waveband
TM1	0.45-0.515	30	blue
TM2	0.525-0.605	30	green
TM3	0.63-0.69	30	red
TM4	0.75-0.90	30	Very Near-Infrared
TM5	1.55-1.75	30	Near-infrared
TM6	10.4-12.5	60	Thermal
TM7	2.09-2.35	30	Shortwave infrared
TM8	0.52-0.90	15	Panchromatic

3.2. Methods

- *Preprocessing*

Pre-processing of satellite images prior to vegetation extraction is essential to remove noise and increase the interpretability of image data. This is particularly true when a time series of imagery is used or when an area is encompassed by many images since it is essentially important to make these images compatible spatially and spectrally. Thus, it is recommended to consult with the image distributor and get to know at what level the imagery is (usually including level 0, 1A, 1B, 2A, 2B, 3A, 3B with image quality gradually increased) before imagery purchase. For example, for most sensors, level 3A means that radiometric correction, geometric correction and orthorectification have been processed for the images. A procedure of mosaicing where used to create the scène of our study.

- *Vegetation indices*

In vegetation studies the ratios, commonly known as vegetation indices, have been developed for the enhancement of spectral differences on the basis of strong vegetation absorbance in the red and strong reflectance in the near-infrared part of the spectrum. It has been shown that a ratio of near-infrared band 4 and red band 2 is significantly correlated with the amount of green leaf biomass [17]. There are a number of vegetation indices such as:

1. *Normalized differential vegetation index (NDVI)*: *or index of Tucker*

The independent variable is the surface area of NDVI. The standard equation for NDVI is calculated using Eq. (1). The ratio of these two bands combination has proven to be highly correlated with vegetation parameters as green biomass, absorbed radiation by photo synthetically active vegetation [17, 19]. The NDVI being a ratio of two bands can correct eventual errors due to topography and shade and compensate for illumination variation due to terrain. Healthy forests reflect strongly in the near infrared (NIR) portion of the spectrum while absorbing strongly in the visible red (RED). On the other hand, soil, bare ground, and rock show near equal reflectance in both the near infrared and red portions and have NDVI values close to 0. Water bodies have the opposite trend to vegetation and the NDVI is negative. The NDVI image would significantly enhance the discrimination of vegetation cover from other surface cover types. While high values indicate temper ate and tropic al forests. NDVI generally ranges from 0.05 for sparse vegetation cover to 0.7 for dense vegetation cover.

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

2. *Transformed Vegetation Index (TVI)*

This index is conceived for the elimination of the negative values of the NDVI, and for the stabilization of the variance [18]. It is calculated using Eq. (2)

$$TVI = \sqrt{\frac{NIR - RED}{NIR + RED} + L} \quad (2)$$

3. *Soil adjusted vegetation index(SAVI):*

This index, suggested by Huete [20], he introduce a parameter of adjustment, noted L, which characterizes the ground and its rate of covering by the vegetation. Huete showed that the isolignes vegetation is not parallel to the right-hand side of the grounds, but which they cut this one in a point according to the density of vegetable cover. The parameter L takes the value of 0, 25 for a strong density and 1 for a very low density of vegetation. For intermediate densities, it is equal to 0, 5.

$$SAVI = \frac{PIR - RED}{PIR + RED + L}(1 + L) \quad (3)$$

4. Vegetation mapping: Result and discussion

The tree vegetation indices were processed from the mosaic images. The result is showed by Fig.2.
It is possible to visually compare all of the vegetation index images we have produced. Some obviously have better contrast than others. Some seem to show more variation within the low-value areas. However, without ground-truth information about the status of vegetation in the area, we cannot determine which indices are most useful. What we will do is analyze the set of images as a whole to see what different characteristics are illustrated by the various indices.

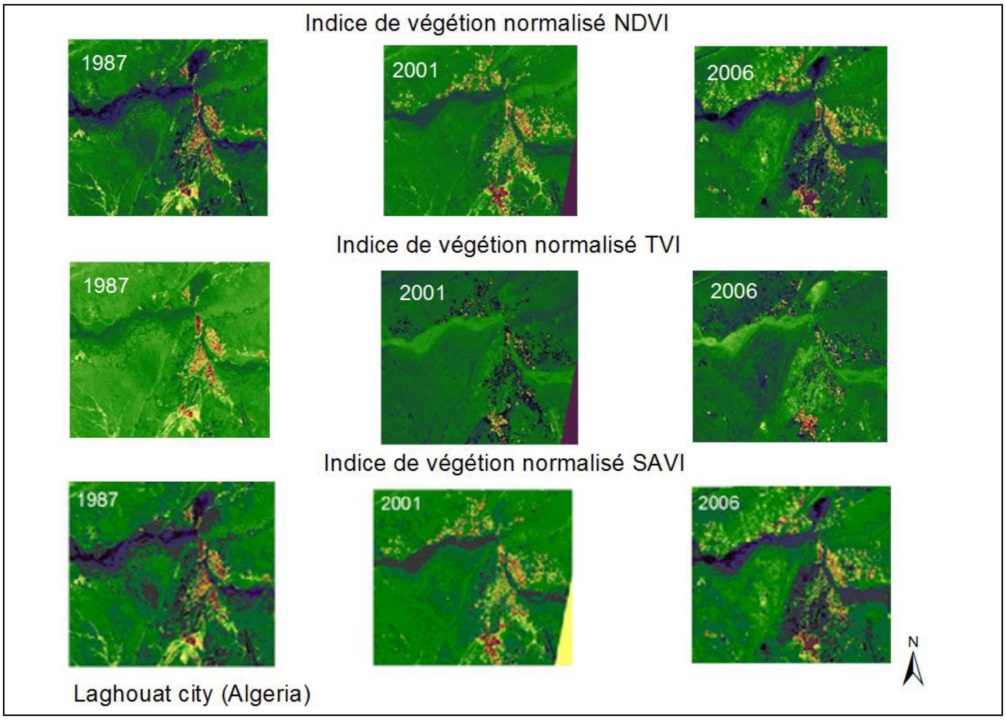


Fig. 2. The three vegetation indices applied to the three satellite image

To convert the vegetation index images to byte binary format, we will perform a linear stretch on each image to transform the original range of values to the new range of 0-255. The threshold values may also be derived from the histogram of the image. Table.2 shows the low and high values of each threshold.

Table 2. Choice of for each vegetation index image

	low - high threshold value		
Vegetation index	ETM+(1987)	ETM+(2001)	ETM+(2006)
NDVI	0.015 - 0.145	0.01- 0.18	0.02 - 0.36
TVI	0.60 - 0.82	0.71- 0.83	0.71 - 0.96
SAVI	0 - 0.20	0 - 0.30	0 - 0.53

There are two approaches that reduce the specific contribution of the ground so that the sensitivity of the index for the vegetation: One is based on a modified formulation of (NDVI) differentiation respective contributions of red and near infrared bands e.g. SAVI index. On comparing the (NDVI) index with (TVI) which is designed to eliminate negative values and stabilize the variance, we note a clear description of spectral behavior of vegetation index TVI with a larger spread of the histogram compared to that of the NDVI. As for SAVI index conceived for weak covering by the chlorophyllian vegetation is used to decrease the spectral contribution of the grounds and more adapted to the semi-arid area. We note a

spreading out of the spectrum of the vegetation of the SAVI compared with the NDVI and TVI, therefore a better description of the vegetation by SAVI index in semi arid zone.
By adopting the adjusted vegetation index SAVI ground and classifying thematic images as following: the de1987 blue, green 2001 and the 2006 red and superposition of three layers, one obtains a thematic map representing the vegetation change from 1987 to 2006, Fig.3. The choice of these three dates specifically related to the fact that the analysis is sensitive to vegetation season (vegetation different from one season to another).

A simple way to perform change detection between two satellite images is to put a composition of colours. The algorithm chosen for the detection of changes in our case is the simplest possible, i.e. the colour composite and multi thresholding images dates, Fig. 4.

As shown in Fig.4, new vegetation areas are represented by colour red, the stable vegetation zones are represented by white colour whereas the vegetation in 1987 and which is always stable are represented by magenta. We notice that in 2006, new vegetation areas (in red colour) are appeared, those correspond to the agricultural zones. The vegetation low on the level of the industrial park is a bad interpretation that the two images were can be taken during one rains time what led to the appearance of a low vegetation. The new red and yellow zones outside the city are arable lands appeared within the framework of the development of new arable lands to stop the turning into a desert around the town of LAGHOUAT and its surroundings.

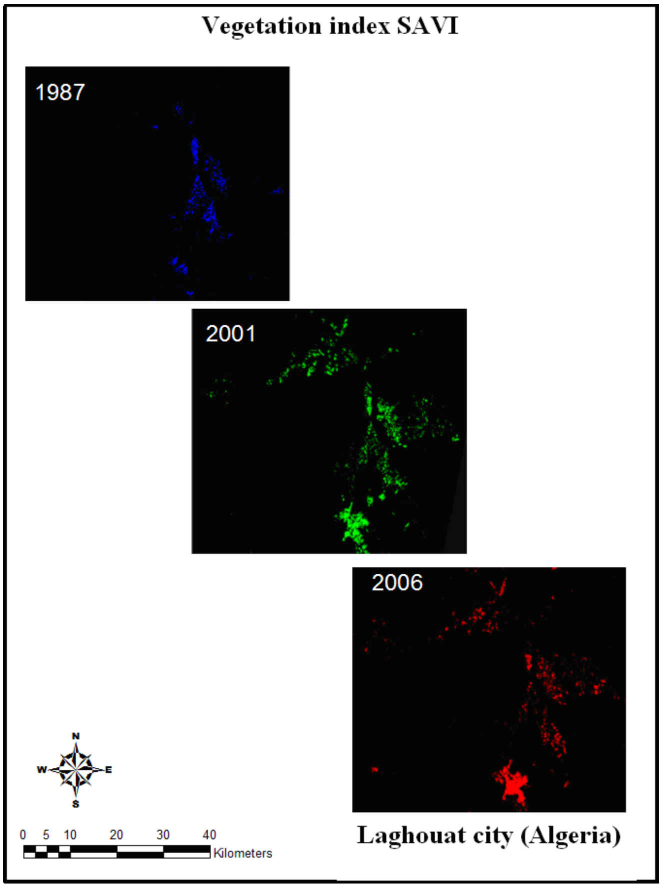


Fig. 3. The three plant RGB (red, green, blue)

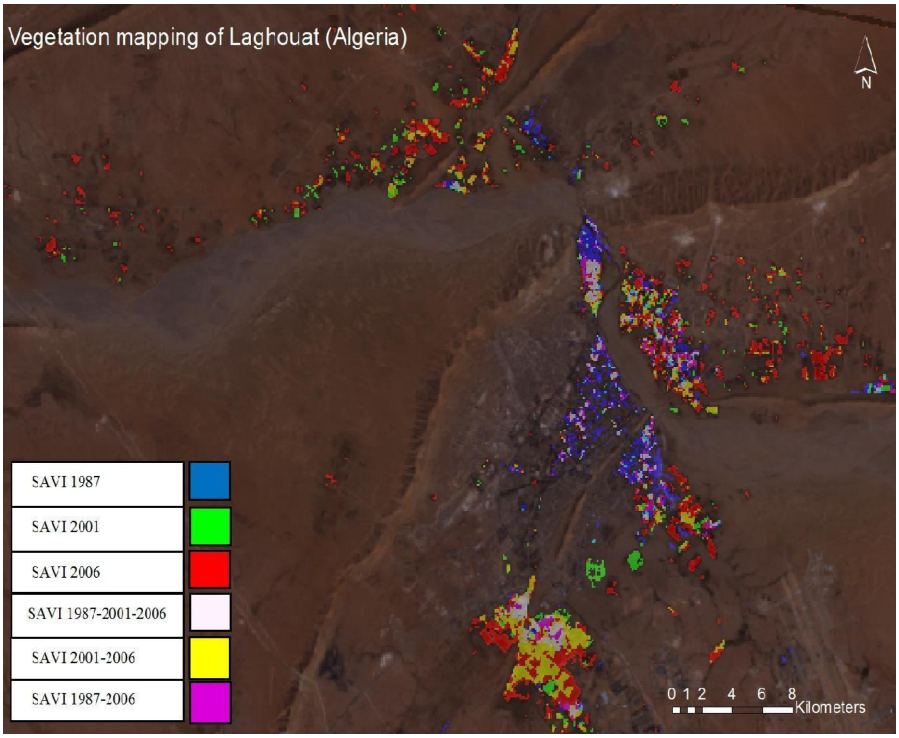


Fig. 4. Evolution of the vegetation of Laghouat from 1987 to 2006

5. Conclusion

In this paper we have implemented three vegetation indices most usually used in remote sensing. Based on combinations of reflectance these indices enable us to highlight the differences in behaviour between green vegetation and ground, in the visible and the infra-red relation. In this study we could carry out a chart set of themes representing the evolution of the vegetation, a work which gives a rather total and realistic vision of the vegetation dynamics in a semi arid area from Algeria. We note a spreading out of the spectrum of the vegetation of the SAVI compared with the NDVI and TVI, therefore a better description of the vegetation by SAVI index in semi arid zone.

We can note a negative change of the vegetation inside the old city of Laghouat which was replaced by individual houses and buildings. A positive change of vegetation in the new zones especially in north and the east of the city (in red colour) resulting from the development of new agricultural lands to stop the wind erosion and desertification around the city of LAGHOUAT (Algeria) programmed by the state.

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