THE NORMALIZED DIFFERENCE VEGETATION INDEX AS AN INDICATOR OF DYNAMICS

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ABSTRACT

Mediterranean ecosystems are considered particularly sensitive to climate change. Any change in climatic factors affects the structure and functioning of these ecosystems and has an influence on plant productivity. The main objective of this work is to characterize one of the Mediterranean ecosystems; the Chettaba forest massif (located in the North-East of Algeria) from a vegetation point of view and their link with monthly variations using Landsat 8 satellite images from five different dates (June 25, 2017, July 27, 2017, August 28, 2017, October 15, 2017). The comparison of NDVI values in Aleppo pine trees was performed using analysis of variance and the use of Friedman's non-parametric test. The Mann-Kendall statistical method was applied to the monthly distribution of NDVI values to detect any trends in the data over the study period. The statistical results of NDVI of Aleppo pine trees indicate that the maximum value is recorded in the month of June, while the lowest values are observed in the month of August where the species studied is exposed to periods of thermal stress.

Keywords: *Pinus halpensis, NDVI, Friedman's test, monthly variations*

INTRODUCTION

Forest degradation has become a serious problem, particularly in developing countries. In 2000, the total area of degraded forests in 77 countries was estimated to be 800 million hectares, of which 500 million hectares had been converted from primary to secondary vegetation [1].

Among its various negative impacts, the process of forest degradation constitutes a significant part of greenhouse gas emissions. There is an urgent need to measure and analyze this process in order to design actions that can reverse it.

This work describes how a method combining the analysis of remote sensing data and field data to observe forest degradation has been put into practice. It presents a study conducted to identify the relationship between indicators of forest functions and the normalized difference vegetation index (NDVI). This index

provides estimated values of the "green intensity" of forests, resulting from the analysis of satellite data. The approach is based on the principle that NDVI is an indicator of plant health, insofar as a degradation of the vegetation of an ecosystem, or a decrease in the intensity of green, would result in a decrease in the value of NDVI.

The forest massif of Chettaba (Algeria) is part of the Mediterranean basin, and it is constituted of a very important floristic richness, in particular a mixed forest of holm oak - Aleppo pine, maquis and grasslands accounting for a total area of 2398 ha. On the orographic plan, these forest groups are distributed between 755m and 1292m of altitude. The monthly climatic variations are effectively perceived, namely the thermal variability on the concerned massif. The objective of this work is to monitor the evolution of the degradation process by using GIS (Geographic Information System), aerial photos and satellite imagery will allow establishing maps of distribution, thermal and normalized vegetation index (NDVI).

MATERIAL AND METHODS

Description of the study site

The state forest of Chettaba belongs to the watershed Kebir Rhumel; it is located southwest of Constantine, south of Ibn Ziad, north of Ain Smara and east of Oued Athmania. It covers an area of 2398ha 94a 30ca. The altitude varies between 755 m to 1292 m (Figure 1) of which 34.63% of the area is represented by the class of altitude from 855m to 955m (Figure 2).

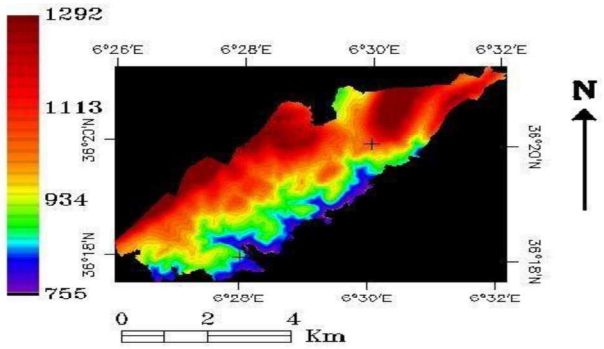

***Fig. 1**. Hypsometric map of Chettaba forest using ENVI 5.1 software.*

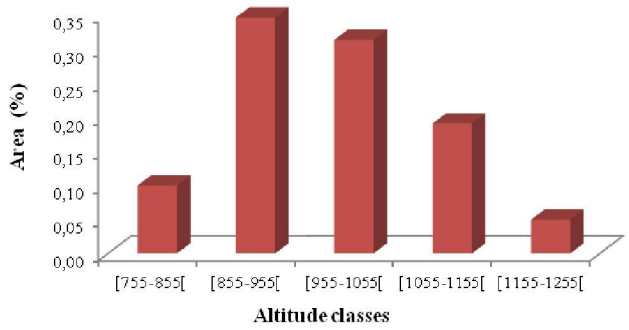

Fig. 2. *Distribution of altitude classes in the Chettaba forest.*

Study methodology

Choice of the stations

In order to carry out this work, field investigations have been adopted through observation. The objective is to determine the typology of these formations as well as the plant species that compose it. Stations of 30m by 30m were randomly selected in order to explain their phenological character with the help of satellite images (Figure 3).

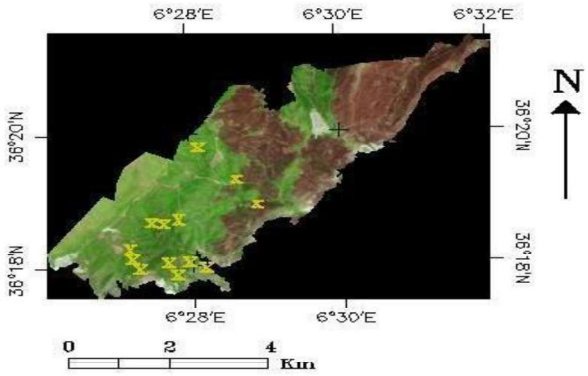

Fig. 3. *Location of study stations on a true color composition of the Landsat 8 (June 25, 2017 using ENVI 5.1 software).*

Calculation of the Normalized Vegetation Index (NDVI)

Before analyzing the selected images, it is necessary to correct them in order to make them usable and comparable. The pre-processing corresponds to a set of operations on Landsat 8 satellite images of five different dates (June 25, 2017, July 27, 2017, August 28, 2017, October 15, 2017), which aim to modify the raw images according to three aspects: a correction of geometric, radiometric and atmospheric

distortions using ENVI 5.1 software. The calculation of the normalized vegetation index (NDVI) is based on two spectral bands, red R and infrared IR [2] using the following formula:

$$NDVI = (PIR - R)/ (PIR + R)$$

Statistical analysis

The comparison of NDVI values in Aleppo pine trees was performed using analysis of variance and Friedman's non-parametric test. The calculations were performed using the XLSTAT 2019 version 1.2 software.

The Mann-Kendall statistical method [3], [4] was applied to the monthly distribution of NDVI values to detect any trends in the data over the study period. It is a non-parametric statistical test well suited to measure changes in data over time [5]. Positive values (+) indicate an increase over time while negative values (-) indicate a decrease. The test observes whether a random response variable increases or decreases monotonically over time.

RESULTS AND DISCUSSION

The results of the descriptive statistical analysis of the variance of NDVI of Aleppo pine trees indicate that the maximum value is recorded in June, while the lowest values are observed in August (Table 1).

Table 1. *Results of the descriptive statistical analysis of the NDVI values of Aleppo pine.*

NDVI	Observations	Observations without missing data	Minimum	Maximum	Average	Type of Gap
25/06/2017	21	21	0.186	0.310	0.237	0.033
27/07/2017	21	21	0.185	0.285	0.231	0.029
28/08/2017	21	21	0.148	0.236	0.194	0.024
13/09/2017	21	21	0.155	0.268	0.215	0.028
15/10/2017	21	21	0.132	0.253	0.197	0.031

In order to determine whether the samples are from the same population or not, we applied the Friedman test (Figure 4). Applied the Friedman test, the proposed hypotheses are:

H_0: The samples come from the same population.

Ha: The samples come from different populations.

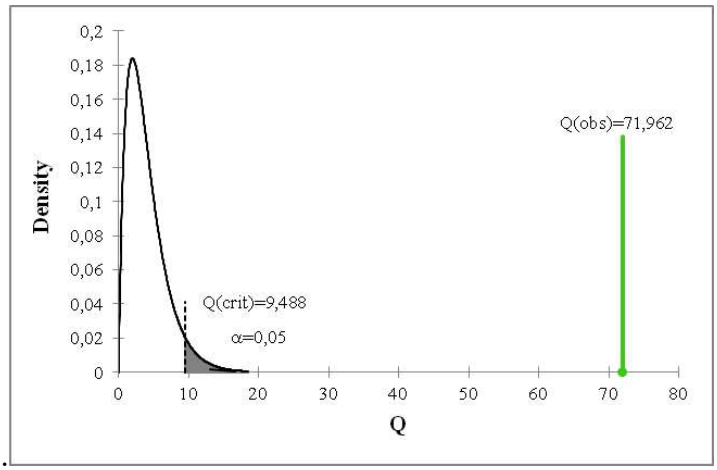

Fig.4. *Friedman's test of NDVI values of Aleppo pine.*

During the statistical calculations, the F-test of the analysis of variance (at the probability threshold (α=0.05) proved to be highly significant ($p < 0.0001$). Since the calculated p-value is below the significance level α=0.05, the null hypothesis H_0 should be rejected, and the alternative hypothesis Ha should be retained (Table 2). Great variability of the NDVI values of Aleppo pine trees has been highlighted. This is probably directly related to the months.

Table 2. *Friedman's test results.*

Q (Observed value)	71.962
Q (Critical value)	9.488
DDL	4
p-value (unilateral)	< 0.0001
Alpha	0.05

Pairwise multiple comparisons following the Nemenyi procedure indicate the presence of four Presences of four homogeneous groups, where group A corresponds to the NDVI values of August and October with the lowest values, and the last group includes the NDVI values of June with the highest values (Table 3).

Table 3. *Multiple pair-wise comparison of NDVI values following the Nemenyi/Two-Way Test.*

Sample	Workforce	Sum of the ranks	Average of the ranks	Groups
25/06/2017	21	29.000	1.381	A
27/07/2017	21	34.000	1.619	
28/08/2017	21	67.000	3.190	B
13/09/2017	21	89.000	4.238	BC
15/10/2017	21	96.000	4.751	C

Concerning the month effect, the analysis of variance showed a very highly significant effect on significant effect on the variation of NDVI values for the trees studied (Figure 5). The statistical analysis of variance revealed a very highly significant interaction (NDVI * Month). The month factor has a strong influence on the variation of NDVI values of Aleppo pine trees.

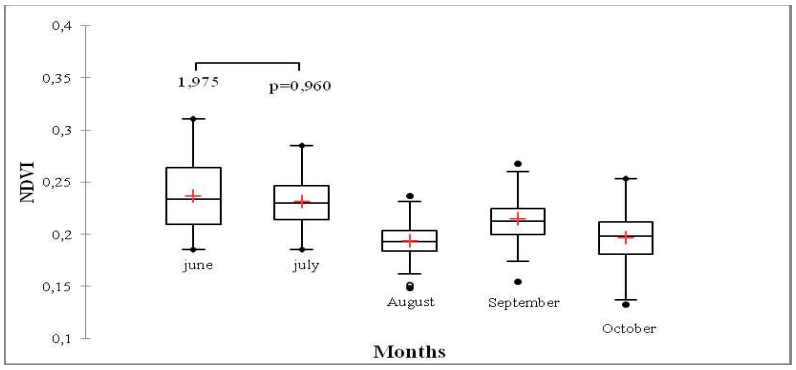

Fig. 5. *Box plots of NDVI values by month.*

CONCLUSION

There are limitations to the use of NDVI as a measure of forest degradation, but also areas of potential refinement. Since phenology plays an important role in the analysis of change processes, the dates of Landsat 8 satellite images used to assess these processes must be selected very carefully. These images are suitable for the analysis of changes resulting from degradation, when the impact has been large enough to be reflected in the radiometry, and thus in the NDVI. NDVI has an anticipated behavior and can therefore be used as an indicator.

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