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Thermal Disturbances and their Impact on Vegetation Productivity in Natural Reserve of Beni Salah (North East of Algeria) from 1986 to 2015

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ABSTRACT

This study characterized one of the Mediterranean ecosystems, which is the Natural Reserve of Beni Salah (located in the North East of Algeria in province of Guelma), from the vegetation and climate points of view. The link between these two parameters was also studied using meteorological data and satellite imagery in the period from 1986 to 2015. For this reason, the homogeneity of temperature series was tested using Standard Normal Homogeneity, Pettitt ; Buishand and Von Neumann tests. The Mann-Kendall trend test and Sen's slope were applied to test the trends and changes over a long period of maximum, minimum and mean temperature data. Also, the vegetation was analyzed through the calculation of the normalized difference vegetation index (NDVI) from satellite images of Landsat. The obtained results showed the important inhomogeneous structure for the months of April and July in 1999 and 2000; respectively. It was found that maximum temperature presented positive Kendall's value which indicated an increasing trend over the time, with the significant warming of 0.11 °C for the spring season. Over the years, the diachronic of the vegetation productivity (NDVI) varied from a type of formation to another with a peak values in forest formation (zeen oak and cork oak), while a decrease was observed from year to year in this formation corresponding to stressed vegetation. The strong negative correlation between NDVI and the maximum of temperature was observed, which indicated that the warming had a great impact on forest formation productivity, leading to changes in plant physiological processes.

Keywords: *Climate, Forest, Natural reserve of Beni Salah, NDVI, Satellite image, Temperature, Vegetation.*

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1. INTRODUCTION

Due to the existing multiple factors like climate, geomorphology, soil, hydrology and land use, the Mediterranean region has been considered as a highly complex environment. It has been estimated that about 25000 plant species inhabit the region (Myers et al. 2000), among them about 60 percent is endemic (Thompson John et al. 2005), making the region having one of the highest concentrations of endemic plants in the world (Myers et al. 2000) and one of the most important genetic hotspots for natural resources (Cavalli-Sforza 1991; Cavalli-Sforza et al. 1994). It has been classified among the hotspots of biodiversity with several protected sites. One of these sites is the Natural Reserve of Beni Salah which is situated in the north-east of Algeria. This reserve contains very important superficies of forests of cork oak (Quercus subers L.) and zeen oak (Quercus canariensis), and it needs special care from the scientific community in order to protect this biodiversity. This region has been affected by many factors such as climatic changes and human activities. The climatic changes influence on the composition of the ecosystems and the distribution of plant communities. The application of remote sensing can be used to illustrate the impact of climate on regional ecosystem processes by the response of vegetation to climatic features. It can observe and identify land cover change at various spatial and temporal scales, especially with high temporal resolution satellite data (Carlson & Arthur 2000). NDVI (the normalized difference vegetation index), and the relationship between plant cover and temperature have been affected by a wide range of climatic and physical variables. Solar radiation, air temperature close to the earth's surface, and rainfall can be considered as the most important variables (Churkina & Running 1998; Nemani et al. 2003).

Temperature is one of the primary climatic parameters, and the variations in its pattern can influence the living components of the earth (Onoz & Bayazit, 2003). Rising temperatures cause vegetation to displace in latitude and altitude. In the Mediterranean region, according to the research by PNUE/PAM-Plan Bleu in 2009; it has been estimated that a 1°C increase in temperature could cause certain plant species to migrate approximately 180 km to the north or 150 m in altitude.

This paper has focused on the current climatic situation in the forestry sector of the Natural Reserve of Beni Salah, especially temperature variations and their influence on the vegetation productivity in this site. These variations have been actually perceived over the last decade (from 2006 to 2015). The homogeneity tests of time series of temperature were applied using Standard Normal Homogeneity (SNHT), Pettitt ; Buishand and Von Neumann tests. In order to check the reliability and homogeneity of the monthly maximum and minimum temperature series, Tuomenvirta et al. 2000 applied the SNHT method. In this study, Mann Kendall and Sen slope tests were used to better explain temperature trends (changing and variability of monthly, seasonal and annual temperature from 1986 to 2015). The studies of Atılgan et al.in 2017 and Alhaji et al. in 2018 were done using Mann Kendall non-parametric test because of its applicability for a time series distribution, which does not follow a typical statistical distribution. Moreover, the survey of the possible modifications of the forest formation (distribution area, dynamics, etc.) of this study site were examined from satellite data using NDVI and their relationship to climatic variability.

1.1. Study site

Natural Reserve of Beni Salah is one of the forest series of Beni Salah which extends over an area of 2272.14 hectares in the north east of Algeria in the province of Guelma, created in 1972, to house the population of Barbary deer (Cervus elaphus barbarus), species on the way of disappearance (fig.1). As a result, it enjoys protected area status according to the recommendation of the Convention on Biological Diversity ratified by Algeria in 1992. In this study, the following formations of Cork oak, Zeen oak, mixed formation of Cork oak and Zeen oak, scrub and lawn were found. This study's site was enlarged to 3201.12 hectares in order to survey peripheral area, too. The altitude varied between 520 and 904m (fig.2).

2. MATERIALS AND METHODS

2.1. Data collection

For investigation of tree and shrub productivity, the study area was divided into six zones considering the type of formation of vegetation and the land cover. In each type of formation, different points were taken in the site (the geographic situation: longitude and latitude of each group of vegetation using Globoling Position System). Every point contained the type of formation, geographic situation and altitude.

2.2. Data sources

The data in the present study included measurements of maximal and minimal temperature, which were obtained from the State Meteorological Service (ONM) in Algeria from 1986 to 2015.

The satellites images of LandSat were used dated from 1987 to 2015. Three scenes covering the study area were obtained on 04September 1987 (Landsat 5 TM), 11July 1999 (Landsat 7 ETM+) and 14July 2015 (Landsat 8 OLI) to survey the natural vegetation in the study area which varied from deciduous woodland to evergreen species, and also to analyze the relationships between forest and the increase of temperature. Topographic maps and Digital Elevation Model (DEM) were also used.

2.3. Analysis of temperature

The time series data of monthly and annually average of temperature (maximum and minimum), were computed using excel spreadsheet. Statistical method was applied to, monthly, seasonal and annual temperature from 1986 to 2015 to detect any possible trends in the data over the study period. XLSTAT 2019.1 is a statistical software for data and time series analysis. It offers homogeneity tests for time series tests which allow to detect changes along a time series. In this study, Standard Normal Homogeneity Test (SNHT), for single rupture; Pettitt test ; Buishand range test and Von Neumann ratio test were used to identify the inhomogeneous temperature series for the annual mean, maximum and minimum temperature values of the station. Standard Normal Homogeneity Test (SNHT) was proposed by Alexanderson (1986) to determine the inhomogeneous structure in the time series. The inhomogeneous structures were identified by the SNHT at the beginning and/or towards the end of the series. Pettitt (1979) developed a test named as the Pettit test which is a nonparametric test which identifies one point of change in the observed time series; this test can sensitively identify the inhomogeneous structures in middle of the time series (Costa & Soares 2009). The null hypothesis, H0, of all the tests was that the observations are independent and uniformly distributed, therefore, there was an equal probability for all the possible permutations, while the substitute hypothesis, H1, was that a change in the average value happens for SNH, Pettitt, and Buishand tests, and that observations are not randomly distributed in Von Neumann ratio test, i.e. the observations are correlated. All the four tests provided the information on the existence of a rupture point, in addition, SNHT, Pettitt, and Buishand tests provided an indication of when the shift occurred (Renata et al. 2012).

In this study, the non-parametric Mann-Kendall test was used for the detection of the trend in a time series. Mann-Kendall Statistic (u(t)) was calculated. Equations 1 and 2 below were used to calculate the MKT statistic:

$$t = \sum_{i-1}^{n} n_i \qquad \text{(Equation 1)}$$

$$u(t) = \frac{(t-E(t))}{\sqrt{var(t)}} \qquad \text{(Equation 2)}$$

The u(t) value, calculated as a result of the test, was directly compared with the table value (tCritic) of the 95% confidence interval (t2,(n2)) in the Student-t distribution, and the existence of a trend in the variables was identified (Atılgan et al. 2017).

The magnitude of the trend was determined using Sen's estimator. A positive value of b indicated an upward (increasing) trend and a negative value indicated a downward (decreasing) trend in the time series (Atılgan et al, 2017).

2.4. Vegetation analysis

To assess the dynamics of the vegetation productivity in the Natural reserve of Beni Salah, the diachronic method was used. This method has been applied to compare two maps or two photographic covers from different areas based on the exploitation of the planimetric data (density), either systematically or by sampling (grids method) and statistical tools like confusion matrices (Foundi et al. 2001). These comparisons showed the average speed of evolution which led to losses or gains of surfaces wooded to a special amount of density or some level of recovery through the study period. In this study, three missions of the years 1987, 1999 and 2015 were considered.

Vegetation indices have been widely considered as a sign for assessing the greenness of plants and observing the multi-temporal changes of vegetation within satellite data (Yacouba et al. 2009). The NDVI layer has been defined as: NDVI = (NIR-R) / (NIR+ R),

Where: NIR and R represents the spectral reflectance measurements acquired in the red (R) and near-infrared (NIR) bands, the result of this algorithm is a single data band with

NDVI values ranging from -1 to 1 (Sabins 1997; Jensen 2000). Considering the variations of vegetation, the floristic list cover percentage was determined using the ordinal scale of values of NDVI in four classes:

Class1: NDVI<0.1; corresponded to barren areas of rock, sand or snow
Class2: 0.1<NDVI<0.2; corresponded to soils
Class3: 0.2<NDVI<0.3; corresponded to shrubs and grasslands
Class4: 0.3<NDVI<0.8; presented forests.

2.5. Environmental variables

To gain additional insight of the drivers of the changes in NDVI, the response of the vegetation productivity to thermal variables was analyzed. In this case, the maximal temperature values and NDVI values of each group of formations in the Natural Reserve of Beni Salah from the period 1986 to 2015 were used. Maximal temperature values were taken to join the hour of the pass of the satellite in this region (satellite images were taken at 12h00). The values were statistically analyzed in XLSTAT using Pearson correlation coefficient (Evans 1996).

3. RESULTS AND DISCUSSION

3.1. Temperature analysis

Air temperature has had a crucial impact on the vegetation in the natural reserve of Beni Salah. The analyzed temperature, the recorded data, and the employed descriptive statistics which included the mean, standard deviation (SD), minimum, maximum, median, and coefficient of variation (CV) have been given in (table 1) and (table 2).

The results of the descriptive statistics of low temperature (table 1) showed that February was a very cold month, and August was a very hot month. The coefficient of variation (CV) in T_{min} was the highest in January, and the lowest in August. During 30 years, the lowest recorded minimum temperature has been observed at the month of January (1.86°C), while the month of August has been marked as having the highest maximum temperature (22.9°C).

The results of the descriptive statistics of high temperature (table 2) indicated that January was marked by the lowest mean values, while the highest temperature was observed in August. The highest values of coefficient of variance (CV) were found in February with the smallest minimum of the high temperature (12.76°C).

The maximum and minimum temperature trend analysis have been presented in (fig. 3) and (fig. 4); respectively. They varied greatly throughout the sampling period.

A weak increase of the maximum mean annual temperature, about 0.048°C was observed in 30 years during the period of 1986-2015 (fig. 4).

This finding showed that we have been approaching the global warming in the Natural Reserve of Beni Salah in the last three decades, where the increase of the maximal temperature has been observed during the last two decades (fig.5).

To detect the presence of change points, homogeneity tests (the SNHT, Pettitt, Buishand, and Von Neumann) were applied on the annual mean, maximum and minimum temperature data covering the years between 1986 and 2015. The value of the test variables have been reported in table 3, while figure 6 shows the behavior of the important months where there was a rupture. The results of each method were evaluated for the significance level of 90 %, 95% and 99%, and the inhomogeneous years were determined.

The results shown in the table 3 indicates that the inhomogoneous of the temperature series was generally observed between 1998 and 2000 and in 2002. As can be seen from the table, inhomogeneous structure in mean temperature was detected in April in 1998 by using the SNHT and Von Neumann tests. It was also seen that in the maximum temperatrure, both the Pettitt, SNHT and Buishand tests detected inhomogeneity in the same month and year (March 1999). Inhomogeneous structure was detected by all the tests for the months of April and July in 1999 and 2000; respectively. It can be deduced from these findings that the inhomogeneous structure might be related to the climate change.

In order to demonstrate the statistical significance of the trends, Mann-Kendall and Sen's Slope Estimator has been used to determine the trend of the study area through collecting the temperature data of 30 years, from 1986 to 2015 (Table 4)..

The results indicated that the statistic tests were significant in the trend of maximum temperature. The Sen's slope agreed with the Mann-Kendall Statistic result of positive value as an indicator of increasing trend. In the mean and minimum temperature, a non significant decrease and increase of trends in all the months were found. The obtained results were in a good agreement with those found in the previous study by Chong et al. in 2010. The findings illustrated that the annual and seasonal maximum temperatures were increased significantly in the arid ecosystem in the Blue Nile-eastern Sudan. On the other hand, the results of this study were also in accordance with the results obtained by Alhaji et al.2018. In their study, they investigated the increasing trend in maximum temperature in Gombe State Nigeria. The impact of climate change was behind the significant increase in the temperature which could lead to the weather extremes in this studied area.

In the studied period, there were four hottest years in 2001, 2006, 2012 and 2014.The analyzing of monthly distribution of temperature showed that there was a weak increase in maximal temperature in the months of April and July about 0.11°C and 0.087°C; respectively. This meant that there has been a tendency towards the warm springs and hot summers (fig. 7).

3.2. Change in vegetation health

Vegetation greenness

In order to detect changes in forests distribution (deforestation or regeneration), it was useful to use summer satellite images to survey the areas of deciduous forests. The comparison between the values of vegetation index (NDVI) from three different years (1987, 1999 and 2015) directly showed the fix changes of forests distribution, like disappearance or appearance of vegetation which was detected at such images by different colors (blue and red), whereas the black color was attributed to areas without changes (fig. 8 and 9).

Vegetation greenness analysis showed maximum NDVI declined from 1987 to 2015 by around -0.4 while the minimum NDVI increased from approximately 0.9, mainly in zeen oak and mixed formations of the natural reserve. However, the minimum NDVI was high in 2015 than in 1999 in all the areas.

The class of vegetation superficies was estimated using NDVI class values (fig. 10). Over the years, the results showed that the scrubs and forests represented a very important surface in the area, and the forests were increasing from year to year : 2414.15 hectare in 1987 to 2761.37 hectare in 2015, while a remarkable decrease was observed in soils from 286.19 hectare in 1987 to 42.38 hectare in 2015. These results indicated that the biodiversity conservation management by the forest service's gave reliable results through actions as a part of the rehabilitation of the Natural Reserve of Beni Saleh since 2007 (double the fence of the reserve, the arrangement of water points, creation of the pond of water, Fire Trenches…).

Vegetation activity in relation to an environmental variable

For indeterminate cycle species like grass or forests, the budburst will be made faster in spring, and the browning will be delayed in autumn in warmer conditions, which on the whole will lead to a remarkable increase of the duration of growth season (Seguin 2010).

Change in the study area was particularly inspected through the values of NDVI of each formation and maximal temperature. As shown in figure 10, it was found that in the Natural Reserve of Beni Salah, vegetation productivity varied from the type of formation to another with a peak values in forest formation (zeen oak and cork oak), while a decrease was observed from year to year in this formation. The increase in the enclaves was interpreted by the presence of water due to the development project.

To gain the additional explication of the variation of NDVI, the response of vegetation productivity to temperature variables was analyzed. Tucker and Choudhury (1987) found that NDVI could be used as a response variable to identify and quantify drought disturbance in semi arid and arid lands, with low values corresponding to the stressed vegetation (Arnonkarnieli et al. 2009). In the natural reserve of Beni Saleh, a strong negative correlation was noticed between the maximum of temperature and NDVI in the forest formation of Cork oak and Zeen oak, whereas a weak negative correlation was observed in the shrub formation (fig.11).

These results were statistically analyzed using the Pearson correlation coefficient from the maximum values of NDVI and the maximum values of the temperature (Table.5).

The sign of the correlation coefficient identified whether the correlation was positive or negative. The amount of the correlation coefficient identified the strength of the correlation. Correlation has been an effect size; therefore, we could verbally explain the strength of the correlation using the guide that Evans (1996) suggested for the absolute value of r:

- 0.00-0.19: "very weak"
- 0.20-0.39: "weak"
- 0.40-0.59: "moderate"
- 0.60-0.79: "strong"
- 0.80-1.0: "very strong"

The Pearson correlation coefficient showed a strong negative correlation between the maximum NDVI values and the maximum temperature, which meant that when the temperature increased, the vegetation productivity decreased in the Natural Reserve of Beni Salah.

4. CONCLUSION

This study looked at temporal changes in land cover and climatic situation in the Natural Reserve of Beni Salah from 1986 and 2015. Long term impacts on vegetation have been covered, and degradation and vegetation health were particularly evaluated. The study of vegetation dynamics at the inter annual scale has proved to be a good way of investigating the climate and its variability on a regional scale. Both temporary modification of land cover attributes and thermal variation in the study area were statistically analyzed. The inhomogeneous of the temperature series was generally observed between 1998 and 2000 and in 2002. The inhomogeneous structure was detected by all the tests for the months of April and July in 1999 and 2000; respectively. A significant increase in the trend at 5% level significance of maximum temperatures was found in six months (January, March, April, June, July and December). Also, It has been determined that there was a statistically significant increase of trend of the maximum temperature in the months of April and July about 0.11°C and 0.087°C; respectively. This finding showed that this study area has been approaching to global warming. A major aspect of change processes was revealed in Natural Reserve of Beni Salah including the values of NDVI (plant productivity), of cork oak and zeen oak forest which varied from year to year, because of the exposure of plant groups to intense periods of heat stress, with a strong significant decrease in NDVI values due to the thermal stress.

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Tables

Table 1. Descriptive statistics of low temperature from the period 1986 to 2015

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aver	4.74	4.70	6.30	8.28	11.56	15.14	18.26	19.41	17.49	14.17	9.51	6.04
STDEV	1.49	1.08	1.52	1.41	1.55	1.68	1.08	1.17	1.17	1.33	1.11	1.26
CV	0.31	0.23	0.24	0.17	0.13	0.11	0.05	0.06	0.07	0.09	0.12	0.21
Median	5	4.86	6.17	8.31	11.5	15.19	18.5	19.38	17.40	14.32	9.46	5.81
Min	1.86	2.5	3.63	5.54	7.65	11.01	15.86	17.23	15.23	11.09	7.11	3.70
Max	7.66	8.1	12.27	13	14.53	17.6	20.78	22.9	19.65	18.05	11.98	8.50
Count	30	30	30	30	30	30	30	30	30	30	30	30
Variance	2.14	1.13	2.22	1.92	2.31	2.74	1.13	1.32	1.32	1.71	1.18	1.52

Unit of measurement: Degree Celsius. Aver: Monthly average, STDEV: Standar deviation, CV: Coefficient of variance, Min: Minimum of low temperature, Max: Maximum of low temperature, Count: Number of years.

Table 2: Descriptive statistics of high temperature from the period 1986 to 2015.

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aver	15.71	16.67	18.94	22	27.04	31.58	35.87	36.44	31.78	27.68	21	16.77
STDEV	1.35	2.63	1.37	1.79	2.63	2.76	1.33	1.56	1.55	2.19	1.55	1.79
CV	0.09	0.16	0.07	0.08	0.1	0.09	0.04	0.04	0.05	0.08	0.07	0.11
Median	15.58	16.06	19.21	22.09	27.64	31.31	35.8	36.33	31.7	27.58	20.56	16.53
Min	13.23	12.76	16.3	17.56	18.46	23.97	32.44	33.3	29.14	24.37	18.51	13.77
Max	18.4	24.21	21.08	25.06	30.41	36.2	38.56	39.81	35.1	31.76	25	19.9
Count	30	30	30	30	30	30	30	30	30	30	30	30
Variance	1.76	6.67	1.83	3.11	6.71	7.36	1.72	2.36	2.33	4.63	2.33	3.08

Unit of measurement: Degree Celsius. Aver: Monthly average, STDEV: Standar deviation, CV: Coefficient of variance, Min:Minimum of low temperature, Max: Maximum of low temperature, Count: Number of years.

Table 3. Comparison of results of the Homogeneity test. The rupture dates are mentioned.

	Rupture Year (Test statistics)			
	Pettit	Test SNHT	Buishand	Von Neumann
T mean	NS	April (1998)**	NS	April (1998)**
T maximum	-January (2007)* -March (1999*, 2002**) -April 1999*** -June 1999* -July 2000***	-March (1999)* -April 1999*** -July 2000***	-January (2007)* -March (1999)* -April 1999*** - Mai 1999* -June 1999* -July 2000***	-April 1999** -July 2000*
T minimum	NS	NS	NS	NS

N.S: non significant , *: 90% significance level, **: 95% significance level, ***: 99% significance level

Table 4 : Mann kendall and Sen's slope result of mean, maximum and minimum temperatures.

	T mean			T maximum			T minimum		
	Kendall's Tau	p-value	Sen's Slope	Kendall's Tau	p-value	Sen's Slope	Kendall's Tau	p-value	Sen's Slope
Jan	0,134	0,850	0,018	0,241	**0,031**	0,047	0,046	0,361	0,011
Feb	-0,069	0,296	-0,015	-0,069	0,704	-0,029	-0,002	0,507	0,000
Mar	0,189	0,928	0,030	0,254	**0,025**	0,056	0,091	0,243	0,014
Apr	0,372	0,998	0,068	0,423	**0,001**	0,119	0,196	0,065	0,034
Mai	0,099	0,779	0,033	0,118	0,181	0,045	-0,021	0,564	-0,004
Jun	0,168	0,904	0,057	0,239	**0,032**	0,091	0,016	0,450	0,003
Jul	0,297	0,989	0,053	0,387	**0,001**	0,087	0,053	0,341	0,009

Aug	-0,051	0,347	-0,005	0,131	0,155	0,031	-0,106	0,794	-0,013
Sep	-0,074	0,284	-0,014	0,009	0,472	0,004	-0,021	0,564	-0,007
Oct	0,044	0,633	0,011	0,087	0,249	0,026	-0,011	0,536	-0,003
Nov	0,127	0,837	0,024	0,210	0,052	0,048	0,060	0,321	0,011
Dec	0,101	0,784	0,025	0,214	**0,049**	0,075	-0,071	0,710	-0,015

Values in bold are significance at level alpha=0,05

Table 5. Correlation matrix (Pearson)

Variables	NDVI MAX	Tmax
NDVI MAX	**1**	**-0,763**
Tmax	**-0,763**	**1**

Values in bold are different from 0 with a significance level alpha=0,05

Illustrations

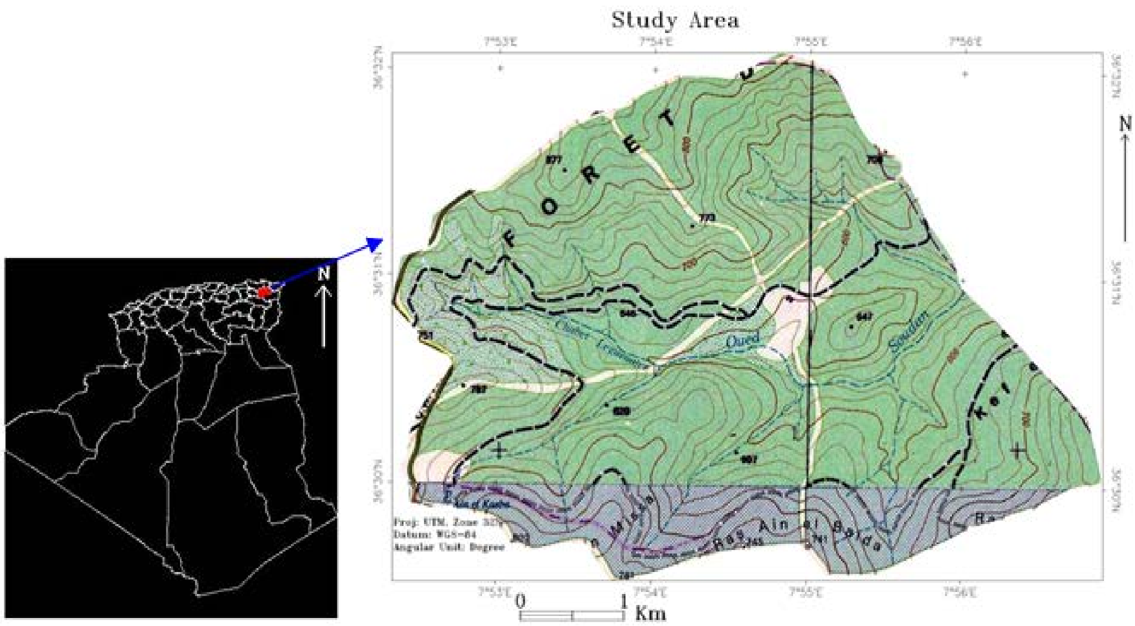

Figure 1. Location map of study area

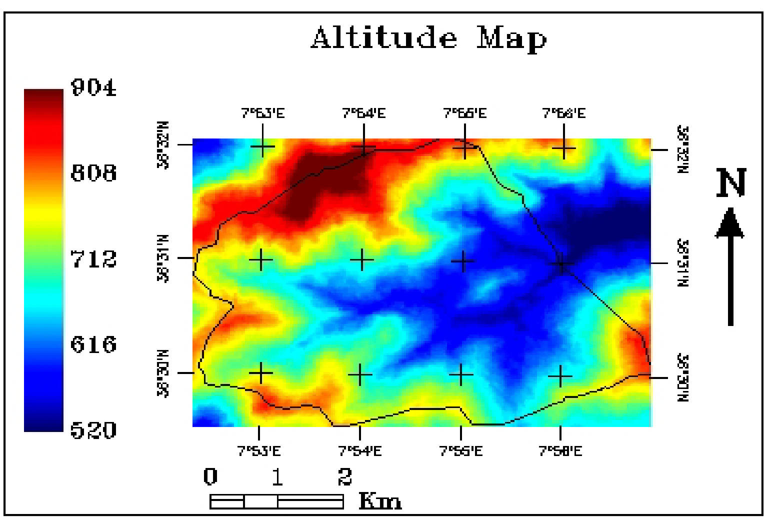

Figure 2. Altitude map of study area

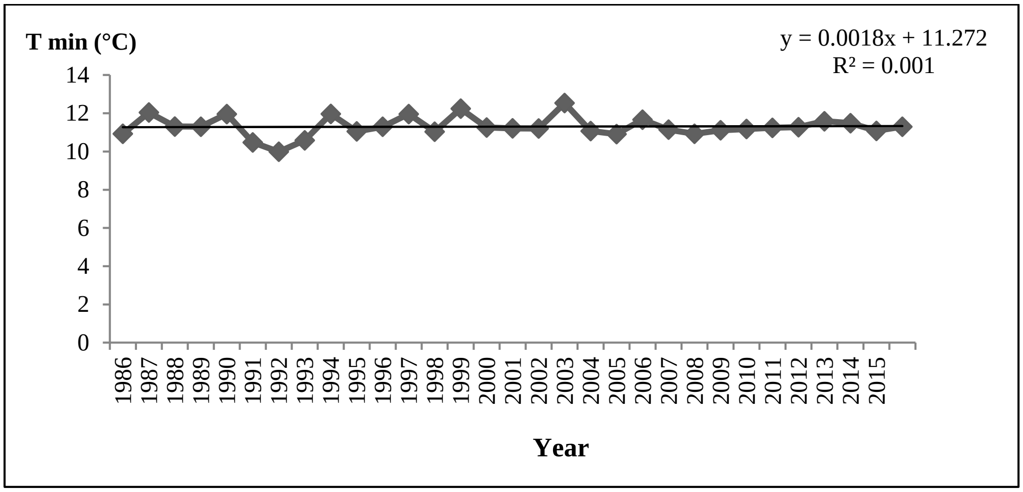

Figure 3. Evolution of the low temperature average in the study area from 1986 to 2015

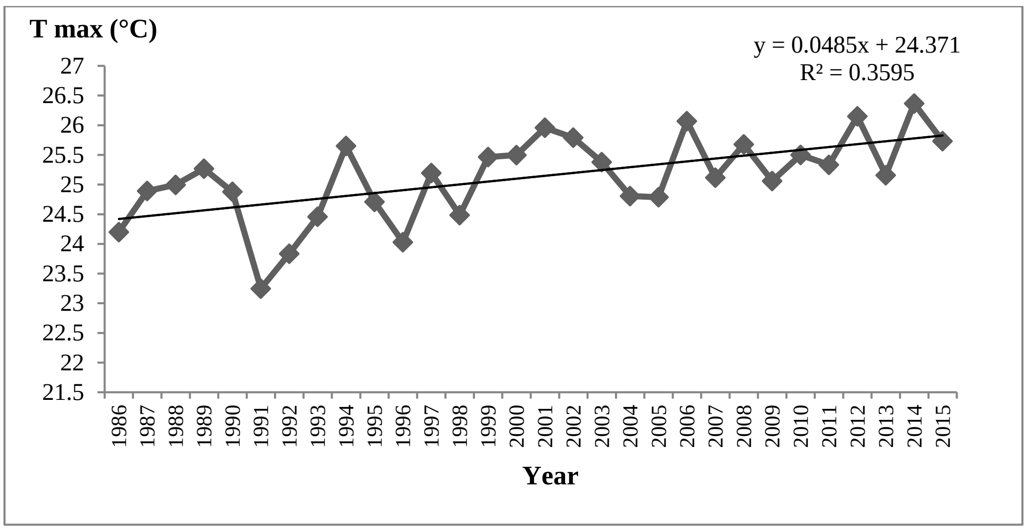

Figure 4. Evolution of the high temperature average in the study area from 1986 to 2015

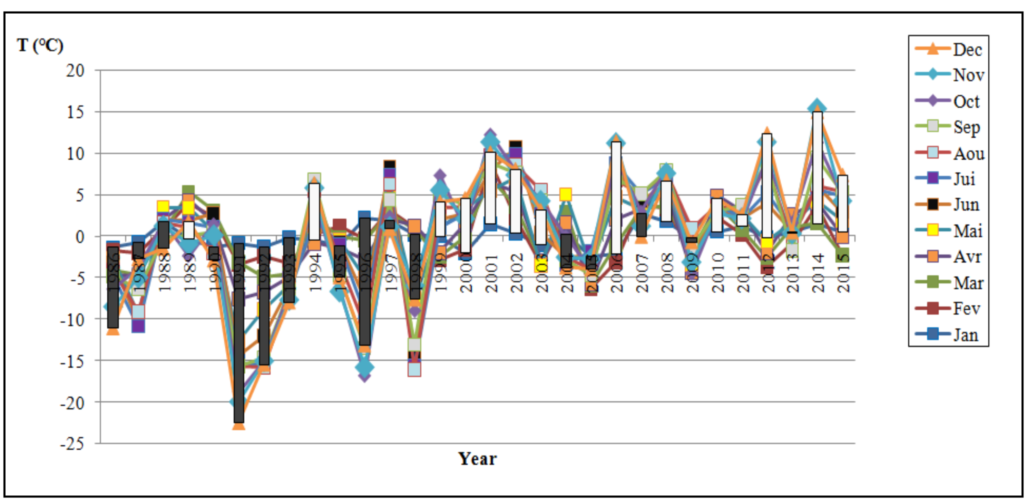

Figure 5. Variation of maximal temperature interval in the study area between 1986-2015

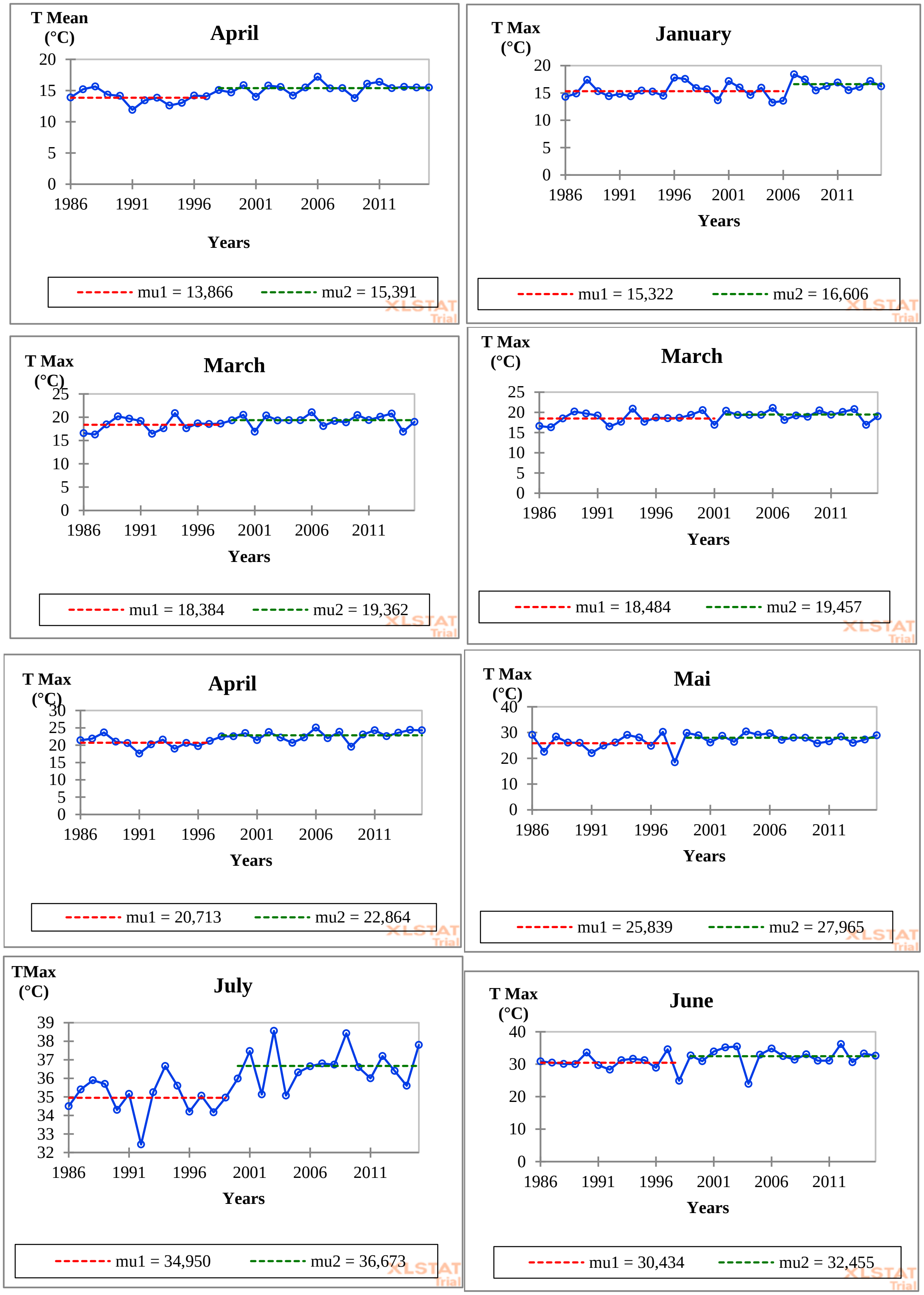

Figure 6. Homogeneity tests variables for inhomogeneous mean and maximum monthly temperature in the study area between 1986 and 2015 (mu1 : the first period, mu2 : the second period)

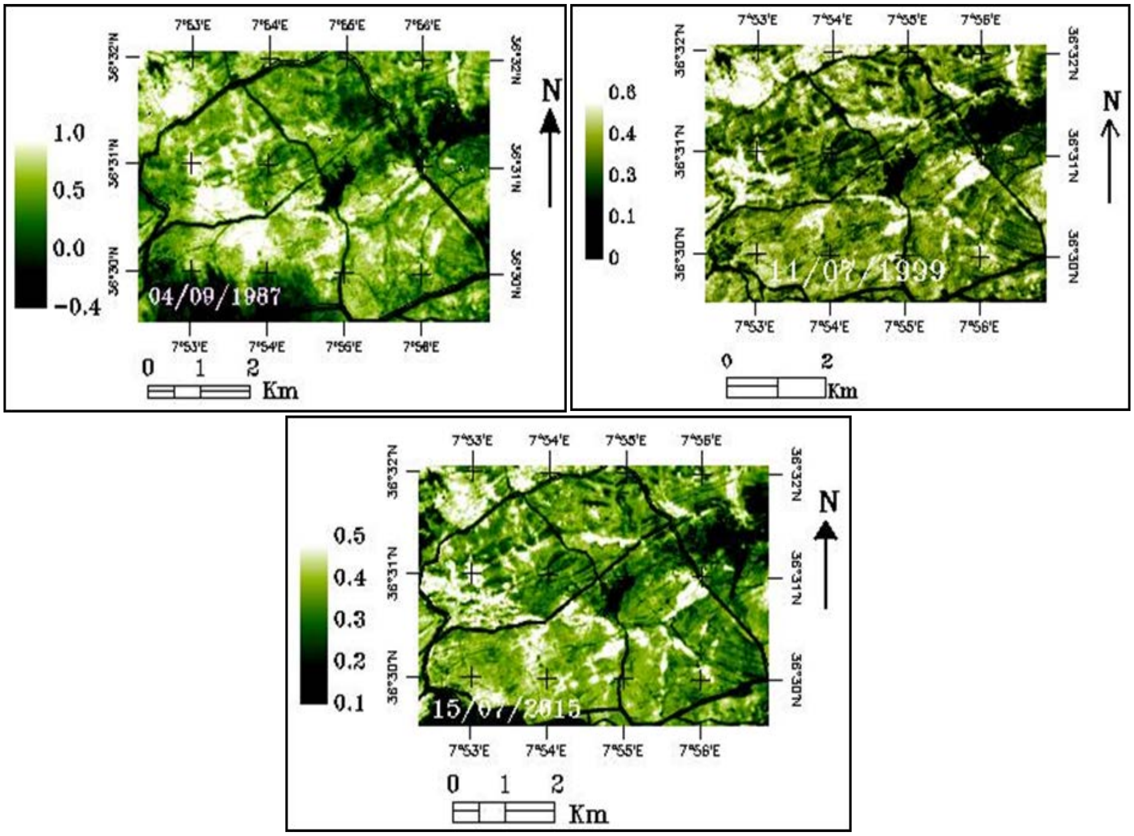

Figure 7. NDVI of the summer season in the Natural Reserve of Beni Salah of LANDSAT images for the years: 1987, 1999 and 2015.

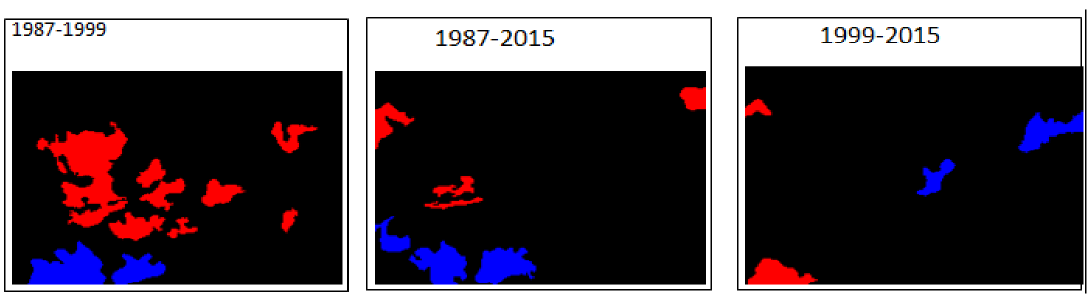

Figure 8. Change detection in NDVI of the summer season in the Natural reserve of Beni Salah of LANDSAT images.

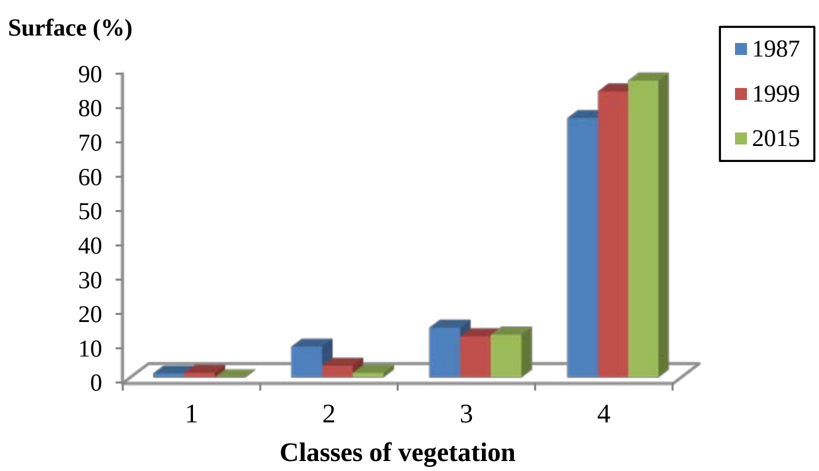

Figure 9. Diachronic evolution of the surface of vegetation classes from the period 1987 to 2015 of the Natural Reserve of Beni Salah

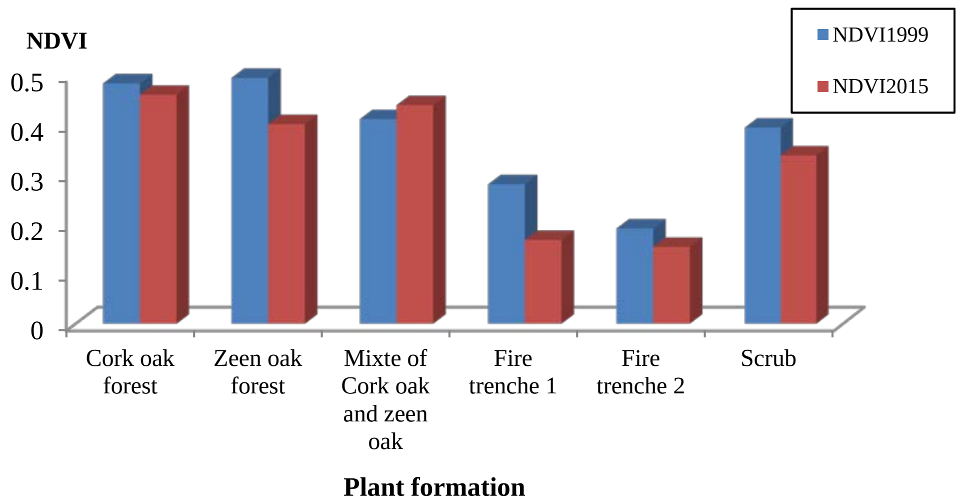

Figure 10. Diachronic variations of NDVI in plant formation from the period of 1999 to 2015

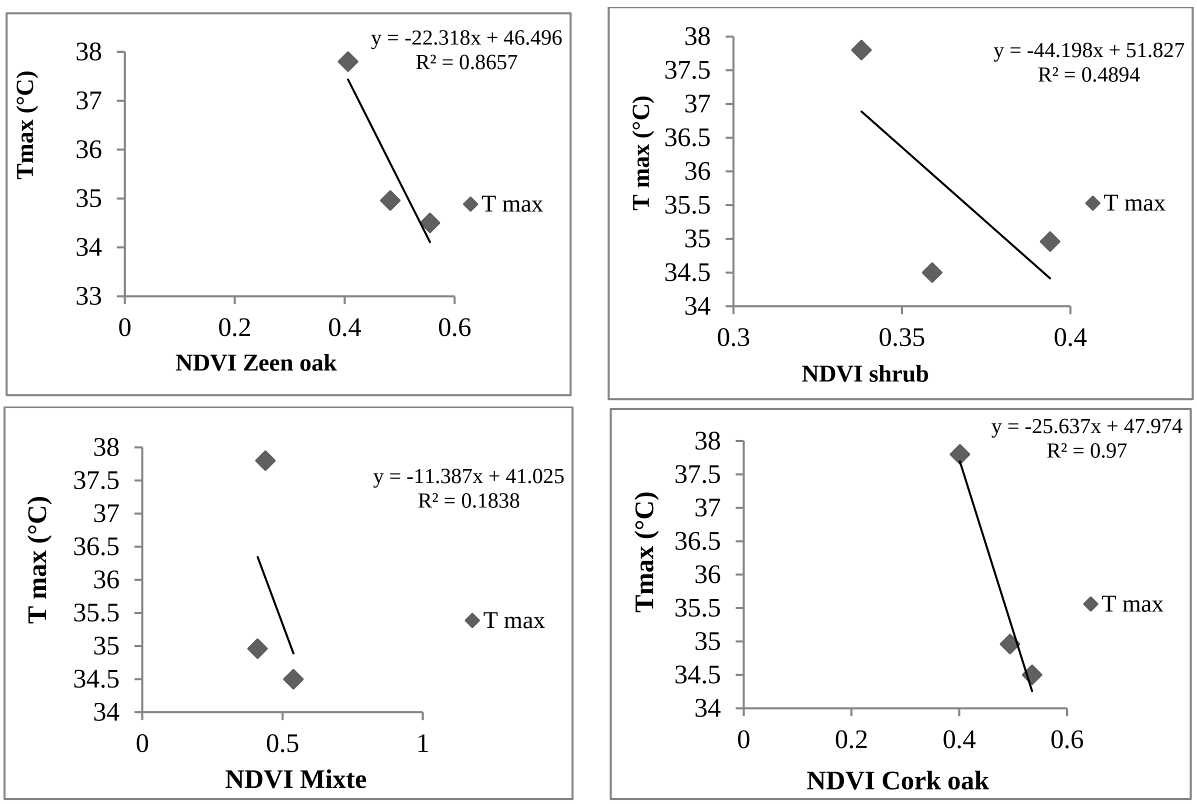

Figure 11. Correlation between NDVI and the maximum temperature in different vegetation formation of the natural reserve of Beni Salah