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Multi-temporal relationship between surface temperature, land use and normalized vegetation index

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ABSTRACT/RESUME

Abstract: *Land surface temperature can reflect environmental interactions and exchanges between soil, land cover and atmosphere, which is important for studying environmental changes. Nevertheless, research on surface temperature in ecologically fragile saline areas is rare. Thus, in most previous research articles, the main study areas were large agglomerations and other areas characterized by natural phenomena such as erosion. In fact, the study of this parameter is difficult at the local scale because it is influenced by climatic variations and anthropogenic practices that determine land use. In summary, the Atmospheric Correction Model from Landsat data can easily extract surface temperature and explore its relationship with land use and NDVI. Indeed, the variation of the surface temperature is according to the type of land use. This study provides a reference for land use planning, restoration of the ecological environment in round of saline areas. The days of 03/31/1987, 03/26/2000 and 03/28/2015 were chosen mainly for the quality and availability of the images and that the vegetation is ripe at this time of the year.*

I.Introduction

Remote sensing was initially used for the spatial partitioning of the observed environments without quantifying the physical or chemical variables of soils and land use. The efforts made by scientists have reinforced its use so that it has become a means characteristic of physical quantities. The main surface parameters are structural (leaf index, etc.), optical (albedo, etc.), biochemical (chlorophyll, nitrogen, lignin, etc.) and physiological (quantum yield of photosynthesis, etc.). The spatial and temporal variability of these parameters reinforces the need for a remote sensing tool because of its capacity for continuous and global observation of the planet [7].

Land use is an important element that affects surface temperature. The reflectance and surface roughness of different land use types are different, leading to differences in surface temperature [5].

Therefore, the relationship between surface temperature and land use should be studied to further analyze the natural effects of surface temperature and to solve regional environmental problems. Vegetation can effectively influence surface temperature by selectively absorbing and reflecting solar radiation energy and regulating latent and sensible heat exchanges [14].

The Normalized Vegetation Index (NDVI) is an indicator of vegetation that is generally used in the study of the relationship between surface temperature and vegetation [12]; [6]. As the relationship between surface temperature and NDVI, which is affected by many factors, is quite complex [4]; [10], It is necessary to further investigate the relationship between surface temperature and NDVI.

Many objectives methods based on infrared remote sensing data have been proposed for surface temperature estimation. Currently, remote sensing has become an important tool in the analysis of the relationship between surface temperature, land cover and NDVI [4]; [13]; [2].

Different research methods were used to estimate the surface temperature. In addition, in previous studies, the main study areas were large cities [9]. The main content of the research was the effect of land changes related to urbanization. Our work focuses on the multi-temporal relationship between surface temperature, land use and NDVI in areas affected by salinity is characterized by a specific geographical space and a fragile natural environment.

To reveal the characteristics of the soil surface temperature in such a region, we have chosen the m'léta plain which is juxtaposed to the large sebkha of Oran, as a study area and calculation of the surface temperature and NDVI from Landsat data. During this time, the land cover map was obtained by the supervised classification method of the SVM (Support Vector Machine) genus. This study aimed firstly to analyze the spatial distribution characteristics of surface temperature in the study area, secondly to examine the relationship between surface temperature and its influencing factors in the different land cover types and thirdly to determine the relationship between surface temperature and NDVI. Finally, the multi-temporal study was carried out for the conformity of the existing relationship between surface temperature and NDVI for the different land use types.

II. Study Area

The M'léta plain spreads over the southern part of the endorheic basin of the great Sebkha of Oran. It is located between the Tessala Mountains in the south, culminating at 1061 meters and the Murdjadjo Mountains in the north, whose summit is at 584 m.

This plain is delimited by the longitude 0°25' and 1°00' West of the Greenwich meridian and by the latitude 35°22' and 35°37' North. Its surface area is about 500 Km²; it is bounded to the north by the great Sebkha of Oran, to the south by the mountains of Tessala, to the east by the plain of Tlelat and to the west by the basin of Oued El Melah.

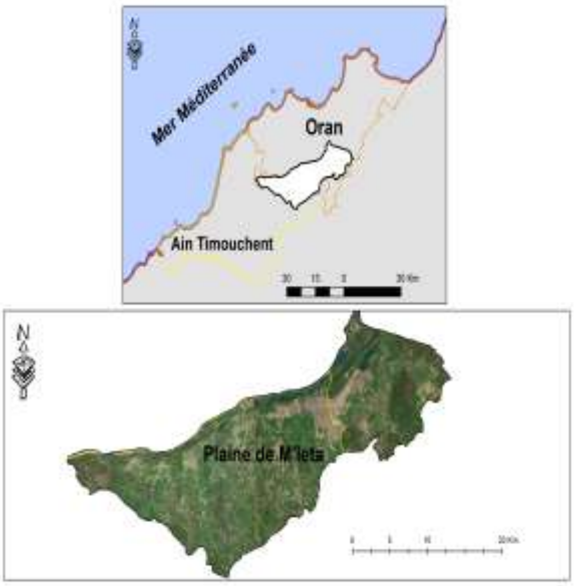


Figure 1. *Study area " plain of m'léta".*

III.Methodology

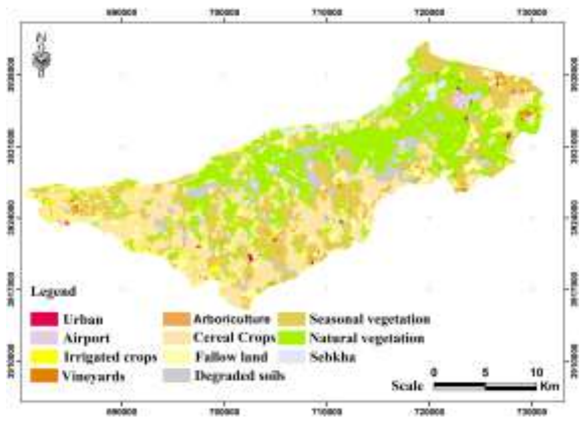
The work corresponds to the processing of optical data, including the choice of images, the dates of shooting, the delimitation and extraction of the study area corresponding to the M'léta plain. The objective is to calculate the surface temperature, NDVI and to perform a supervised classification to extract the different types of land use in the study area. The exploitation of thermal channels from atmospheric-corrected satellite images allows the determination of the temperature for each land use class. Thus a correlation is applied between temperature and NDVI to analyze the close relationship between these two factors and to confirm the state of the land.

III.1 Satellite data

The scenes taken into consideration are distributed in the interval of time, between the year 1987 and the year 2015 and are relative to those of March 31, 1987, March 26, 2000 and that of March 28, 2015. This choice is made in such a way that it represents the appropriate period for detecting vegetation and for differentiating between land use objects.

III.2 Treatments

The data used have undergone an atmospheric correction by the flaash module (ENVI 5.1), then a Principal Component Analysis (PCA) is applied to the images to gather information in the first neo channels. Subsequently, a segmentation was applied to all the selected images in order to differentiate between the different land cover themes, based on photo-interpretation and with reference to auxiliary data such as Google-Earth tools and the 1/25000 topographic map of the region. The SVM supervised classification method (Support Vector Machine, Vapnik (1995)) is performed on the resulting images of the PCA, this algorithm seems the most adequate to perform a correct and efficient classification. This method consists in assigning each pixel to its appropriate class taking into account the predefined samples. The validation of the classification results is done through the confusion matrix and the calculation of Cohen's KAPPA coefficient. [3] respectively, of 90% for the year 1987, 74% for the year 2000 and about 91% for the year 2015.Finally, since these classifications, eleven main types of land use have been identified, Figure 2.



a)

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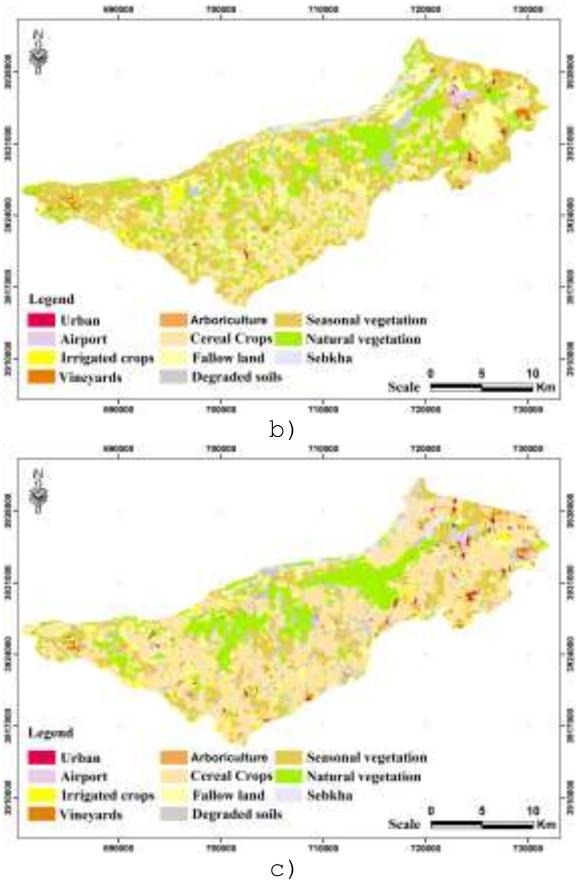


Figure 2. *Land use map of the plain a):31/03/1987, b): 26/03/2000, c): 28/03/2015*

The representation of the classification results is carried out according to the conventional CORIN LANDCOVER nomenclature. These results are illustrated at a scale of representation to be readable and inserted in the text.

III.3 Temperature estimation

The thermal channels of the selected images are all calibrated and have undergone radiometric correction. This operation was carried out using the Flaash module incorporated in the ENVI 5.1 (Environment for Visualizing Images) remote sensing image processing software, which consists of transforming the digital counts (DN) of the image according to calibration parameters for the various Landsat sensors. The radiation is then converted to reflectance by normalizing the solar elevation angle (NASA, 2002).

The thermal channel relative to band 6 for ETM+, between 10.4 and 12.5 µm. For Landsat -8 OLI (the thermal channel has two bands, band 10 ranging from 10.3 to 11.3 µm and band 11 ranging from 11.5 to 12.5 µm, is converted to temperature brightness, with TB meaning "Temperature brightness" [8] ; [11]. Such as: $TB = K2 / (\ln (K1/ L\lambda + 1))$

TB = temperature brightness (in Kelvin) ; K1, K2 are constants applied for Landsat7 ETM + ; $L\lambda$ (spectral radiance at sensor aperture) = Grescale * Qcal + Brescale [W/(m2 . sr . µm)].

For Landsat-8, k1 and K2 are respectively 774.89 and 1321.08 for band 10 and 480.89 and 1201.14 for band 11 [1].

According to the laws of Planck and Stefan Boltzmann, estimates of surface temperature (Ts) can be calculated as follows: $Ts = TB/(1 + (\lambda\ TB/\rho) \ln\varepsilon$

T(s) = the surface temperature (in Kelvin); λ = the wavelength of the emitted radiation (11.5 µm); $\rho = h\times c / \sigma$ (1.438×10^{-2} m K); h = Planck's constant (6.26×10^{-34} J s), c = the speed of light (2.998×10^{8} m/s); σ is Stefan Boltzmann's constant (1.38×10^{-23}J K^{-1}) and ε is emissivity.

Finally the surface temperature is converted to degrees Celsius by converting the degree kelvin to degrees Celsius by subtracting the value of 273.15.

These formulas are applied to all the images to come out with surface temperature maps. Figure 3.

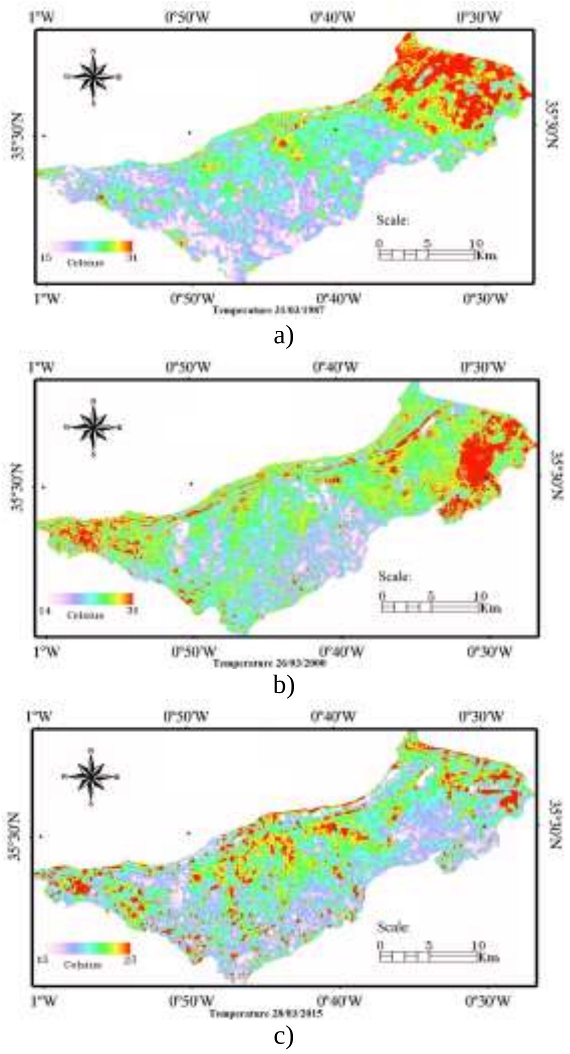
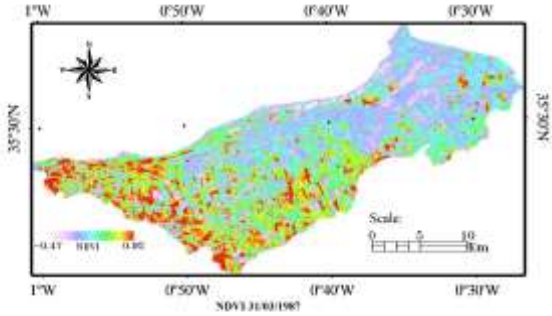


Figure 3. *Temperature maps a):31/03/1987, b): 26/03/2000, c): 28/03/2015*

III.4 Evaluation of the vegetation index

The normalized difference vegetation index, also called NDVI, is calculated from the red (R) and near infrared (NIR) channels. The normalized vegetation index highlights the difference between the visible red band and the near infrared band, such as: NDVI = (PIR-R)/ (PIR+R). This index is sensitive to the density and quantity of vegetation.



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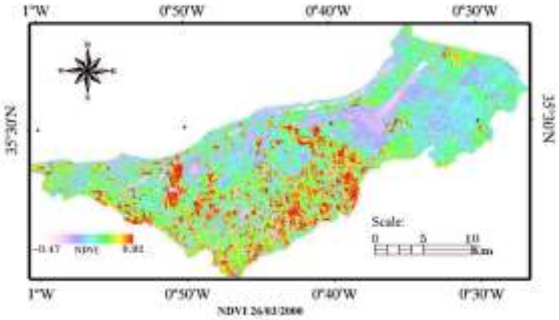

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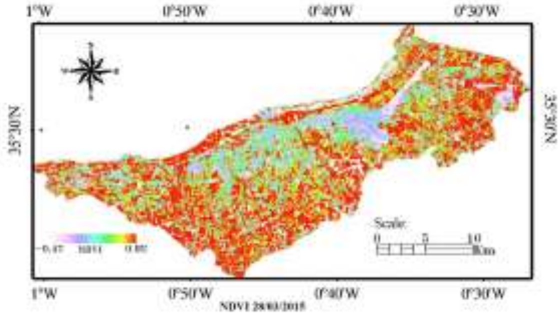

c)

Figure 4. *NDVI maps a):31/03/1987, b):26/03/2000, c): 28/03/2015*

Table 1. *Description of land use from satellite data*

Types of land use	NDVI values		
	31-03-1987	**26-03-2000**	**28-03-2015**
Arboriculture	0.1636 à 0.5551	0.1494 à 0.6246	0.4024 à1
Cereal Crops	0.7068 à 0.9119	0.6754 à0.8946	0.563 à 1
Fallow land	0.1604 à 0.296	0.1127 à 0.2	0.1122 à 0.2664
Irrigated crops	0.7731 à 0.8935	0.7466 à 0.9253	1 à 1
Sebkhas	0.1025 à 0.1881	0.0508 à 0.173	-1 **à** -0.2706
Degraded soils	0.2176 à 0.3521	0.0904 à 0.1368	-0.581 à 0.2471
Urban	0.1433 à 0.3949	0.0929 à 0.2807	-0.0557 à 0.4675
Vineyards	0.2655 à 0.3407	0.3753 à 0.4545	0.4691 à 1
Natural vegetation	0.1828 à 0.4473	0.1394 à 0.2066	0.1142 à 0.5771
Seasonal vegetation	0.2236 à 0.3614	0.237 à 0.4855	0.7703 à 1

Types of land use	Temperature values in °c		
	31-03-1987	**26-03-2000**	**28-03-2015**
Arboriculture	19.282 à 21.5021	21.8164 à 25.369	19.6082 à 20.1334
Cereal Crops	15.6419 à 18.3823	18.6854 à 21.3003	18.8321 à 19.4109
Fallow land	23.6829 à 25.8263	24.8677 à 25.8681	22.6797 à 23.873
Irrigated crops	15.6419 à 17.4759	18.6854 à 21.3003	18.7995 à 19.2509
Sebkhas	20.6189 à 24.5446	19.213 à 24.3645	15.4987 à 16.8243
Degraded soils	22.8152 à 24.5446	25.8681 à 26.8605	18.9853 à 20.3096
Urban	21.9414 à 22.8152	22.8421 à 23.8591	20.8932 à 21.763
Vineyards	25.4005 à 28.3519	26.8605 à 27.3538	19.0078 à 19.5708
Natural vegetation	19.282 à 21.5021	24.3645 à 26.3653	19.8151 à 20.322
Seasonal vegetation	23.6829 à 26.6737	24.3645 à 25.8681	19.1307 à 19.5608

IV. Results and discussions

In this phase of the study, NDVI and temperature values are calculated for the three images. Cereal-growing and vegetated areas represent high NDVI values and low temperatures, in contrast to areas without any vegetation where the

As a result, the combinations of NDVI and temperature showed a strong degree of binding for most different land use types, with such high values of the correlation coefficient sometimes exceeding 70%. Table 1.

***Table 2.** Linear regression analysis of the results between surface temperature and NDVI based on land use types: 1987 cases.*

Le : 31-03-1987	linear regression	number of pts	R : coefficient of correlation
Arboriculture	y = -6.1863x + 22.177	94	0.73
Cereal crops	y = -9.1111x + 24.567	146	0.75
Urban	y = 2.7774x + 21.829	41	0.54
Sebkha	y = -36.989x + 27.149	141	0.53

The high levels of NDVI show the presence of vegetation with high chlorophyll activity, corresponding to cereal and irrigated areas. The surface states recording the highest temperatures correspond to the least vegetated areas, i.e. the part of the degraded soils or urbanized building of the study area. Low or moderate temperatures are mainly observed in areas corresponding to dense vegetation types and humid surfaces. Such temperatures are also detected for pixels associated with urban spaces, which can be explained in part by the mixture between urban and vegetation, and also revealing the complexity of analyzing the surface properties of mixed pixels, specific to highly anthropized surface states.
From there, another phase of the study is initiated to try to establish the relationship between the types of land use, their chlorophyll activity since the NDVI, and the associated surface temperature. Figure 5.

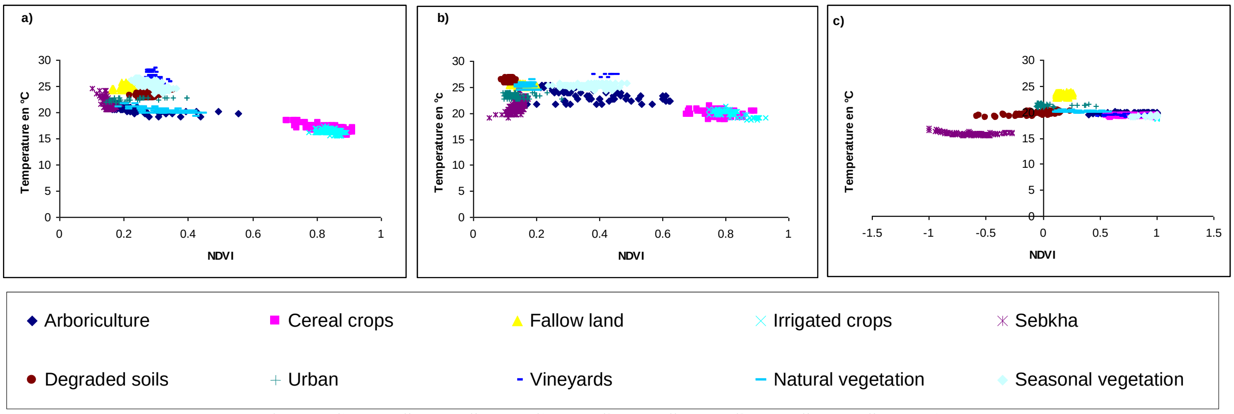

***Figure 5.** Relationship between surface temperature and NDVI of land cover from landsat images, a):31/03/1987, b): 26/03/2000, c): 28/03/2015*

The temperature distribution as a function of NDVI is distributed in the same way overtime. The multi-temporal analysis thus shows that the relationship between these two variables is independent of time and is only a function of the nature of land use.

V.Conclusion

The atmospheric correction algorithm was used in this study to extract the surface temperature from Landsat data. Then, the relationships between surface temperature and NDVI of the different types of land cover from the classification of multi-date images were determined. The important conclusions can be summarized as follows: 1) - the temperatures recovered by the Landsat atmospheric correction corresponded to the actual temperature data. During the spring season and at this time of the year, influenced by the land cover types, the surface temperature of the study area showed a general downward trend from bare soil to denser vegetation cover. 2) - Analyses showed that the difference in surface temperature between most types of land use was significant, with urban and bare soil having the highest temperature of around 30°C and land with high vegetation covers such as cereal crops or irrigated crops having the lowest temperature of around 15°C. 3) - For the only type of land use, the sebkha in the presence of water had low temperature and NDVI values, while the surface temperature and NDVI values of built-up land, degraded soils and fallow land showed a negative linear correlation.

VI. References

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