Vegetation Changes Detection in Gabes Oases Using EO1/Hyperion Data

Poster · January 2018

DOI: 10.1007/978-3-319-70548-4_516

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Keywords

Gabes • Coastal oases • EO1/hyperion data • Radiometric index • Cartography • Vegetation changes

1 Introduction

Gabes region, located on the southeastern coast of Tunisia, is characterized by unique maritime oases in Mediterranean basin (Carpentier and Gana 2014). These oases are characterized by an arid climate with a high temperature and potential evaporation rate of 1400 mm and low annual average precipitation 190 mm (Riou 1980). In the last decades, changes in oasis environments of Gabes are mainly influenced by human activities. Unfortunately these oases are sensitive areas due to a harsh competition for land and water between different user groups (urban, industry, agriculture). An industrial complex is now located in the center of this region, the cultivation practices have shifted from a traditional multi-layer plant association system and Gabes city itself is expanding in the very core of oases. The oases of Gabes are transformed into city oases; they undergo multiform interactions which amplifies their environmental dynamic (Hatira et al. 2007; Abdedaiem and Veyrac Ben-Ahmed 2014).

In this context, this study, is a continuation of the research carried out on the mutations of the oasis structures of southern Tunisia, started by the geographers (Abdedayem 1997; Abdedaiem and Veyrac Ben-Ahmed 2014; Carpentier and Gana 2014) and anthropologists (Battesti 2005). Our research work thus aimed to study the complexity of the oasis environments of Gabes by analyzing the dynamics of the vegetal cover in the face of socio-environmental issues. In the oasis of Gabes, a follow-up of about 40-years of land cover was carried out starting from the diachronic analysis of Landsat images. While relying on the vegetation index, Ben Arfa et al. (2015) highlighted a retraction of agricultural spaces in the central zone of the oases and contrary an extension to agricultural spaces to their periphery, confirming in particular the observations of A. Hatira et al. (2007). However, this only vegetation index did not provide sufficient precise details making it possible to characterize the qualitative evolution of the oasian ecosystem. Thus, the objective of this article was to evaluate if the new capacities offered by hyperspectral satellite (and derived indices) make it possible to give an account of a more precise cartography of the evolution of the state of the vegetal cover. We have the opportunity to access EO1/Hyperion data on seven different dates on 2009 and 2010. This dataset allowed us to compare various hyper-spectral-based processing both on the basis of information pertinence and time stability. In this framework, some indexes appear as significantly efficient:

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A. Kallel et al. (eds.), *Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-319-70548-4_516

vegetation mask, photochemical reflectance index (PRI), disease water stress index (DWSI). An inter-comparison of various hyper-spectral based indices has been carried out with a focus on information complimentary from normalized vegetation index. They allowed the analysis of vegetation status beyond a global greenness assessment. Indeed, hyperspectral radiometric indices are widely used in vegetation mapping (classification, species identification, disease detection), both at the canopy and the leaf scales (Delbart 2005). In this context, several hyperspectral sensors (AVIRIS, CASI, HyMap) and the indices derived from them have shown good results at different spatial scales. B. W. Pengra et al. (2007) tested the Hyperion sensor for mapping invasive plants in Australia, showing that this hyperspectral technique could provide a high level of accuracy despite a spatial resolution of 30 m. R. Pu et al. (2005) studied the contribution of the Compact Airborne Spectrographic Imager-2 (CASI) sensor in detecting vegetation diseases and mortalities at a Blodgett forest research station in California. In the same context, A. Apan et al. (2003) detected diseases affecting sugar canes planted in Australia from the Hyperion data. In order to evaluate the changes in oases through the evolution of the vegetation cover, this study presented the materials and methods used, the results from the satellite image and statistical processing and a discussion of these results, in the light of the field observations, and the methodological contributions.

2 Materials and Methods

Coastal oases of Gabes are located throughout the Gulf of Gabes. These ecosystems cover many areas such as Oudref, Matouia, Bouchemma, Chott Essalem, Ghannouch, Chenini, Teboulbou, El M'dou and El Hamma. According to Hyperion data before hand we analyzes six scenes from Teboulbou in 2009 and 2010. Hyperion images were acquired from NASA web site in different phenological seasons. Briefly, Hyperion data have 30-m pixel resolution, a 185-km long swath and 7.5 km wide. Hyperion samples the 400–2400 nm region of the electromagnetic spectrum at intervals of 10 nm yielding 242 bands (USGS 2006).

However, two complementary data sources were evaluated in this study to analyze the state of the oasis vegetal cover. A global spatial analysis derived from the radiometric indexes extracted from the Hyperion scene was supplemented by a local analysis based on interviews and field observations. The Hyperion data chain processing was carried out in three stage:

- **Radiometric correction**: The downloaded images is in radiance; to facilitate the calculation and interpretation of the indices, the pixel values were converted into reflectance by means of a radiometric calibration. The calibration parameters were taken from the USGS site; thus making it possible to divide the radiance by the solar irradiance specific to each of the bands used in this study (USGS 2006).
- **Application of the vegetation mask**: Densely vegetalized spaces represent only a small part of the Hyperion scene. To ensure the statistical validity of the results, the other types surface (rangeland, sea, urban area) have been eliminated thanks to a vegetation mask. To this end, the method developed by M. Mboup (2014) was applied. It consists in searching for each pixel, the wavelength of the visible spectrum for which the spectral response of the vegetation is the lowest (i.e., 680 nm). Once detected, the pixel is classified as "vegetation". The physical justification for this method is based on the fact that chlorophyll is characterized by a peak red absorption at 680 nm.
- **Choise of radiometric indices**: In terms of changes in pigment content, the radiometric response of vegetation indices is an indicator that is sensitive to photosynthetic activity, nutritional status of the plant and stress detection in crops (Wu et al. 2008). An intercomparison of various hyperspectral based indices has been carried out with a focus on information complimentary from the normalized vegetation index. By applying a correlation matrix, the index that weakly correlated with the NDVI provides complementary information. On this basis, the most efficient indices are the anthocyanin reflectance index (ARI2), the disease water stress index (DWSI) and the photochemical reflectance index (PRI) (Table 1). They allow an analysis of vegetation status beyond a global greenness assessment.

3 Results and Discussion

These indices have made it possible to classify the oases of Gabes according to their countries and uses and to propose a map of the state of the vegetation cover, thus highlighting the oasis vulnerability. Referring to the field observations, the spatial variation from responses of index is linked to the intensification of human activities. However, the factor analysis applied between indices show that the PRI which has the lowest correlation coefficient compared to NDVI presents additional information. While ARI2 and DWSI strongly correlated with NDVI and show similar results related to the response of the pigments of leaves and their water states. The obtained results confirm that the PRI is an indicator of water stress which shows problems of irrigation deficit in vegetation oases of Gabes. The Hyperion sensor has a number of limitations: missing spectral band, poor

Table 1 The radiometric indexes used in this study

Index	Formulae	References
NDVI	$\mathrm{NDVI1} = \frac{R800 - R670}{R800 + R670}$	Rouse et al. (1973)
ARI2	$\mathrm{ARI2} = R800 * \left[\left(\frac{1}{R550}\right) - \left(\frac{1}{R700}\right)\right]$	Gitelson et al. (2001)
PRI	$\mathrm{PRI} = \frac{R531 - R570}{R531 + R570}$	Gamon et al. (1992)
DWSI	$\mathrm{DWSI} = \frac{R800 + R550}{R1660 + R680}$	Apan et al. (2003)

signals to noise and a swath of only 7 km. Despite these pitfalls, the sensor allows a fine analysis of the surface states. It presents a good potential for detecting the proprieties of vegetation through its continuous spectrum in a wide spectral range (400–2500 nm). According to the exactitude of spectral range Hyperion data allows a better discrimination of the oasian space.

4 Conclusion

The study aimed at both: (1) testing the hyperspectral imaging capabilities of the Hyperion sensor in the analysis of vegetal cover subjected to anthropogenic constraints and spatially very heterogeneous and (2) trying to characterize the qualitative state of the oases. ARI2 and DWSI, strongly correlated with NDVI2 show similar results related to the response of leaf pigments and their water states. In these heterogeneous spaces, where there are variations in production strategies, the spectral response of vegetation cover depends on irrigation strategies. On the other hand, the PRI, weakly correlating with the NDVI, makes it possible to differentiate the spaces with shrub cover from the spaces with herbaceous cover. However, the results have often been obtained in an experimental setting and their effectiveness in observing oasis environments is an open issue.

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