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Comparison of Biophysical Changes Affecting Oasis Ecosystems Using Remote Sensing Data and Published Local Environmental Assessments

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Abstract: Oasis ecosystems in desert areas have undergone rapid changes over recent decades due to the increasing development of irrigation. This paper investigates biophysical changes affecting oasis ecosystems in three locations in Egypt and Tunisia, comparing trends in NDVI to accounts of the evolution of the cultivated areas in published sources and through published studies, national statistics and field observation.

Keywords: Arid environments, Cultivation, Landcover change, NDVI, Oasis

1. Introduction

Generic time-series data that is provided by satellite images enables inter-temporal exploration of ecological trends in oasis environments (White, 2007). Such observations are increasingly used to support to decision-making for environmental management. Three cultivated oasis ecosystems are examined in this study. The locations were chosen on the basis of their comparable biophysical characteristics as inland endorheic basins, where soil and water conditions are affected by high levels of salinity. The selection also took into account the strength of available scientific literature on local environmental management issues.

1.1. The Nefzaoua region

Study area (Lat 8˚46'59''–9˚02'34''E and Lon 33˚47'51''–33˚21'51''N) is located in the Tunisian Governorate of Kebili. In this region, the cultivated area has tripled over the last fifty years, while pumping of groundwater has increased six-fold (Belloumi and Matoussi, 2006; Sghaier, 2006). Sahnoun (1998) observed a five-fold increase in cultivated area occurring during the high growth period of 1972-1993. More recent studies (eg Zammouri *et al*., 2007) have observed land degradation and salinization overtaking productivity increases.

1.2. The Siwa Depression

Study area (Lat 25˚21'57''– 25˚44'62''E and Lon 29˚19'12''– 19˚06'32''N) is located in the Egyptian Governorate of Matrouh, close to the Western border of Egypt with Libya. In 1950, the population was around 5,000 inhabitants. By 1975 it had reached around 10,000 full or part time residents, and in 2005 it was more than 20,000 (CAPMAS, 1986, 1996, 2006). The expansion of the cultivated area has been traced by various studies using remote sensing techniques (QRDP, 1991; Masoud and Koike, 2006; Ahmed, 2001, 2007).

1.3. The Depression of Wadi El-Natroun

Study area (Lon 30˚05'49''– 30˚36'09''E and Lat 30˚29'59''– 30˚17'37''N) in the Governorate of Behaiyra. Since the 1950s, population growth has progressively accelerated to reach over 180% between 1996-2006 (Ayyad *et al*., 1999, 2002; CAPMAS, 1986, 1996). Land cover changes associated with spreading urbanization have been mapped by UN-Habitat (2008). Awad (2002) observed natural and cultivated land cover types in the area 1997-2000. Ali and El Baroudy (2008) overlaid environmental indices from DEM, climate atlas data, land-use observation and soil sampling.

1.4. Moghra

In addition to these three cultivated oases, the uncultivated oasis of Moghra, situated in a smaller depression in between Siwa and Wadi El Natroun (Lat 28˚53'27''-28˚58'21''E, Lon 30˚17'07''–30˚12'42''N), was included in this study as a control site. The natural vegetation at this uncultivated oasis

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(see Salem and Waseem, 2006) may be considered comparable to the natural vegetation occurring at Siwa and Wadi El Natroun (El-Khouly and Zahran, 2002).

2. Materials and Methods

A coarse resolution multi-temporal dataset was obtained from the Global Inventory Modelling and Mapping Studies (GIMMS) through the University of Maryland Global Land Cover Facility. GIMMS contains Normalized Difference Vegetation Index (NDVI) data for 1982 - 2006. The data set is derived from imagery obtained from the Advanced Very High Resolution Radiometer (AVHRR) instrument onboard the NOAA satellite series 7, 9, 11, 14, 16 and 17. The dataset has been corrected for calibration, view geometry, volcanic aerosols, and other effects not related to vegetation change (Tucker *et al*., 2004; Tucker, 2005). This dataset was processed for this study at the University of Reading, UK (see White, 2007). A set of three consecutive high resolution Landsat images from each of the study sites was obtained from the University of Maryland Global Land Cover Facility for further analysis of the spatial distribution of changing trends in NDVI.

In each location, an area of 24 km × 48 km, centered around the main area of the oasis cultivation, was selected for analysis of both the GIMMS data and the Landsat images. Analysis of trends in NDVI over the period 1982-2006 was then performed using ERDAS Imagine software. These analyses were complemented by visual inspection of the images, unsupervised classification of landcovers (see Lillesand *et al*., 2004), and comparison to the current vegetation and cultivation conditions on the ground in each of the study locations (with the exception of Moghra), as well as accounts of trends in vegetation and cultivation patterns over the study period, as reported in the available literature (see introductory section). The site visits took place during April and November 2008 (Nefzaoua), July and November 2008 (Siwa) and October, 2008 (Wadi El Natroun).

3. Results

The analysis of annual average NDVI showed increasing trends in all of the cultivated oasis locations examined in this study. However, in the control site of the uncultivated oasis at Moghra, average annual NDVI remained constant throughout the period 1982-2006. Differences in the rates of increase amongst the study sites are indicated in **Figure 1**, below, with higher rates of increase noticeable at Wadi El Natroun and Nefzaoua than at Siwa. In all of the cultivated oasis cases studied, after a peak period 1986-96, increases in NDVI have tailed off, and in the cases of Siwa and Nefzaoua, decreasing trends in NDVI are becoming apparent.

The trends observed through analysis of the NDVI correspond with accounts of increasing agricultural productivity that are available from the published agricultural census records of both countries. In both countries, results of the agricultural census, including figures on the productivity of crops in the

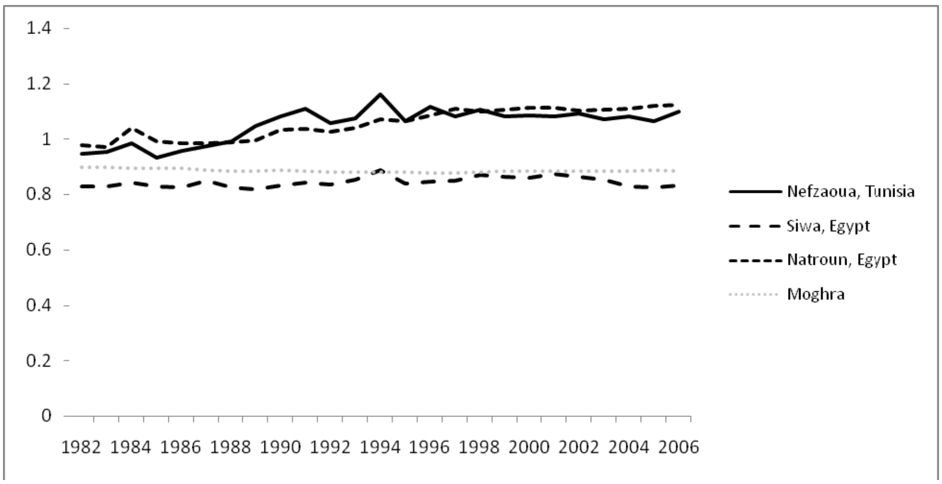

Fig. 1. Averaged Annual NDVI from GIMMS AVHRR Data.

oasis districts of Siwa, Wadi El Natroun and the Governorate of Kebili are published every ten years (MALR 1982, 1990, 2000; MARH 1996, 2006). These statistics confirm the steep increases in productivity observed in Wadi El Natroun between 1990 and 2000, and in Kebili, as well as the more modest increase observed in Siwa. In Tunisia, a dedicated annual survey of productivity in the oasis region of Nefzaoua also exists, in addition to the agricultural survey. In addition to corresponding with these available statistics, the NDVI data provide further indications of trends in productivity that occurred between the census dates.

The comparison of increases in NDVI at each of the study sites may be considered to capture the extension of cultivated areas, as reported separately in previous studies and published agricultural statistics from each location. However, the additional information provided by the NDVI, and the comparative levels and trends observable between locations and time periods may also be affected by other factors, including the varying timing and quality of the images, as well as the sensitivity of the NDVI to spectral effects caused by changes unrelated to cultivation. The most important qualifying factors may be summarized as follows:

3.1. Salt and soil reflectance

The use of NDVI to observe land cover in arid environments is imperfect, due to high soil and salt reflectance in sparsely vegetated desert areas. NDVI is based on variations in spectral patterns and does not differentiate between sources of reflectance. Salt reflectance can be high and variable across the year in saline playa lakes and sabkhas, such as those included in the study area (Bryant, 1999; Bryant and Rainey, 2002). The use of a coefficient to correct for soil characteristics is recommended in arid environments (Huete, 1988; Masoud and Koike, 2006; Alhammadi and Glenn, 2008). However, the coefficient adjustment can only be as effective as the soil quality data on which it is based. Spatially comparable inter-temporal data on soil and salt crust reflectance were not available for this purpose in the present study, therefore no correction was included.

3.2. Climatic and anthropogenic effects on vegetation

Possible changes in natural vegetation due to climatic effects, grazing pressure or other human-induced impacts on the natural vegetation cannot be distinguished from cultivation changes. The control case from the uncultivated oasis of Moghra captured changes in natural vegetation caused by local climatic effects. A noticeable peak in NDVI occurring in all of the Egyptian sites in December 1984 may well be related to a change in natural vegetation caused by a rainfall event. This should be further verified through comparison of the trend in NDVI to rainfall data over the same period and locations.

4. Conclusions (or Recommendations)

NDVI remains the best available generic tool for observation of trends in vegetation productivity (White, 2007), and provides the basis for ongoing global assessments of land productivity and degradation (Bai *et al*., 2008). In this study, NDVI proved useful for generating comparative profiles of vegetation trends at different oasis locations. Triangulation between the remotely sensed data and other sources including observations in the field and national statistics enabled analysis of the observed trends, adding depth to the profiles of evolving productivity at each location.

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