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Mapping Long-Term Variability of Vegetation Greenness and Sand Dunes around Watering Points in the Rangelands of Dahar and El Ouara (Tunisia) during the Period 1975-2000 through Remote Sensing Data

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Abstract: This study investigates the ability of satellite remote sensing and GIS tools to map temporal and spatial patterns of sands dunes, vegetation greenness variability and their interrelationships around water points in the rangelands of Dahar and El Ouara (Tataouine -Tunisia) during the period 1975-2000. Use was made of both supervised and non-supervised classification, vegetation indices, image differentiation, change detection, and pattern metrics of Landsat MSS, TM and ETM+ time series images. While the physical framework (rainfall and wind erosion) emerges as the dominant causative factor for the degradation, there are evidences of human-induced changes (dry-farming and livestock) coupled to climate trends. Although the comparative study has not resulted in a consensus on either the direction of changes or its underlying causes, the results indicate that the proposed method is applicable to identify the dynamic nature of the local ecosystems and its susceptibility to changes and, therefore, has good potential for monitoring desertification processes.

Keywords: Change detection, Desertification, Rangelands, Remote sensing, Watering points

1. Introduction

Desertification and land degradation encompasses a wide range of physical and biological processes: decline of harvest, plant cover deterioration, exacerbation of soil physical mechanisms, qualitative and quantitative deterioration of water resources, and air pollution (Mainguet, 1998). Such quantitative and/or qualitative degradation may be accompanied by irreversible or reversible changes (Tarhouni *et al*., 2006) which might affect the entire ecosystem components, and consequently, the human well beings. Studying the erosion risks through tracking the distribution of ecological indicators is a key issue for rangeland ecosystem management. Among varied criteria proposed to assess desertification severity, vegetal cover seems to be the most relevant indicator, particularly in case when results are obtained from remote sensing images (Huang and Siegert, 2006). With lack of precise and adequate tools to monitor desertification, several studies have emphasized remote sensing possibilities in the Tunisian arid regions (Le Floc'h *et al*., 1978). Satellite data, jointly analyzed with other data (field work, socio-economy, etc.) in order to extract understandable information that can be integrated in a GIS offer an undeniable potential for knowledge and modeling environmental phenomena. In this context, this study aims at analyzing degradation and desertification risks around watering points in the rangelands of the dry areas of southern Tunisia through the use of multi-temporal satellite data.

2. Materials and Methods

The study zone encompasses four watering points in the El Ouara plain (Bir Ouled Hamed and Bir Jaouacha) and in the Dahar plateau (Bir Mijna and Bir Angoud) located in the southern arid region of Tunisia (Tataouine). A multi-sources cartography was attempted to bring analysis elements about soil degradation risks through detecting temporal and spatial changes of biomass and sand dunes and, consequently determine high-risk zones in the area of watering points from 1975 to 2000. Change detection of time-series Landsat (MSS, TM, and ETM+) images was used to map vegetation (natural or cultivated) and sand dunes evolution around the studied watering points. **Figure 2** summarizes different levels of preprocessing, processing, and post-processing of remote sensing multi-temporal data, run mainly in IDRISI software.

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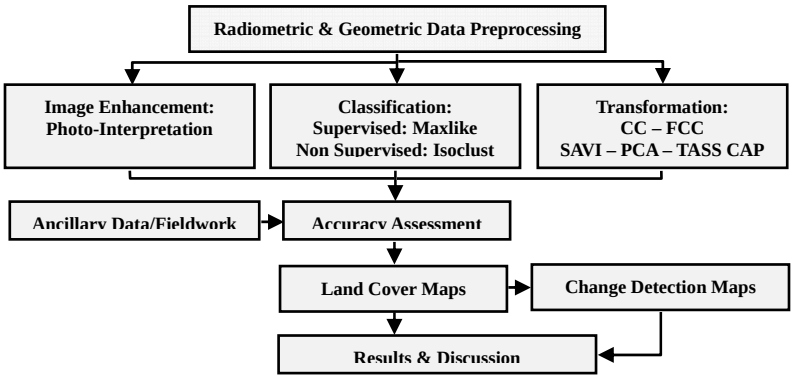


Fig. 1. Flow chart of the study methodology.

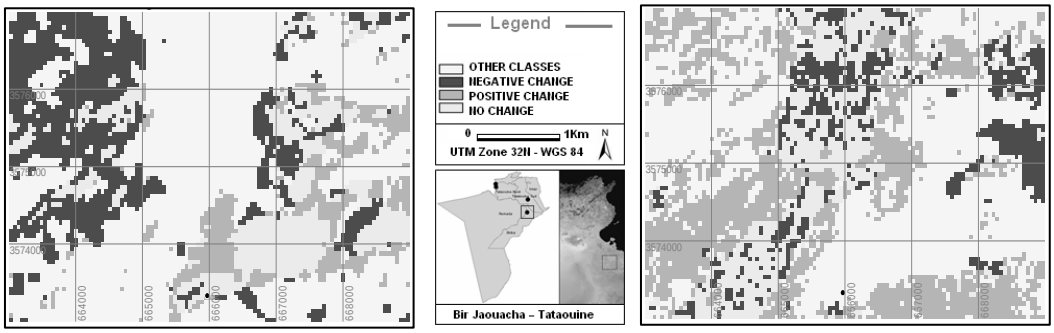
Table 1. Land cover classification scheme.

LAND COVER CLASSES - DAHAR	LAND COVER CLASSES - EL OUARA	CHANGE DETECTION CLASSES
Active Steppic Vegetation/Cropland	Active Steppic Vegetation	BV: Bright Vegetation
Sand Dunes	Sand Dunes/Psammophitic Vegetation	BBS: Bright Bare Soil
Sparse Steppic Vegetation/Bare Soil	Bare Soil/Sparse Vegetation	OV/BS: Other Vegetation/Bare Soil

In El Ouara, characterized by very heterogeneous land cover, an Isoclust (Iterative Self Organizing Cluster Analysis) non-supervised classification approach was applied whereas in Dahar, the training sites with a large size relative to the different land cover categories were appropriately delineated, Maximum Likelihood (Maxlike) supervised classifier was used (Eastman and Thiam, 2001). Although not entirely adopted, the classification scheme (**Table 1**) has had the advantage of simultaneously coupling information about vegetation and soil (Crews-Meyer and Adamo, 2006).

3. Results and Discussion

The results[A)], shown in El Ouara, are closely linked to satellite snapshots timing at the end of cropland season (December). Therefore, these parcels, generally associated to soil degradation, were integrated in the photosynthetically active vegetation class (**Figs. 2** and **3**). Though methodologically necessary, it cannot be interpreted as a sign of plant cover recovery. In fact, signs of vegetation decline around watering points are the most expressed in the combination: bare soil/less chlorophyllian shrubs. This class has been the most often observed in the region of Bir Ouled Hamed with about 61 % in 1975 and 42 % in 1999, which means that water deficits is the normal situation in general. Similarly, these trends are encountered in Bir Jaouacha: sand dunes have decreased from about 35 % in 1975 to 23 % in 1990.

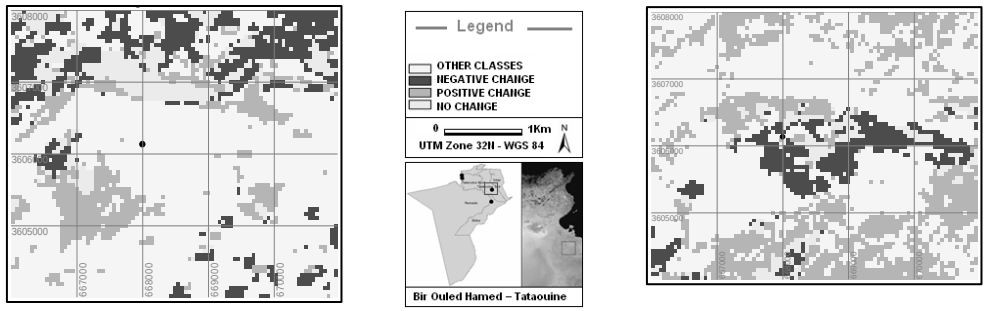


↘ BBS: 19 ha/year – 35% to 23%
Change Detection-Sanddunes (1975-1990)

Bir Jaouacha

↗ BV: 27 ha/year
Change Detection-Vegetation (1975-1990)

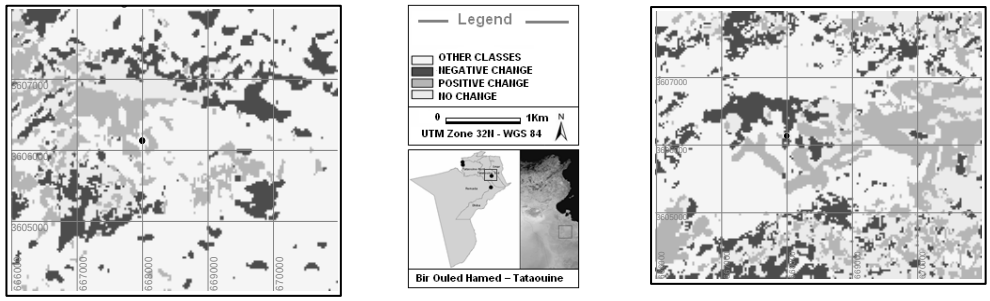
Fig. 2. Change detection maps of sand dunes and vegetation between 1975 and 1999 around Bir Jaouacha.



↘ **BBS: 3 ha/year – 25% to 23%**
Change detection-Sand dunes (1975-1990)

Bir Ouled Hamed

↗ **BV: 25 ha/year – 14% to 33%**
Change detection-Vegetation (1975-1990)



↘ **BBS: 7 ha/year – 25% to 20%**
Change detection-Sand dunes (1990-1999)

Bir Ouled Hamed

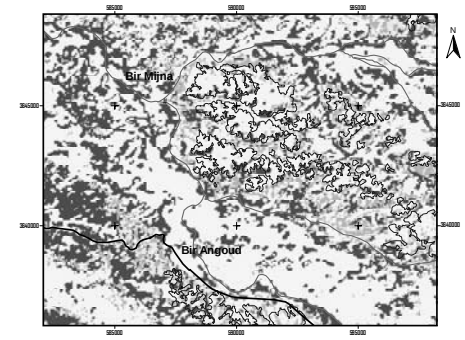
↗ **BV: 11 ha/year – 14% to 38%**
Change detection-Vegetation (1975-1990)

Fig. 3. Change detection maps of sand dunes and vegetation between 1975 and 1999 around Bir Ouled Hamed.

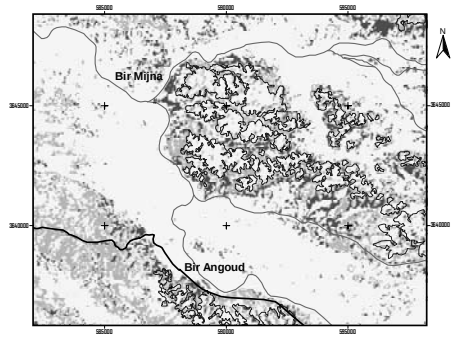
According to the FAO methodology (Mtimet *et al*., 1983), the two watering points are classified in the class of strong gravity for a percentage of sand dunes area between 15 and 30 % (Bir Jaouacha: 23 % in 1990, and Bir Ouled Hamed: 20 % in 1999). Besides, with a heavy population pressure on agricultural area, the erosion risk is strong to very strong. It seems that overgrazing, fuel-wood collection, and cropland expansion through rangeland clearing are the major degradation causes around Bir Ouled Hamed and Bir Jaouacha.

In addition, livestock pressure is involved in the two sites, considered as crossing points for transhumant flocks (Bir Ouled Hamed) or element of hydraulic network (Bir Jaouacha), and therefore there is higher water demand. On the other hand, sand dunes can be explained through a redistribution realized by the erosion agents (active winds higher than 3 m/s). The situation is growing worse, after plowing: pulverized soils having no protection against aeolian erosion which removes soil surface layer, and creates dune fields; especially in Bir Jaouacha where the S-SE side evolves at present in dunes. The land cover change analysis in El Ouara is a critical question for the interpretation of ecosystem condition because it indicates a probable recovery but it greatly depends on climatic constraints and mapping scale. Nevertheless, it's obvious that satellite images, each one representing a fixed point in time, can record just a stage of an ongoing continuous process.

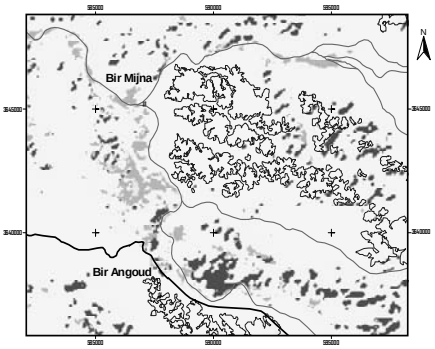
Visual inspection of the change detection maps gives an idea about spatial distribution of changes. In the Dahar (Bir Mijna and Bir El Angoud) (**Fig. 4**), the results indicate that two sites can be qualified as moderately sensitive to desertification with more accentuated degree in Bir Mijna: 6.71% of the studied zone was sand encroached in 2000. According to the FAO criteria (Mtimet *et al*., 1983), it corresponds to the class of moderate gravity. Furthermore, the annual rate of vegetal cover decrease between 1987 and 2000 is about 1.75%; which corresponds to the mean class of speed of desertification processes. In order to explain these results, it's useful to mention that the plateau of Dahar is dominated by rocky outcropping and limestone crust; sands essentially accumulated in spreading zones (*wadis*). Considering the meteorological data of Remada station as reference for the study zone, we can deduce that the region is particularly windy (January-May with 13-21 km/h), and consequently higher speed of sand redistribution. On the other hand, the degradation, particularly in Bir Mijna, is due to flocks repetitive trampling and absence of croplands in the vicinity of the studied sites. However, the observed vegetation cover reduction is spectacular following long years of drought.



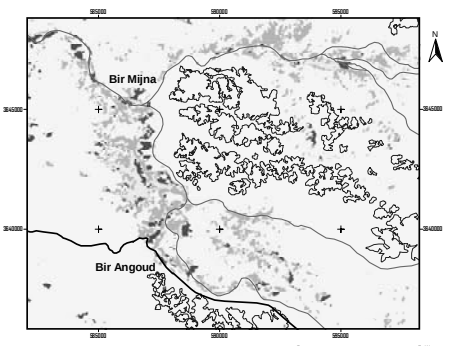
↘ BV: 436 ha/year – 31% to 14%
CHANGE DETECTION MAP - VEGETATION (1975-1987)



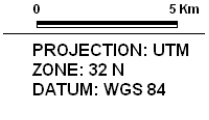
↗ BV: 73 ha/year – 14% to 17%
CHANGE DETECTION MAP - VEGETATION (1987-2000)



↘ BBS: 62 ha/year – 6% to 3%
CHANGE DETECTION MAP – SAND DUNES (1975-1987)



↗ BBS: 77 ha/year – 3% to 7%
CHANGE DETECTION MAP – SAND DUNES (1987-2000)



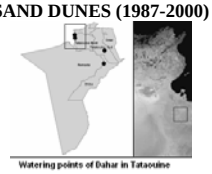


Fig. 4. Change detection maps of vegetation and sand dunes between 1975 and 2000 in Dahar.

Precipitations, often localized, don't allow to steppic species to recover.

Annotation

A) The percentages are expressed here in relation to the extent of the studied area which differs in each site.

References

Crews-Meyer K.A., Adamo S.B. (2006): Aridity and desertification: Exploring environmental hazards in Jachal-Argentina. *Applied Geography*, **26**:61-85.

Eastman J.R., Thiam A. (2001): *IDRISI Release 2: Guide to GIS and Image Processing, Vol.1 and 2*. Clark Univ., USA;

Huang S., Siegert F. (2006): Land cover classification optimized to detect areas at risk of desertification in North China based on SPOT VEGETATION imagery. *Journal of Arid Environments*, **67**: 308–327.

Le Floc'h E., Coque A., Long G., Pontanier R. (1978): *Contribution à l'analyse écologique des zones arides de Tunisie avec l'aide des données de télédétection spatiale: Expérience ARZOTU: rapport final*. CNRS-CNES-CEPE L. Emberger, Montpellier ;

Mainguet M. (1998): Désertification et insécurité environnementale dans les écosystèmes secs. *Aménagement et nature*, **06**:19-22.

Mtimet A., Souissi A., Hentati A. (1983): L'estimation et la cartographie de la désertification par les processus éoliens: méthodologie de la FAO. *Séminaire PNUE/UNESCO sur les problèmes de l'érosion éolienne dans les zones pré-désertiques*, 21-26 Nov. Djerba, Tunisia.

Tarhouni M., Ouled Belgacem A., Neffati M., Henchi B. (2006): Validation de quelques attributs structuraux de l'écosystème sous l'effet de la sécheresse saisonnière et la pression animale autour de points d'eau en zone aride tunisienne. *Belgian Journal of Botany*, **139**:188-202.