Ecological Indicators xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original articles

Can palm date plantations and oasification be used as a proxy to fight sustainably against desertification and sand encroachment in hot drylands?

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ARTICLE INFO

Keywords:
Sahara desert
Oasis
Desertification
Land cover
Spatiotemporal land survey
Date palm plantation
Remote sensing
GIS

ABSTRACT

Using GIS and remote sensing tools, the current dissertation shows the impact of agricultural mutation in drylands and highlights the effect of date palm (*Phoenix dactylifera*) plantations (DPP) on desertification phenomenon in oases of the Algerian Sahara Desert. The spatiotemporal survey was conducted using three Landsat satellite images (TM-1984, ETM+-1999, and OLI-2013). Likelihood supervised classification was used to quantify DPP change over three decades, whereas four remote sensed indices were extracted as indicators of desertification process in the study area: Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), Salinity Index (SI-T), and Crust Index (CI). Generalized linear mixed models (GLMMs) were applied to test the effects of year and DPP 'presence/absence' for NDVI; year, DPP and NDVI for both CI and NDMI; year, DPP, NDVI and NDMI for SI-T. DPP area and tree numbers quadrupled over the last three decades with a surface increase of 4822 ha and more than 0.5 million trees. DPP presence positively influenced NDVI, NDMI and CI, but negatively affected SI-T. Highly significant positive relationships were found between NDVI—DPP, NDVI—NDMI, and NDVI—CI, although negative relationships were obtained between SI-T—NDVI and SI-T—NDMI. DPP areas indicated higher NDVI, NDMI and CI values, but with lower SI-T values compared to the rest of the desert habitats. Our results highlighted the potential role of DPP in controlling and mitigating desertification in hot drylands. This arises from the effectiveness of strategic agricultural policy programs. Landsat series data provided a cost-efficient tool for monitoring change in oases and arid environments.

1. Introduction

According to the United Nations Convention to Combat Desertification UNCCD, desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (Benabderrahmane and Chenchouni 2010; Ci et al., 2010). In 1998, more than 900 million people in 100 countries were affected by this phenomenon, which is expected to double by 2025 (Dooley 2002). Drylands are the most sensitive areas to desertification worldwide (Reynolds et al., 2007). Due to its geographical position, drylands of the Mediterranean region are mostly affected by desertification and land degradation compared to the rest of the world (Safriel, 2009). Nowadays, the assessment, monitoring and combating of desertification and land degradations represent a real challenge under the current and projected global climate change for both scholars and decision-makers (Chasek et al., 2015; Gnacadja 2015; Liu et al., 2015; Stavi and Lal 2015; Van den Elsen and Jetten 2015).

Intimately dependent on water resources and climatic conditions, oasis is simultaneously a fertile and fragile ecosystem of hot desert zones, in which agriculture is the main human activity (Shanzhong and Xiaoyu 2010; De Grenade et al., 2016). Oasis is structured in a multilayered vegetation composed of wild and crop plants and dominated by a canopy underneath high biodiversity of animal and plant species occurs within the lower vegetation stratum (Gebauer et al., 2007; Guezoul et al., 2013). The dynamics of oasis in arid lands have two opposite trends: (i) oasification that refers to oasis expansion by the plantation of new lands and the use of sustainable and modern farming practices, and (ii) desertification inducing oasis range contraction and agricultural land degradation due to the combined effects of land

Abbreviations: CI, crust index; DPP, date palm plantations; GIS, geographic information system; GLMM, generalized linear mixed model; LU/LC, land use/land cover; NDMI, normalized difference moisture index; NDVI, normalized difference vegetation index; SI-T, salinity index-Tripathi; TM-1984, thematic Mapper-1984; ETM+-1999, enhanced thematic mapper plus-1999; OLI-2013, pperational land imager-2013

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https://doi.org/10.1016/j.ecolind.2017.11.027
Received 27 April 2017; Received in revised form 11 November 2017; Accepted 15 November 2017

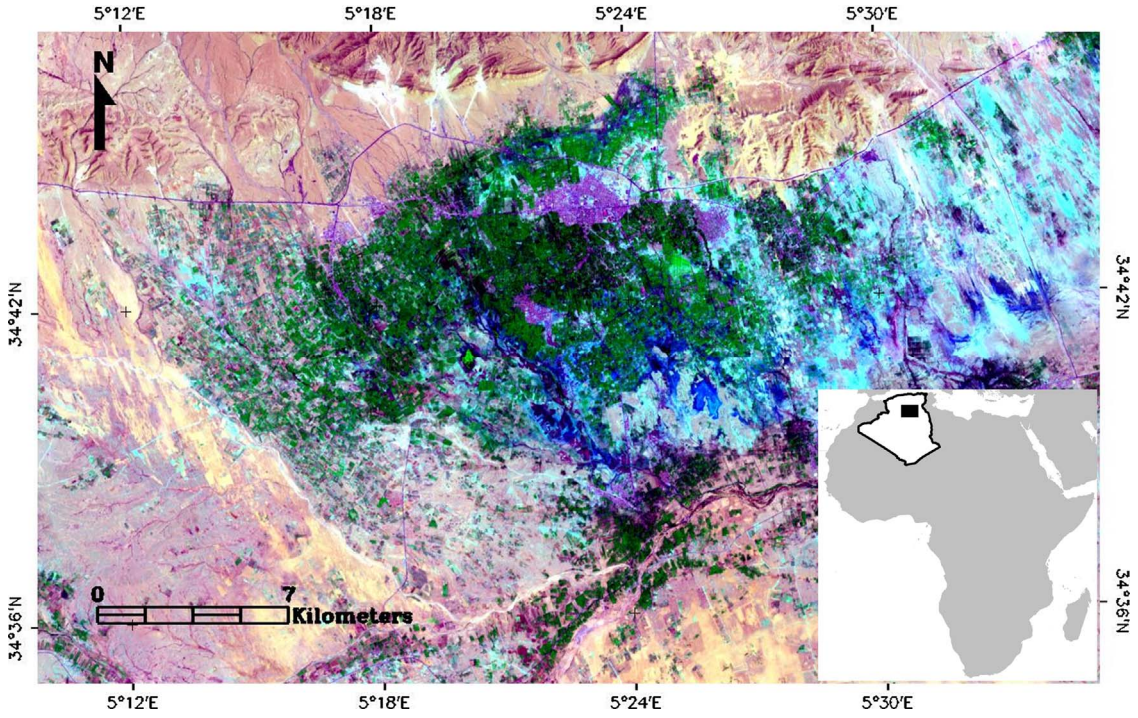

Fig. 1. Study area, Landsat scenes 8 OLI for the year 2013 (RGB composite, Bands 7-5-2).

abandonment, severe climate conditions, and urban expansion (Safriel 2009; Xie et al., 2015). During the last decades, agricultural lands remarkably expanded in North African oases including the Ziban region in Algerian Sahara (Afrasinei et al., 2017a), a result of the sustainable water irrigation management adopted in oasis agroecosystems (Carr 2013; Bouguedoura et al., 2015; Hamamouche et al., 2017).

During a long period of stagnation and sometimes abandonment of the date palm oases in the Algerian Sahara, large area of date palm groves suffered from urbanization, advanced tree age, and the escape of manpower from the agriculture sector. However, since the 80s, the date palm farming has experienced a significant recovery in the Ziban region especially during the last three decades due to: (i) the new sustainable agriculture policy adopted by the Algerian government, (ii) many environmental assets including favourable climatic conditions, extensive lands, sufficient water resources, and a large population with high manpower (Dubost and Larbi-Youcef, 1998; Bouzaher and Alkama 2013). In fact, since ancient times, the date palm has been recognized as '*the tree of life*' because (i) environmentally, DPP trees create suitable microclimates under hot desert conditions and host diverse animals/plants as they find there shade, food, and living habitat, (ii) socially, DPP play important role in providing rural communities with food resources and livelihood opportunities for employment in drylands, and (iii) economically, date palm is an economic crop, income-generating, foreign exchange earnings, and offers added-value products for the national economy (Jain et al., 2011; Al-Khayri et al., 2015a). Within this context, our study aims to test if the planting of date palm trees can provide vital defence against desertification staring from geomatics-based approach using long-time series of Landsat images as cost-efficient tool (Arar and Chenchouni 2012; Afrasinei et al., 2017a).

Landscape management of oasis and date palm groves are indissociably related in hot desert regions where the date palm production is the economic centre of oasis agriculture (Benchelah and Maka 2008). The date palm (*Phoenix dactylifera* Linnaeus 1753) is known as a species with high tolerance to hot conditions and can be grown under moderate soil salinity (Tengberg 2014). Due to vertical growth of date palm trees, the latter play a key-role in maintaining a suitable microclimate for Saharan agriculture and shelter for several plant and animal species (De Grenade 2013; Guezoul et al., 2013). Date palm is one of the most permanent crops cultivated within desert regions worldwide (Al-Khayri et al., 2015a,b).

Many studies revealed the sustainability and efficiency of biological methods to control and combat desertification using trees and shrub species (Pasternak and Schlissel 2001; Hooke and Sandercock 2012; Neffar et al., 2013). The role of date palm plantations (DPP) in stopping sand invasion and mitigating the advancement of desertification in hot deserts was reported in several studies. DPP improve soil quality (structural stability, increase in moisture and organic matter) and serve as a sand barrier for fixing sand dunes (Al-Khayri et al., 2015a,b). Nevertheless, up-to-date no study clearly proved the impact of DPP on desertification trends at large or small scales. Within this context, the assumptions tested in the current study are that DPP in hot sandy deserts positively influence desertification control or at least stop its advancement by reducing sand encroachment at regional scale. Indicators of desertification regression such as the increase in vegetation cover/density assessed with the normalized difference vegetation index (NDVI) and soil moisture (Ibrahim et al., 2015), are expected to significantly increase in habitats with DPP compared to unplanted or barren arid environments. Furthermore, this survey aims (i) to demonstrate the potential role of DPP in combating desertification in the Sahara Desert of Algeria and how this can be used as an indicator to promote a sustainable agro-ecological system in oases, (ii) to affirm the potential of remote sensing image processing techniques for monitoring and rapid detection of land change in oasis and desert landscapes.

2. Materials and methods

2.1. Study area

Geographically, the Ziban region is located at southeastern Aures mountains in Algeria, it stretches within latitudes 34°35′N to 34°50′N and 5°10′E to 5°35′E (Fig. 1). The study area covers an area of 890 km^2. The main human activity in this region is agriculture, where the permanent crop is the DPP. Date palm is a long-living tree (over 100 years), however aged trees represent a constraint for date fruit production. Thus, the old DPP (traditional oases) are gradually replaced with young and modern oases established over larger cultivated areas for ensuring