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Vegetation changes as an indicator of impact from tourist development in an arid transgressive coastal dune field

Antonio I. Hernández-Cordero*, Luis Hernández-Calvento, Emma Pérez-Chacón Espino

Grupo de Geografía Física y Medio Ambiente, Instituto de Oceanografía y Cambio Global, IOCAG, Universidad de Las Palmas de Gran Canaria, ULPGC, Parque Científico-Tecnológico de Taliarte, Calle Miramar, 121, 35214 Telde, Las Palmas, Spain

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ABSTRACT

Arid transgressive coastal dune fields experience significant changes over short time periods. They are ideal systems to analyze environmental changes induced by human activities. This research analyzes the changes in vegetation produced by tourism in the dune field of Maspalomas (Gran Canaria, Canary Islands, Spain). Plant communities were mapped using GIS in digital ortophotos before tourism development in 1961 and then in 2003. The layers were overlaid in a GIS to analyze variations in the spatial distribution and extension of the vegetation. Detected changes were grouped into five types: no change, urban occupation, plant colonization, plant community changes and vegetation loss. Half of the dune system presented no change in vegetation. The most significant modifications were associated with urban occupation (tourist urbanizations, infrastructures and tourist facilities) and plant colonization. Urban occupation decreased the dune system surface area and resulted in disappearance or reduction of three plant communities. Plant colonization was indirectly induced by tourism infrastructure development, since it modified wind flow, there by stabilizing the dunes in some areas and forming deflation surfaces in others. The changes in spatial extent of plant communities are bioindicadors of environmental changes arising from tourism development. Vegetation changes in this study reflected stabilization processes (colonization and expansion of psammophilous herbaceous and xerophilous shrub plant communities), erosion (colonization as well as the expansion of hygrophilous and halophilous plant communities) and anthropogenic processes (occurrence of ruderal plant communities).

1. Introduction

The earlest alterations of coastal dune fields were associated with traditional activities. The intervention of the humans in these ecosystems has been occurring for centuries. Traditional activities, such as grazing, agriculture, the use of fire and exploitation of plant species, have favored the mobilization of dunes to the point that they are the precursors of the existence of some of current mobile coastal dune fields (Granados Corona et al., 1988; Piotrowska, 1989; Kutiel et al., 2004; Levin and Ben-Dor, 2004). More recently, and linked to an urban-touristic model, beaches and dune fields have experienced environmental changes due to more intensive human activities (Jackson and Nordstrom, 2011): infrastructure construction, resource extraction, trampling and vehicle traffic, modification of the surface for recreational uses, sediment redistribution, creation of landforms and planting of vegetation, and remobilization of stabilized landscapes. Overall, there has been a sharp decline of these ecosystems. In Europe 25% of the coastal dunes have disappeared since 1900 (Delbaere, 1998).

One of the specific effects of humans on dune vegetation is the alteration of succession. In northwestern Europe in the last century, dune successional processes have been altered or the dunes have been fixed by (Provoost et al., 2011): changes in land use, reduction in rabbit populations, increased dune stabilization by human factors, substrate eutrophication, climate change and human impact on the landscape. With development for tourism, which includes urbanization, forest plantations and the extraction of groundwater, impacts on vegetation include: expansion of invasive alien plant species (Kim, 2005; Jørgensen and Kollmann, 2009; Kollmann et al., 2009; Faggi and Dadon, 2010), the replacement of hygrophilous plant communities by xeric plant communities (Muñoz-Reinoso, 2001), reduction of pioneer species on mobile dunes (Dolnik et al., 2011; Faggi and Dadon, 2011) and reduction of vegetation cover and species richness (Curr et al., 2000; Kutiel et al., 1999; Hesp

* Corresponding author.
E-mail addresses: hernandez.cordero@ulpgc.es (A.I. Hernández-Cordero), luis.hernandez.calvento@ulpgc.es (L. Hernández-Calvento), emma.perez-chacon@ulpgc.es (E.P.-C. Espino).

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et al., 2010). In turn, the changes of vegetation can lead to the transformation of the geomorphology of the dunes through changes in dynamics and types of landforms (Buell et al., 1995; Hellström, 1996; Wiedemann and Pickart, 1996; Hilton et al., 2005; Hilton et al., 2006; Hart et al., 2012). Therefore, the dune vegetation, due to its close relationship with the landforms (Araújo et al., 2002; Stallins, 2006; Hesp et al., 2011), is an excellent indicator of the environmental characteristics and the human impacts in the coastal dunes (García-Mora et al., 1999; Tzatzanis et al., 2003; Grunewald and Schubert, 2007; Levin et al., 2007; Lomba et al., 2008).

In the Canary Islands, due to the predominance of coastal cliffs (66.8% according to ISTAC, 2009), dune systems are scarce, so the vegetation associated with them has always occupied small areas. Human activities development has resulted in a further decline of dune plant communities and the destruction of some of these systems (Santana Cordero et al., 2014). Currently dune plant communities occupy an area of 12,659 ha of a potential 24,091 ha (Del Arco Aguilar et al., 2010). Therefore, there has been a reduction of 52.5%. Dune systems in the Canary Islands contain plant communities and plant species unique in the European context, as most of them are only shared with the northwest coast of Africa and the Macaronesia or are endemic species (Santos, 1993; Géhu and Biondi, 1998). For these reasons, it is very important to know the degradation processes that produced this reduction of dune vegetation and their ecological and geomorphological consequences, so that there can be the potential for reconciling tourist development with sand dune conservation. This is especially relevant in arid transgressive dune systems, like Maspalomas, where changes happen very quickly (Cabrera-Vega et al., 2013; Hernández-Calvento et al., 2014).

Before the tourist development, until the 1960's of the last century, the coastal dune systems of the Canary Islands had marginal land uses. These uses were linked to traditional activities such as agriculture, grazing, exploitation of plant species, recreational uses and sand extraction (Santana Cordero et al., 2016a, 2016b). In any case they were little intensive uses due to the environmental limitations of the dune fields. The dunes were an obstacle to agriculture, as the sand invading crops as it did in the Maspalomas dune field. The intensity of use depended to a great extent on the location of the same. The Guanarteme dune system, located in the northeastern part of the island of Gran Canaria, experienced intense land uses since the beginning of the 20th century due to the development of the city of Las Palmas de Gran Canaria and the port associated with it (Santana Cordero et al., 2016b). In contrast, the Maspalomas dune field, located on the southern tip of the island of Gran Canaria and far from the poles of economic attraction, presented uses associated with grazing and in the surroundings of the same were developed some crops. In short, in an economy based on the primary sector and trade, the dunes presented few attractions for the human activities.

The change of the economic model of the Canary Islands as a consequence of the development of sun and beach tourism from the 1960's of the last century, produced the transfer of economic interest towards the coast and the south of the island of Gran Canaria, where Maspalomas is located. In this context, the beaches and dunes became tourist attractions of first importance. From this moment great tourist urbanizations were built around of Maspalomas dune field, produced the most important tourist center of Spain (Domínguez-Mujica et al., 2011). However, before this tourist development, most of the dune field of Maspalomas had no vegetation (Esteve, 1968). Tourist development produced changes in vegetation (Hernández Calvento, 2006), but these have not been quantified until now.

The aim of this paper is to analyze the changes in the vegetation in the Maspalomas dune field as the result of development for tourism, which was implemented in the beginning of the 1960's of last century.

2. Area of study

The Maspalomas dune field is located at the southern tip of the island of Gran Canaria (Canary Islands, Spain; Fig. 1). Its area is 360.9 ha. It is a transgressive dune system where barchanoid ridges and barchan dunes predominate (Hernández Calvento, 2006). Sediments access the system by El Inglés beach to the east, moving through the effect of the trade winds from E-NE as free dunes, then go back to the sea on the beach of Maspalomas (south) (Hernández et al., 2007). This system has three zones, depending on the aeolian sedimentary activity and associated with different landforms: active area (beach, foredune, transgressive low dunes, deflation surfaces, transgressive high dunes and interdune depressions), semi-stabilized area (barchan dunes and sand sheets, hummock dunes, and deflation surfaces) and stabilized area (stabilized dunes and interdune depressions) (Hernández-Cordero et al., 2015a).

The climate is arid, registering an average annual rainfall of 81 mm (period 1952–2008), with a large annual and interannual variability. The average annual temperature is 21 °C (1997–2007). However, the location of the dune field on the alluvial fan allows the existence of a water table near the surface, which in the interdune depressions and deflation surfaces (slacks) becomes accessible to plants (Pérez-Chacón et al., 2007). Therefore, the vegetation in Maspalomas dune field is conditioned by disturbances related to burial by sand, by the scarcity of rainfall and the existence of a water table near the surface. The current vegetation at this dune field is comprised of 19 plant communities, represented by psammophilous, halophilous, xerophilous, hygrophilous species, and in the human disturbance areas, ruderal species (Hernández-Cordero et al., 2015a). These plant communities are associated with different habitats (Table 1). Maspalomas is legally protected as a special nature reserve by Law 12/1994, of 19 December, of Protected Natural Spaces of the Canary Islands.

3. Methods

To analyze the changes in vegetation in the dune field of Maspalomas, two cartographic documents on the distribution of vegetation were produced; one of them corresponds to the period before the touristic development (1961), while the second one is from when tourist development had already take place (2003). For this, black and white two digital orthophotos in were used as primary sources of information. The orthophoto from 1961 has a spatial resolution of 12.5 cm/pixel and it was obtained from the spatial data infrastructure of Canary Islands (IDECanarias, GRAFCAN, SA, Gobierno de Canarias). The orthophoto of 2003 has a spatial resolution of 15 cm/pixel and belongs to the research group Geografía Física y Medio Ambiente of the University of Las Palmas de Gran Canaria. We analyzed additional aerial photos between 1961 and 2003, so as to have a better understanding of temporal changes in dune activity and in vegetation cover.

The procedure for generating the vegetation map of 2003 was based photo-interpreted of the digital orthophoto using visual variables for the identification of different vegetation types (color, size, density, texture and spatial pattern). These criteria were used to digitized in GIS the homogenous vegetation units. Through field work, units were checked preliminarily to confirm the type of plant community based on the dominant species. Next, to assign each unit definitely to the corresponding plant community relevés were performed (see details in Hernández-Cordero et al., 2015a).

A regressive historical method was used for the reconstruction of the existing vegetation in 1961. The vegetation map of 2003