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Reconstruction of the land uses that led to the termination of an arid coastal dune system: The case of the Guanarteme dune system (Canary Islands, Spain), 1834–2012

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ABSTRACT

Coastal areas have been under pressure throughout history. Today these environments are occupied by a large portion of the world population and are dramatically affected by human activities. For a better understanding of the natural evolution of coastal ecosystems and their present state, historical studies are necessary. For this purpose researchers should apply methods that combine different historical sources, such as historic mapping and oral sources. In this paper we examine land uses that led to the disappearance of an arid coastal dune system, and the way to study it. Results reveal that each different land use had a different impact on the environment, and this was in correspondence with socio-economic needs. Finally, we discuss the results obtained and the methodology used.

1. Introduction

The coastal areas of the planet, as most natural ecosystems, have been affected from the changes caused by human activity during their history (Nordstrom, 1994). Especially in recent decades, these environments have been particularly affected, enduring much of the urban development and other important land changes (Jackson and Nordstrom, 2011). At global scale, currently almost 30 percent of the coastal areas are altered by development related to human activities, an area where 41% of the world population lives (Martínez et al., 2007). Bajocco et al. (2012) note that in recent decades there has been a significant "littoralization" of societies, which has led to a continuous degradation of the coast. This phenomenon has been observed across the Mediterranean, particularly in Spain, where urban development in the coastal area has intensified and accelerated in recent decades (Ariza, 2011). This has induced a permanent degradation of natural coastal systems, with a constant risk of losing vital ecological processes, as well as for the conservation of biota. In this scenario, many islands are particularly fragile as a result of intense development of urban and tourist infrastructure near their shorelines. Such is the case of the Canary Islands, where this development has exerted significant human pressure on both the ecosystems of high ecological value and some of their characteristic natural processes (Hernández et al., 2007; Hernández-Cordero et al., 2006; Otto et al., 2007).

In this context, coastal dune systems represent environmentally fragile and significantly changed areas, since various human activities that have an impact on their dynamics and natural elements are carried out on or near them. These impacts are particularly significant in Europe and North America where coastal dune systems are a diminishing resource (Jackson and Nordstrom, 2011; Paskoff, 1993; Pye and Tsoar, 1990). The primary cause of these changes is attributed to changes in land uses, both historical (grazing, agriculture, forestry and mining activities) and present uses, amongst which urban-touristic use is highlighted (Cooper and Alonso, 2006; Otto et al., 2007; Santana Cordero et al., 2015).

Most studies of coastal dunes have been conducted in temperate systems, while arid coastal dune systems have received much less attention, especially in terms of the geomorphological consequences resulting from human activities (Cabrera-Vega et al., 2013; Hernández-Calvento et al., 2014). Due to the arid climate that prevails in these environments, the impacts on landforms are evident

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within short periods of time compared with more humid environments (Cabrera-Vega et al., 2013).

To address the study of changes in an ecosystem, several lines of research focused on the changes experienced in the past are currently being developed in order to understand the present, predict future trends, and apply the results to improve the work of restoration and/or management (Anderson et al., 2006; Gimmi and Bürgi, 2007; Grossinger et al., 2007; McAllister, 2008; Robertson and McGee, 2003; Stein et al., 2010; Swetnam et al., 1999; Villagra et al., 2009). The information derived from these studies is particularly useful in systems that are still recoverable from an environmental perspective (Koster, 2009; Thomas and Wiggs, 2008). In systems which have disappeared or are dying out with no chance of recovery, the ultimate goal of these studies is the reconstruction of its environmental history, in order to better understand their eco-anthropic dynamics, since they can serve as a reference for other similar systems at different stages of development. In this line, studies that address changes in land use or land cover are of great interest, especially if they integrate both aspects. This type of analysis constitutes an effective way to characterize the current environmental situation and the ongoing changes of a natural system (e.g. Raj and Azeez, 2010; Ye and Fang, 2011).

In this point, the study of the causes of land change can shed light over the change process itself, allowing understand it better. So, describe the land-use changes, and analyzing the underlying driving forces—fundamental social processes that underpin proximate causes—and proximate causes—land visible changes—(Geist and Lambin, 2002) seems to be a correct procedure to examine this.

This paper presents an historical reconstruction of land uses in an arid transgressive coastal dune system that has already disappeared, the Guanarteme dune field (Gran Canaria, Canary Islands, Spain). Our general goal is to deepen our knowledge of the causes that led to its demise. To do so, the time period when those processes occurred is addressed. Thus, we begin the study in 1834, when we have a historical map showing that the system was working normally. The study concludes in 2012, when the entire surface of this dune system became urbanized, thereby blocking aeolian sediment transport between the input and output areas of this system.

Specific objectives of this research are the following: (1) to identify and characterize the land uses that occurred in the study period (1834–2012), as this is the period when human activities that led to the demise of this dune system were carried out; (2) to analyze the underlying socioeconomic forces that boosted the changes; and (3) to establish a consistent methodology able to work and integrate multi-source information.

2. Study area

The Guanarteme arid dune system was located in the northeast of the island of Gran Canaria (Canary Islands, Spain), covering the isthmus that connects the island of Gran Canaria with the volcanic complex of La Isleta, located to the NE. It had an area of 243.7 ha (2.44 km^2) and the dynamics of the dunes were conditioned by the prevailing winds in a NW-SE direction, resulting from changes in the direction of the trade winds, mainly from the NE, by the interposition of La Isleta (Fig. 1).

The traveller Olivia Stone, who visited Gran Canaria between 1883 and 1884, provides a description about this dune field as follows: 'the sand is disposed in hills, valleys, small tablelands, and plateaus, over which when one begins to walk their extent seems to be much greater than would be supposed from a distant view' (Stone, 1887).

The system consisted of two distinct areas from a topographical point of view: on the one hand, the tombolo (also known as the 'Guanarteme isthmus'), consisting of a flat surface formed by Pleistocene and Holocene sedimentary materials underlying the aeolian deposit; on the other hand, a Pleistocene wedge-shaped sedimentary terrace of about 50 meters height in the south. In terms of dynamics, it was an arid transgressive dune system, whose sand was sourced from the beach in the northwest (Las Canteras beach), crossed the tombolo as sand ridges and returned to the sea along the east coast (Las Alcaravaneras beach) (Santana Cordero et al., 2014).

Currently, the only one elements of this system that can still be observed are the sand input and output areas, the beaches of Las Canteras and Las Alcaravaneras, respectively. The rest of the dune field has been entirely occupied by the city of Las Palmas de Gran Canaria.

From an economic point of view the dune field was, until the late XIX century, an unproductive land, a marginal area regarding land use. Sometimes it was even a handicap to the development of the activities that took place around it. Thus, during high wind periods, sand invaded the agricultural fields located to the south of this aeolian sedimentary system. Anyway, this system represented a potential area of growth for Las Palmas de Gran Canaria, which developed its urban fabric from the mid-XIX to the mid-XX century, by spreading from the historic old town to join up with La Isleta.

Regarding the political context, changes in the national policy system throughout the study period had an effect on urban planning policies. From the 1830s to the Spanish Civil War (1936–1939), several legislative reforms affecting urban planning were introduced, promoted by various political regimes. Then, from 1939 to 1975 during Franco's regime, urban planning changed again. During the dictatorship, patronage and corruption dominated urban planning and in most Spanish cities urban development plans consisted of poor quality draft proposals, at least until the 1950s (Cardesín, 2015).

At the local scale it should be mentioned that the first urban plan for the city was made by Laureano Arroyo and dates back to 1898. This plan increased the available area for building, although at this moment the expansion of the city was already under way (Cáceres, 1983). Therefore, the city's expansion was carried out in absence of rational urban planning nor, of course, any regulation in coastal management.

As a result, by 1940, the urban occupation of much of this territory was a fact:

> This miracle of transformation of sand to orchard, of desert to one of the densest present-day urban agglomerations, has occurred and is still occurring right under our eyes. 40% of the urban extension of Las Palmas currently occupies land that belonged entirely to the domain of the sands and dunes until the last years of the last century (Miranda Guerra, 1940).

3. Materials and methods

3.1. Sources

In this study the following sources have been used:

3.1.1. Bibliographical references

Encompasses from scientific papers to local publications about the study area. These play a determining role in the entire paper, since they provide specific information about the landscape as well as the international scientific context.

3.1.2. Historical maps

9 historical maps from different dates were collected from various historical archives and digital platforms. The use of these documents has been of great interest because they show the dif-