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Factors affecting vegetation and soil recovery in the Mediterranean woodland of the Canary Islands (Spain)

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ABSTRACT

We investigated whether human-induced soil degradation may hinder the regeneration of a semiarid Mediterranean-type ecosystem with high biodiversity and conservation interest on the Canary Islands. To further this aim, the replacement of plant species and life-forms and the variation in soil quality were studied during the process of succession in old fields abandoned at different times and in relicts of the original thermophilous woodland by means of multivariate techniques of ordination (RDA, DCA, CCA) and clustering (*k*-means + IndVal). The studied ecosystem showed a limited capacity for recovery, which appears to be lower than in other similar semiarid Mediterranean ecosystems. Soil parent material exerted a considerable influence on plant reestablishment, and this process was more efficient with pumice-type rocks. Human activities have given rise to a loss of soil organic matter and an enrichment of certain nutrients, which revert to their normal levels once disturbance ceases. However, the erosion resulting from ploughing, farming and subsequent land abandonment has resulted in irreversible degradation of the soil water regime, thus severely limiting the restoration of the original ecosystem. We concluded that aridification due to soil degradation may, in certain cases, prevent the complete regeneration of thermophilous woodlands of the Canary Islands, and it must be taken into account when performing restoration activities. Pumice mulch can be useful for restoration, as it provides a suitable substrate in key stages of the plant recolonisation process.

1. Introduction

Ecosystem resilience refers to the capacity of an ecosystem to absorb disturbances without changing its essential functions, structure, identity and feedbacks (Walker et al., 2004). If the intensity of a disturbance exceeds a certain threshold, the factors and processes controlling the functioning of the ecosystem may be significantly altered. Then, the ecosystem may no longer return to its initial stage but, rather, to an alternate metastable state. Therefore, stability domains are defined as separated by ecological thresholds (Holling, 1973). When ecosystems are degraded by human activities, at least two thresholds to recovery can be distinguished (Bestelmeyer, 2006; Whisenant, 1999). The first of these is controlled by biotic factors, e.g., the availability of diaspores that allow for the return of the original plant species to the ecosystem. The second threshold is related to substantial modification of abiotic factors, mostly related to the degradation of soil and water resources. When one or both thresholds are crossed, the spontaneous regeneration of the ecosystem may be prevented, and restoration actions may be necessary, either by reintroducing species or by regenerating the physical environment.

The Canary Islands are a world biodiversity hotspot (Myers et al., 2000) because of their high diversity of climatic habitats and isolation, which promote particularly active evolutionary and speciation processes. Thermophilous woodlands are some of the richest ecosystems, exhibiting typically Mediterranean, perennial sclerophyllous tree vegetation. The Canary Islands have undergone a severe process of desertification in which deforestation and the erosion and physical–chemical degradation of soils play central roles (Rodríguez-Rodríguez et al., 1998). Canary thermophilous woodlands have become seriously degraded and threatened and currently extend over only 8.4% of their potential extent. The main causes are their conversion to pasture and farmland and the human settlements that have arisen since the European colonisation of the Canary Islands in the XVth Century (Del-Arco et al., 2006). The European Community considers thermophilous woodland

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communities to be 'priority natural habitat types' and/or 'natural habitat types of Community interest' (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). Due to concerns about the conservation of this ecosystem, the European Community-financed Project LIFE04/NAT/ES/000064 was aimed at its restoration and at increasing our knowledge of this habitat (Fernández-Palacios et al., 2008). Recently, important advances have been made in understanding the demography and regeneration strategies related to key species in these woodlands, such as *Juniperus turbinata* ssp. *canariensis* (Fernández-Palacios et al., 2008; Otto et al., 2010). Nevertheless, there is a significant lack of studies addressing the mechanisms that control natural succession at a community scale and the role of soils in the regeneration of the Canary thermophilous woodlands.

The analysis of chronosequences of land abandonment is a classic approach to the study of ecological succession, and its results can be immediately applied to ecosystem restoration (Bonet, 2004; Cramer et al., 2008). In this work, we relied on chronosequences to study the soils and vegetation in fields abandoned at different times and in the relicts of the original vegetation in an experimental area located in the potential domain of thermophilous woodland. Our objectives were to describe the mechanisms of natural regeneration of the Canary thermophilous woodland ecosystem and to analyse the influence and variation of soil properties during succession.

2. Methods

2.1. Study area

This study was performed in the Las Bandas del Sur area, which is located in the southeast of Tenerife, the largest and highest island in the Canarian Archipelago (Spain). The experimental area extends over 100 km^2 at altitudes between 500 and 800 m.a.s.l. (Fig. 1). The relief in the area consists of a steep slope (25–30% on average), furrowed by successive, nearly parallel ravines that vary in depth over a complex bed of volcanic materials aged from the Miocene to the Holocene. Phonolitic pumices (either occurring as ash-flow or ash-fall deposits) constitute the most representative rock type, together with basalts and trachybasalts that have been primarily contributed by recent (Pleistocene) lava flows (Bryan et al., 2002). The climate is warm semiarid, characterised by a mild temperature (average values between 14 and 17 °C) and low rainfall (200–350 mm yr^{-1} with a high seasonal and interannual variability).

Soil development is hindered by the slope and aridity, and thus, shallow Leptosols and poorly developed Cambisols are the predominant soil types. Vertisols and Vertic Cambisols only occur at the southern border of the study area, over ancient colluvial materials at footslopes (Rodríguez-Rodríguez and Mora-Hernández, 2000). The low capacity of the land to support agricultural practices has been overcome by local farmers by using fragmented pumice materials, locally known as *jable*. These materials provide a cation-rich, easy-to-till, hygroscopic substrate with a high water-holding capacity. Since the 1930s, the *jable* system has been extended to other soils in the area by using pumice as a surficial mulching layer (Martín-Martín, 2000; Tejedor et al., 2003).

When the Spanish conquistadors arrived at the end of XVth century, the thermophilous woodland of Las Bandas del Sur still exhibited a high degree of conservation. Contemporary chronicles and the local toponymy report an abundance of tree species that are currently rare or absent from the area. After the conquest, thermophilous woodland areas were chosen for early traditional agricultural activities and human settlements (Rodríguez-Delgado and Marrero-Gómez, 1990). Extensive areas were burned to extend pastureland. In the highest, more humid midland belt above 700 m, non-irrigated crops (vines, cereals, fruit trees and potatoes) were established. Since the 1930s, the implementation of *jable* and irrigation has allowed farming practices to take place on lower-altitude, more arid lands (Martín-Martín, 2000; Rodríguez-Delgado, 1991). Since the mid-1950s, the rural population has decreased, leading to a gradual abandonment of farming areas because of the difficulties of introducing modern agricultural practices in this geographical context, the increasing costs of irrigation water and the decreasing generational replacement of farmers. The abandonment of farms has prompted the recolonisation of former agricultural soils by natural, spontaneous vegetation, together with limited regeneration of thermophilous woodland (Marrero-Gómez et al., 1991).

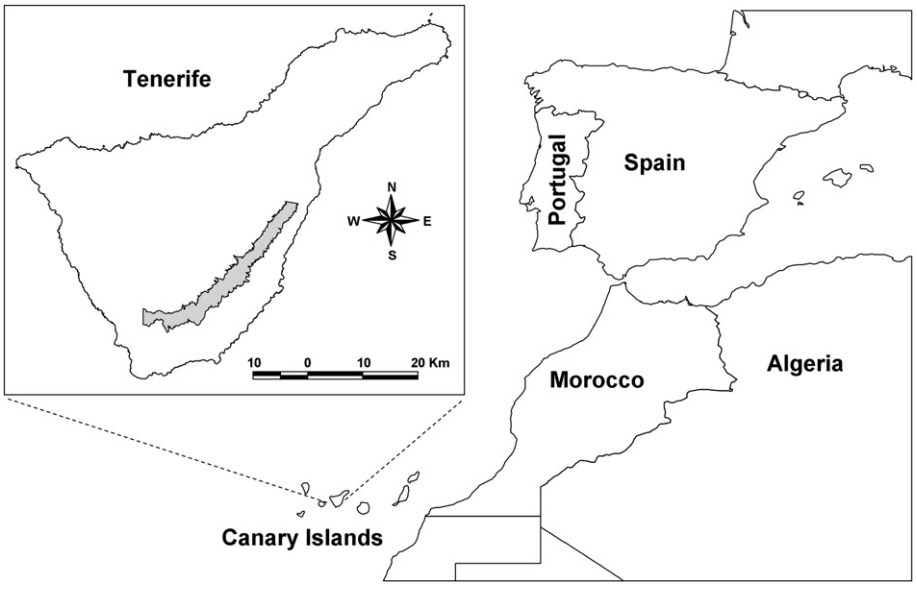

Fig. 1. Location of the study area in Las Bandas del Sur (Tenerife, Canary Islands, Spain).