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RESEARCH ARTICLE

# Species composition and structure of an exotic *Quercus suber* stand on the island of Gran Canaria (Canary Islands)

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## Abstract

*Aim of study:* Although introduced tree species have been recognized as adversely affecting native ecosystems, conversely, some studies suggest they can facilitate recovery and promote the establishment of native plant communities. This study tests whether a native plant community is established under the closed canopies of an exotic species by analyzing regeneration and plant species composition.

*Area of study:* Finca de Osorio, a public property of the Cabildo de Gran Canaria included in the Doramas Rural Park (Canary Islands, Spain).

*Main results:* The results reveal that sapling regeneration is dominated by the exotic species, though some native ones are also present. The sapling regeneration community did not differ from the tree canopy composition, so, a native plant community recovery cannot be expected to occur. In addition, other introduced species were also present in the sapling composition community.

*Research highlights:* The laurel forest of the Canary Islands is the most emblematic plant community of the Canary Island archipelago. The studied area dominated by *Q. suber* does not favor the regeneration of the native plant community. Thus, restoration programs will be required to enhance the native plant community and the area covered by this highly disturbed plant ecosystem on the island of Gran Canaria.

**Keywords:** catalytic effect; invasion; laurel forest; plant community.

**Authors´ contributions:** Conceived, designed and performed the experiments: JRA and MSP. Analyzed the data: JRA, MSP and AMGG. Contributed reagents/materials/analysis tools: AMGG, ANC, EMP. Wrote the paper: JRA and ANC. All authors read and approved the final manuscript.

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## Introduction

Invasive species have been considered one of the main causes of habitat degradation (Gurevitch & Padilla, 2004). This invasion is closely linked to global change and globalization (Kaluza *et al.,* 2010) and has had detrimental economic impacts on human enterprises caused by the spread of plant diseases and competition with agricultural species (Shacklenton *et al.,* 2007; Arévalo & Fernández-Palacios, 2005; Arévalo *et al.,* 2017). Specific elements of globalization that explain the spread of invasive species around the planet are: global changes (e.g. global warming, nitrogen deposition, habitat fragmentation, Dukes & Mooney, 1999); socioeconomic changes, such as gross domestic product (GDP) in relation to global trade and intercontinental trade (Lin *et al.*, 2007; Sharma *et al.,* 2010; Arévalo *et al.,* 2017); transport (Westphal *et al.,* 2008) and tourism (Sutherst, 2000) among others. Indeed, globalization has been one of the most substantial drivers behind the homogenization of insular biotas (Arévalo *et al.,* 2010a) and is linked to a worldwide alien species expansion (Levine & D´Antonio, 2003; Westphal *et al.,* 2008; Pysek *et al.,* 2010). Ultimately, the consequences of invasive species affect different spheres such as the economy (Pimentel *et al.,* 2005), health (Levine & D´Antonio, 2003) and ecological processes (Reaser *et al.,* 2007). The cost of their eradication is also increasing as many more species are introduced into new habitats. The risks of new diseases and problematic weeds for agriculture and how these introduced species disrupt ecological processes in the native plant community have been widely reported (Pimentel *et al.,* 2005).

On islands, infrastructure development is also directly related to the number of invasive species, whose impact can be either immediately evident or can lag for a period over 100 years (Weber & Li, 2008). Moreover, the extinction of native island biota and dismantling of island ecosystems worldwide have been some of the consequences of the high numbers of non-native species introduced (Donlan & Wilcox, 2008; Kueffer *et al.,* 2010). Although we can consider non-native plants as important components of plant communities in many parts of the world (Mack *et al.,* 2000), they have also become a global problem that requires analysis and evaluation of the ecosystems under threat. In some cases, the impact can even reach levels of ecosystem modification that completely alter the plant community, as is the case of *Myrica faya* in Hawaii (Lenz & Taylor, 2001) or *Bromus tectorum* in California (DiTomaso, 2000), while in others they only act by basically occupying disturbed areas and being more competitive than native species (Arévalo *et al.,* 2010b).

The objective of this study is to test the recovery of native plant communities under the closed canopies of exotic species. Our hypothesis is that species composition of the understory below the canopy of the exotic *Quercus suber* may be favored by the environmental conditions and will be dominated by the native plant community, the laurel forest, following a "catalytic" effect of this exotic stand on succession. This effect can be revealed at different levels, such as a increases in soil humidity, organic matter or shade that favor shade intolerant native species (Arévalo *et al.,* 2005), or other processes related to the provision of benign microhabitats that are more favorable for seed germination and/or seedling recruitment than their surrounding environment (Harris & Harris, 1997; Lugo, 1997; Parotta, 1995; Parotta *et al.,* 1997; Whitmore, 1999).

We also aim to put forward proposals to manage the forest following a landscape, ecological, forestry approach involving the manipulation of stands in order to help them recover from natural or anthropogenic disturbances such as afforestation with an exotic species (Oliver & Larson, 1996).

# Methods

## ***Study site***

The study site is located in the northeastern part of the island of Gran Canaria (Fig. 1), in the Finca de Osorio, a public property of the Cabildo de Gran Canaria included in the Doramas Rural Park (geographical coordinates: 28° 4' N, 15° 32' W). A small part of the *Quercus suber* stand is on the border of the Park. The plots were established in an area of 5 ha where there is the highest density of *Q. suber* in the Park. Although disperse individuals can be found in an area of around 10 ha due to the interest in this species by the former owners of the property. The altitude of this stand is around 650-670 m. The climate is influenced by the trade winds, which produce a "sea of clouds" on the windward slopes and wetter conditions on the northern than on the southern slopes. The annual precipitation of the park reaches 550 mm, but can be twice this amount if fog drip is taken into account (Kämmer, 1974). The mean annual temperature is close to 15 ºC with an absence of frost events (and slight variation in minimal annual and daily fluctuations in temperature). These environmental conditions are similar to the conditions of the native areas of the species, *Q. suber*, such as in the south of Spain (Natural Park of Alconorcales (Pérez-Ramos *et al.,* 2008), with a bioclime classified as thermomediterranea inferior subhumid, with temporal presence of fogs. The Doramas Park's vegetation is dominated by laurel forest vegetation with dominant species such as *Arbutus canariensis*, *Ilex canariensis*, *Persea indica*, *Morella faya*, *Visnea mocanera* (*Lauro-Perseetum indicae sigmetum* Association) (Del Arco *et al.,* 2002; Del Arco *et al.,* 2006). In addition, the geology consists of a mainly volcanic area of 2.8-4 My (Balcells *et al.,* 1992) with basaltic and pyroclastic rocks and high dominance of clays that classify these soils as endosols (Sánchez, 1975).

## ***The species***

*Quercus suber* L., commonly called the cork oak, is a medium-sized, evergreen oak tree in the section *Quercus* sect. *cerris*. It is a species of slow growth, which grows up to 20 m in height. The leaves are 4 to 7 cm long, weakly lobed or coarsely toothed, dark green above, paler beneath, with the leaf margins

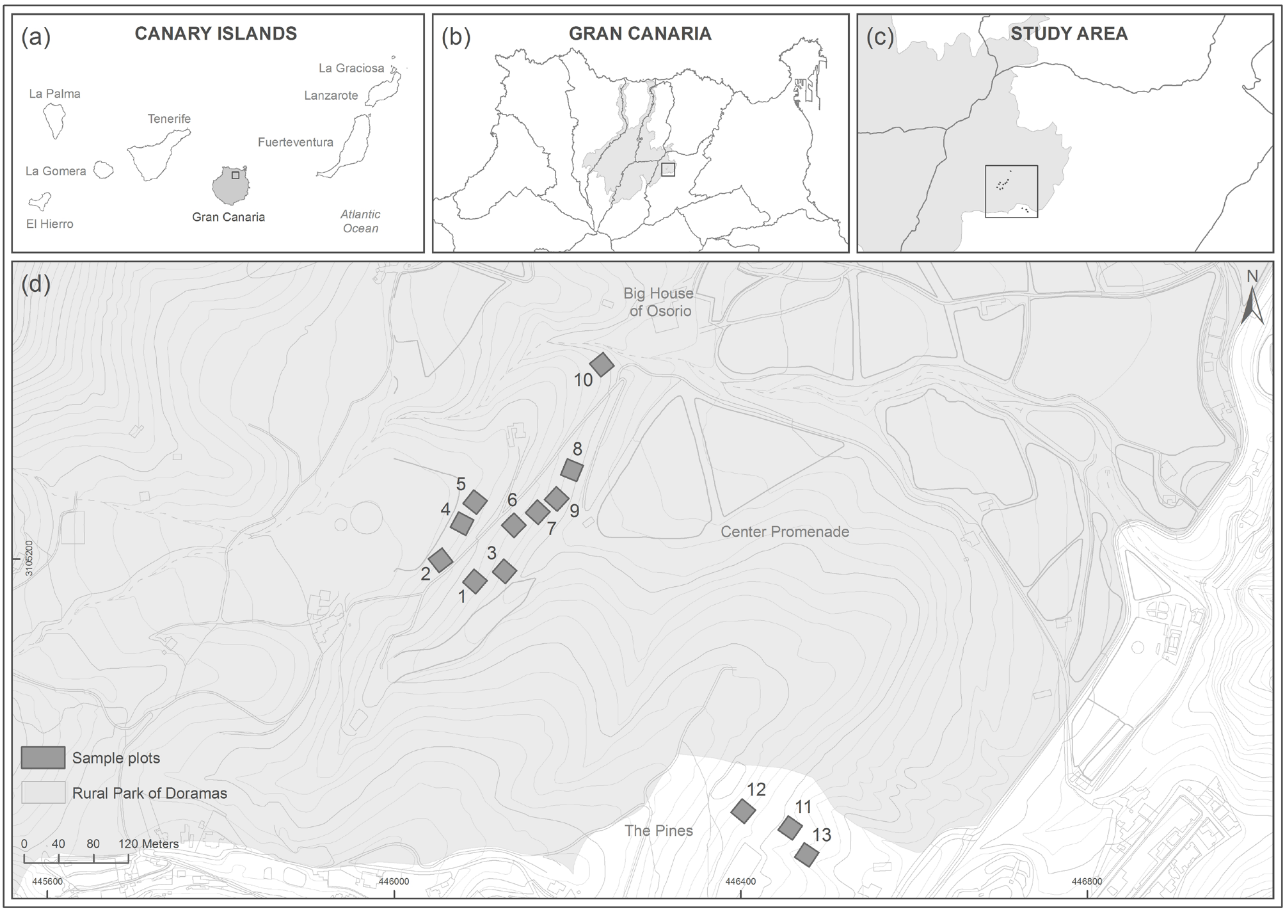

**Figure 1.** Location of the plots in the study site. Below these are the locations of the archipelago, the island and site.

often downcurved. The acorns are 2 to 3 cm long, in a deep cup fringed with elongated scales. It is native to southwest Europe and northwest Africa (Spain, France, Morocco, Algeria and Tunisia). However, one species of the genus *Quercus* is considered to have been present in the Canary Islands 2,400 years ago, based on paleoecological studies (de Nascimento *et al.,* 2016). In the Mediterranean basin, the tree is an ancient species with fossil remnants dating back to the Tertiary period. Although extensively introduced around the planet in appropriate environments, it is not considered an invasive species (Pausas *et al.,* 2009). In natural areas, there are high acorn predation rates (both predispersal and post-dispersal) and high seedling mortality (during the summer drought). These are the main causes limiting the natural regeneration of *Q. suber*, which are related to microsite environmental variability and reduced probability of survivorship (Pérez-Ramos *et al.,* 2008).

The species was introduced in Gran Canaria following the European conquest of the island, around the 16th century due to its many uses in agriculture, especially in cork production. The first reference is from the naturalist Viera y Clavijo (at the beginning of the 18th century) around the area of the study site, though due to the few references about this species, it is suspected that it had a restricted extension (Bory de Saint-Vincent, 1988).

### *Sampling design*

In 2018, in the *Quercus suber* stand of the Finca de Osorio, we established a permanent network of 13 square plots (20 x 20 m) following a straight line from the centre of the stand and separated by at least 100 m (except for three located in a different *Quercus suber* stand, but located following the same method). These plots were located systematically in an area where no other anthropogenic disturbances apart from the introduction of the exotic species had occurred (areas of trails with human interventions were avoided in the sampling).

In each plot, we measured altitude and slope, aspect and estimated canopy cover of the stand using a convex spherical densitometer (Lemmon, 1957). We also visually estimated rock, bare soil, and litter cover within each plot on a scale of 1 to 100%.

We sampled the plant community of the plots at canopy level and the understory species composition.

For the canopy, we sampled the trees, which were defined as stems with at least 2.5 cm diameter at breast height (dbh) and saplings as individuals over 50 cm height and less than 2.5 cm of diameter dbh, as an indication of regeneration of the stand. All the woody species were sampled. At the understory level, we noted species composition (all the plant community) and the cover of all species on the surface was estimated and noted on a scale of 1 to 10 (Cover classes: 1: traces, 2: >1% of cover in the plot, 3: 1-2%, 4: 2-5%, 5: 5-10%, 6: 10-25%, 7: 25-50%, 8: 50-75%, 9: >75%).

Soil samples to describe the plots' nutrient content were collected at 0-10 cm depth at 30 cm distance from each plot corner, mixing the four samples for each plot to form a composite sample. The pH, EC (exchangeable cations, dS/m), Polsen (Phosphorus Olsen extraction on ppm), organic matter (%OM), total nitrogen percentage (TN), nitrate percentage ($NO_3$) and available cations in meq/100 (Na, K, Ca, Mg) were analyzed. The percentages of clay, sand, silt and limestone (Calcimeter Bernad method) were also analyzed. Standard methods of analysis were followed (AOAC, 1990; Anonymous, 1986). Soil samples were collected in May 2018.

### *Statistical analysis*

To determine species diversity of the understory in the plant community dominated by oaks, we calculated species richness per plot as well as Smith and Wilson evenness index (Smith & Wilson, 1996).

#### *Canopy and regeneration analysis*

Basal area of trees and density of saplings were calculated per plot and used in the analyses. Ordination techniques help in explaining community variation (Gauch, 1982) and were used to evaluate trends in plant species composition (ter Braak & Šmilauer, 1998).

We based the analysis on the percentage (in order to standardized basal area of trees and density of samplings) of the species basal area of the plots together with the percentage density of saplings using a DCA (Detrended Correspondence Analysis). In the plane given by DCA axes I and II, we encircled the species of trees with an envelope, using the minimum possible area and in another polygon, the species of saplings.

#### *Understory species composition analysis*

A second ordination analysis was used to determine trends in understory species composition. We used partial Canonical Correspondence Analysis (CCA; Hill & Gauch, 1980) in CANOCO (ter Braak & Šmilauer, 1998) to examine how species composition changed over the different plots as a function of the environmental characteristics included in the analysis. In the environmental matrix, we included the following variables: altitude, slope, aspect (N or S), % of clay, silt, sand and limestone, pH, EC (exchangeable cations, dS/m), Polsen (Phosphorus Olsen extraction on ppm), organic matter (%OM), available cations in meq/100 (Na, K, Ca, Mg). As a biotic matrix, we used the species composition based on cover of the plots' understory. We selected the five most informative environmental variables applying a forward selection procedure to remove the variables that did not explain a significant portion of the variability reported by the analysis when performing the axes (Monte Carlo permutation test 499 interactions for $p<0.05$). Axes I and II are graphically displayed with the selected environmental variables, plots and species.

## Results

The plots did not present substantial environmental differences, with similar altitudes, slopes, canopy cover and litter cover. Some variability can be considered part of the microsite heterogeneity in the area (Table 1). In the case of the soil nutrient composition, there was greater variability in the case of some nutrients. For example %OM presented a range of variations from 4.29 to 13.8 and Polsen varied from 6 to 40 ppm (Table 2).

The tree canopy composition was completely dominated by *Quercus suber*. In some plots, this was almost the only species (>99% total basal area of the plots QS2, 6, 7, 12 and 13). Even the plot with the lowest dominance in basal area of *Q. suber* reached almost 75% of the total (Average basal area of *Q. suber* of all the plots 93.1 ± 8.3 %; Table 3).

In the case of canopy regeneration, *Q. suber* also dominated in all plots with over 80% of density, with the exception of one plot (QS10). However, three more species were also present: *Pinus canariensis*, *Laurus novocanariensis* and *Olea cerasiformis*. In four plots, the woody regeneration of the plots was only *Q. suber*. The average regeneration of all plots for *Q. suber* was more than 92% including the non-dominant plot of the species (Fig. 2 represents the decimal logarithm of regeneration density in order to visualize species with low densities).

The plant community analysis of the trees and regeneration shows the species scores in Fig. 3. These species are enclosed in the same polygon depending on whether their values are from basal area species or sapling species. Discrimination among polygons (as long as this discrimination is related to differences in relative abundance in the plots) revealed differences

**Table 1.** General abiotic and plant community information of the plots

| | | | Cover (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *PLOT* | *Alt(m)** | *Slope(%)* | *grass* | *forbs* | *woody* | *rock* | *soil* | *litter* | *Canopy* | *SpRich*** | *Evenness* |
| **QS1** | 695 | 36.91 | 1 | 21 | 7 | 0 | 5 | 95 | 80.5 | 20 | 0.80 |
| **QS2** | 710 | 36.06 | 2 | 5 | 95 | 0 | 15 | 95 | 72.5 | 20 | 0.83 |
| **QS3** | 685 | 38.07 | 2 | 4 | 90 | 0 | 0 | 100 | 75 | 24 | 0.79 |
| **QS4** | 709 | 40.31 | 1 | 2 | 80 | 0 | 2 | 98 | 84 | 23 | 0.79 |
| **QS5** | 709 | 34.82 | 1 | 2 | 99 | 0.5 | 1 | 98.5 | 88.75 | 17 | 0.72 |
| **QS6** | 690 | 44.72 | 0.5 | 0.5 | 90 | 0 | 2 | 98 | 77.5 | 19 | 0.78 |
| **QS7** | 685 | 41.38 | 1 | 3 | 80 | 0 | 30 | 70 | 73.25 | 23 | 0.81 |
| **QS8** | 678 | 36.4 | 15 | 20 | 85 | 0 | 3 | 97 | 86 | 43 | 0.81 |
| **QS9** | 681 | 33.54 | 5 | 3 | 95 | 0 | 1 | 99 | 78.25 | 35 | 0.83 |
| **QS10** | 676 | 58.31 | 0.5 | 1 | 75 | 0 | 5 | 95 | 80 | 34 | 0.84 |
| **QS11** | 672 | 17.68 | 2 | 3 | 85 | 2 | 5 | 93 | 90.5 | 30 | 0.82 |
| **QS12** | 686 | 42.43 | 1 | 5 | 87 | 1 | 4 | 95 | 87.75 | 35 | 0.82 |
| **QS13** | 659 | 30.21 | 0.5 | 6 | 85 | 0 | 3 | 97 | 83.25 | 16 | 0.81 |

(*Alt: altitude; **SpRich: Species richness).

**Table 2**. Nutrient content and soil structure characteristics of the soil of the plots

| | | | *%* | | | *dS/m* | | *meq/100g* | | | | *%* | | | *ppm* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Clay* | *Silt* | *Sand* | *Limestone* | *C/N* | *EC* | *Ca* | *Mg* | *K* | *Na* | *TN* | *NO3* | *OM* | *Ph* | *Polsen* |
| **QS1** | 46.4 | 46.4 | 7.1 | 0.4 | 12 | 0.08 | 7.1 | 5.7 | 1.3 | 0.4 | 0.3 | 10 | 6.24 | 5.94 | 8 |
| **QS2** | 58.3 | 47.2 | 1 | 0.5 | 12.8 | 0.09 | 6.1 | 7.3 | 2 | 0.6 | 0.33 | 10 | 7.25 | 5.81 | 9 |
| **QS3** | 51.1 | 48.4 | 1 | 0.4 | 12.6 | 0.07 | 5 | 4.5 | 1.6 | 0.5 | 0.27 | 10 | 5.84 | 5.97 | 10 |
| **QS4** | 50.6 | 42.1 | 7.3 | 0.5 | 13 | 0.08 | 7.8 | 7.8 | 1.9 | 0.7 | 0.33 | 10 | 7.48 | 5.84 | 10 |
| **QS5** | 43.9 | 46.7 | 9.4 | 0.4 | 13.8 | 0.1 | 4.9 | 5.5 | 0.9 | 0.7 | 0.33 | 10 | 7.9 | 5.37 | 7 |
| **QS6** | 53.8 | 40.3 | 5.9 | 0.6 | 13.4 | 0.07 | 7.7 | 5.2 | 0.8 | 0.4 | 0.31 | 10 | 7.13 | 5.93 | 9 |
| **QS7** | 69 | 27.6 | 3.4 | 0.6 | 10.5 | 0.05 | 6.4 | 6.6 | 2.5 | 0.5 | 0.29 | 10 | 5.24 | 6.14 | 18 |
| **QS8** | 38.4 | 49.4 | 12.2 | 0.6 | 14.5 | 0.08 | 14 | 8.4 | 1.2 | 0.4 | 0.33 | 10 | 8.3 | 6.46 | 23 |
| **QS9** | 44.1 | 46.9 | 9 | 0.6 | 13.4 | 0.08 | 14.6 | 9.7 | 1.3 | 0.5 | 0.4 | 10 | 9.3 | 6.56 | 13 |
| **QS10** | 36.5 | 53.3 | 10.3 | 0.8 | 14.8 | 0.1 | 11.5 | 8 | 0.8 | 0.7 | 0.54 | 17 | 13.8 | 5.66 | 19 |
| **QS11** | 37.3 | 50.6 | 12.1 | 0.04 | 13.6 | 0.09 | 7.5 | 5.6 | 1.5 | 0.4 | 0.27 | 10 | 6.44 | 5.87 | 40 |
| **QS12** | 39.9 | 53.2 | 7 | 0.04 | 11.4 | 0.07 | 9.2 | 7.4 | 1.9 | 0.4 | 0.22 | 10 | 4.29 | 6.95 | 6 |
| **QS13** | 61.4 | 30.7 | 7.8 | 0.4 | 13.7 | 0.09 | 17.1 | 9.7 | 2.3 | 0.6 | 0.36 | 10 | 8.42 | 6.83 | 6 |

in the regeneration community and canopy tree community. As the analysis shows, the polygon enclosing the regeneration species is included in the polygon of the tree species. There was much more variability in the canopy tree community than in the regeneration one (as we have seen previously, with only four species). This indicates that species in the canopy will be partially replaced and no major changes are expected based on regeneration. We should note the important impact on the regeneration plant community of *Olea cerasiformis*, a species favored by the present environmental conditions created by the canopy of *Q. suber* with respect to the others present in the canopy.

A total of 93 species were found in the study (Table S1 [suppl.]), and there was some variation in the number of species among plots, from 16 (plot QS13) to 43 (plot QS8). However, Smith and Wilson evenness revealed high values on the plots and low differences among these (from 0.72 to 0.84).

The CCA for all the plant community revealed that the most significant environmental characteristics for the plant community (Fig. 4) were C/N, %Limestone, %Silt, $NO_3$ and Na. There was also substantial variability in the plant community, such as plots QS13, QS12 and QS11 had low levels C/N and limestone and were characterized by species such as *Opuntia*

**Table 3.** Basal area of trees (>2.5 cm DBH) per species and total basal area per plot

| Species | *QS1* | *QS2* | *QS3* | *QS4* | *QS5* | *QS6* | *QS7* | *QS8* | *QS9* | *QS10* | *QS11* | *QS12* | *QS13* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Apollonias barbujana*** | - | - | - | - | - | - | - | - | - | 0.01 | - | - | - |
| ***Arbutus canariensis*** | - | - | - | - | - | - | - | 0.10 | - | 0.01 | - | - | - |
| ***Chamaecytisus proliferus*** | - | - | - | - | - | - | 0.02 | 0.23 | 1.43 | - | - | - | - |
| ***Erica arborea*** | - | - | 0.25 | - | - | - | - | - | - | - | - | - | - |
| ***Eucalyptus camaldulensis*** | - | - | - | - | - | - | - | - | - | 0.36 | - | - | - |
| ***Hypericum canariense*** | - | - | 0.24 | - | - | - | - | - | - | - | - | - | - |
| ***Ilex canariensis*** | - | - | - | - | - | - | - | 0.04 | - | - | - | - | - |
| ***Laurus novocanariensis*** | 0.02 | 0.12 | 0.91 | 0.01 | 0.61 | 0.06 | 0.02 | 0.96 | 1.61 | 0.52 | - | 0.01 | 0.09 |
| ***Myoporum laetum*** | - | - | - | - | - | - | - | - | 0.03 | - | - | - | - |
| ***Olea cerasiformis*** | 0.16 | 0.02 | - | - | - | - | 0.01 | 0.37 | - | 1.01 | 0.79 | 0.64 | 0.02 |
| ***Pinus canariensis*** | - | - | - | - | - | - | - | 1.18 | 0.01 | - | - | - | - |
| ***Pinus halepensis*** | - | - | - | 11.45 | 1.56 | - | - | - | - | - | - | - | - |
| ***Quercus suber*** | 3.17 | 30.89 | 6.23 | 32.26 | 43.84 | 10.66 | 29.41 | 14.97 | 32.05 | 43.68 | 24.82 | 49.53 | 42.53 |
| ***Teline microphylla*** | - | - | - | - | - | - | - | 0.01 | - | - | - | - | - |
| ***Total BA m²/ha*** | **3.35** | **31.04** | **7.63** | **43.72** | **46.01** | **10.73** | **29.45** | **17.84** | **35.14** | **45.59** | **25.62** | **50.18** | **42.64** |
| ***% BA of Q. suber*** | **94.63** | **99.52** | **81.65** | **73.79** | **95.28** | **99.35** | **99.86** | **83.91** | **91.21** | **95.81** | **96.88** | **98.70** | **99.74** |

*maxima*, *Erica arborea*, *Rubus ulmifolius* of *Hypericum canariense*, whereas plots QS7, QS4 and QS5 had high values of $NO_3$ and Na and were mainly characterized by species like *Viburnum rigidum*, *Phagnalon purpurascens* or *Andryala integrifolia*. Plots QS8 and QS6 had high C/N values and were characterized by species such as *Carlina salicifolia*, *Teline microphylla* or *Castanea sativa* (Fig. 4).

Common species in all the plots were located as the origin of coordinates such as *Quercus suber*, *Laurus novocanariensis*, *Sonchus acaulis*, *Oxalis pes-caprae* or *Olea cerasiformis*. With respect to native or invasive species, there was no distribution specific pattern on the defined bi-dimensional space of CCA. Some of the species were common for all the plots like *Q. suber*, *Oxalis pes-caprae*, and others were only found near to some plots such as *Scorpiurus muricatus*, *Brunsvigia rosea* (QS8) or *Opuntia maxima* (QS11 and QS12).

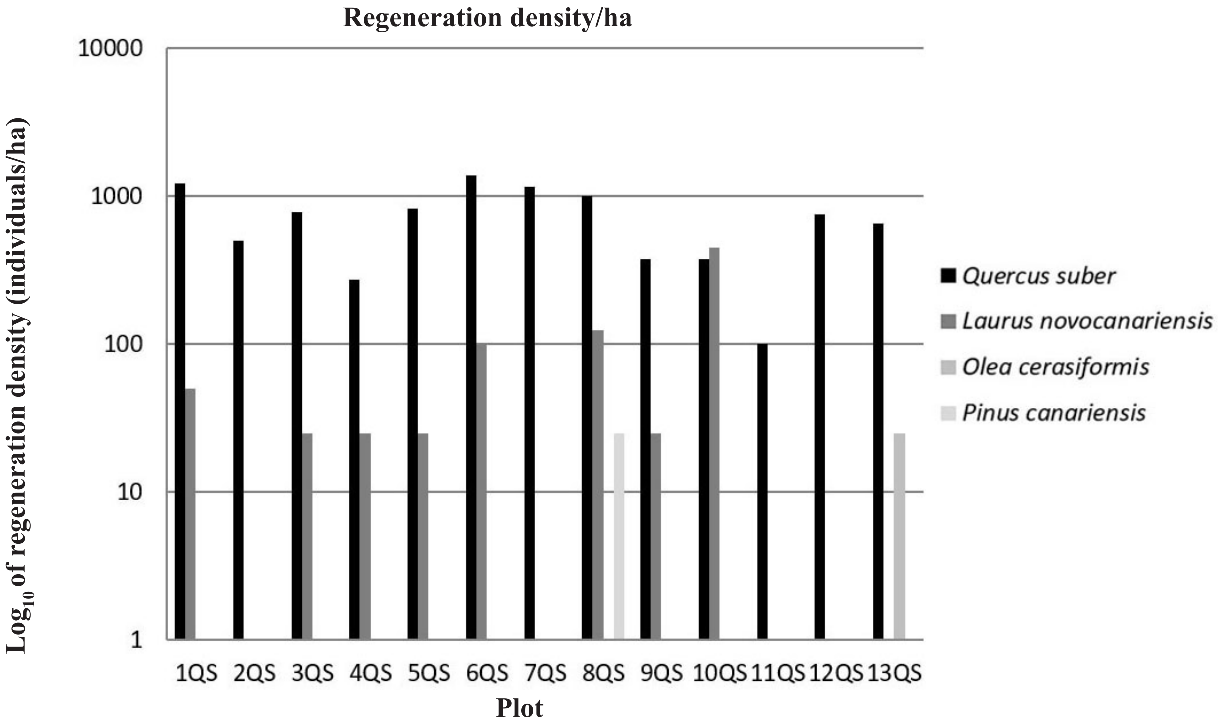

**Figure 2.** Regeneration densities per plot and species (individuals less than 2.5 cm dbh and over 50 cm tall).

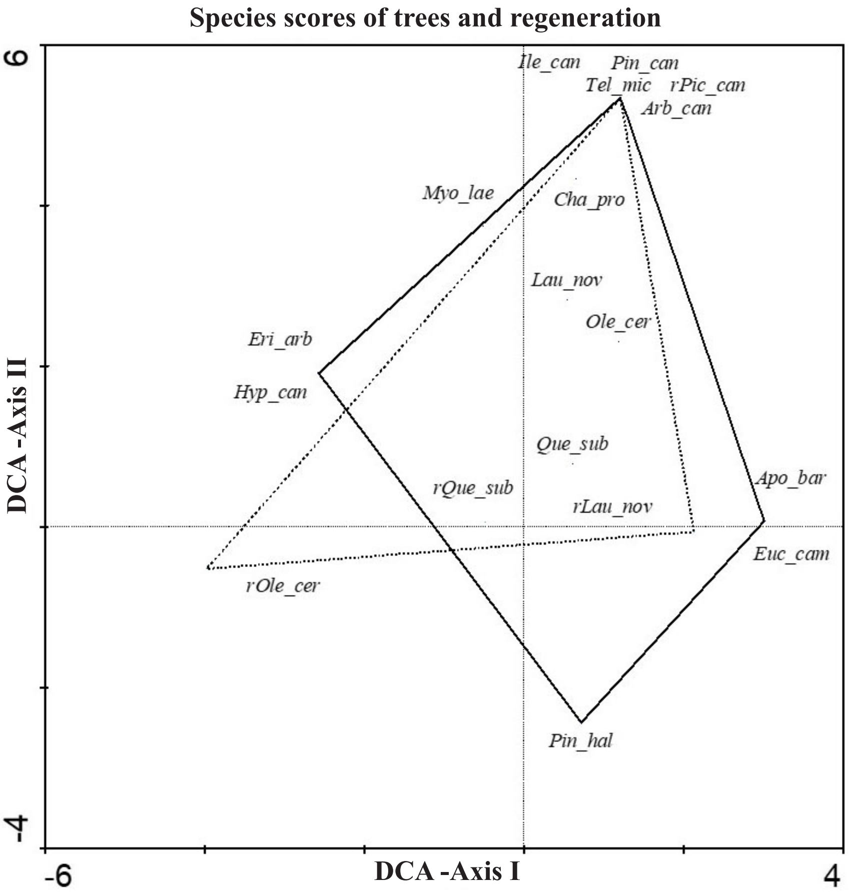

**Figure 3.** Detrended correspondence analysis axes I and II. Species coordinates of trees (based on percentage of basal area) are enclosed in an envelope with a solid line while species coordinates of saplings (based on percentage of density) are enclosed in an envelope with a dotted line. Eigenvalues for axis I: 0.15, eigenvalue for axis II: 0.08, cumulative percentage of total inertia for axes I and II: 57%. The codes of the species are the first three letters of the genus followed by the three first letters of the specific epithet (full name of the species in Table S1 [suppl.]).

# Discussion

Conflicting evidence exists as to whether exotic monocultures exert a predominately negative or positive effect on the regeneration of the native forest beneath their canopies. In our case, the exotic canopy did not favor the recovery of the natural plant community. Exotic tree monocultures adversely affect native ecosystems species composition through competition with native species (Attiwill & Leeper, 1987; Jurgensen *et al.,* 1986; Fimbel & Fimbel, 1996). However, some studies in other areas have indicated that exotic tree plantations in the Canary Islands have facilitated a more rapid restoration of the native forest community, with a significant advance in regeneration of the canopy and establishment of native plant community species (Arévalo & Fernández-Palacios, 2005; Arévalo *et al.,* 2005; Arévalo *et al.,* 2011). Such results also agree with several studies in which exotic species have facilitated forest succession to a native plant community in their understory on sites where disturbances have prevented recolonization by native forest species (Parrotta, 1995; Fimbel & Fimbel, 1996; Loumetto & Huttel, 1997; Arévalo *et al.,* 2005). In these cases, afforestation with exotic species has provided an improvement in environmental conditions favoring the establishment of the native shade-tolerant species. In addition, it has been shown that native forests are resilient to invasion by exotic species (Guldenhuys, 1996).

In this study, we have identified a high number of species in the understory of a stand dominated by the exotic species *Quercus suber*, with one of the plots having 43 species (Table 2), showing high evenness in all the plots (almost over 0.80 in all the plots). However, the DCA analysis was unable to discriminate canopy tree plant community *vs*. sapling plant community. This means there were no differences at plant community level and the dominant canopy species persisted.

Regeneration has lower species richness than the canopy with 14 species for trees and only 4 in

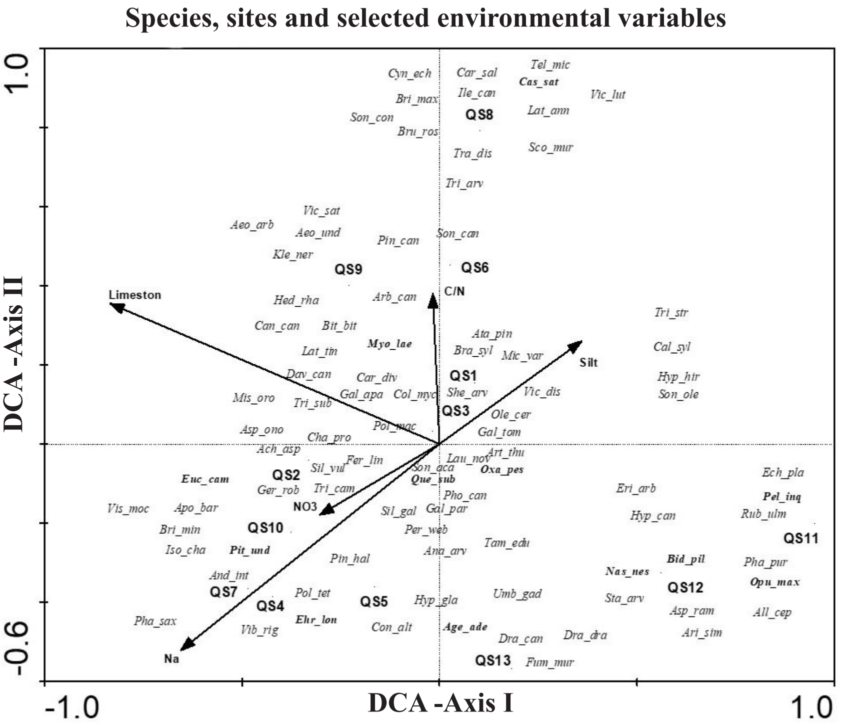

**Figure 4.** Canonical correspondence analysis using five selected environmental variables (Limestone, Silt, Na, C/N and NO3 as NO3), plot scores and species scores (based on species cover of the plot). Eigenvalues axis I: 0.27; axis II: 0.242; both axes cumulative percentages explained by species composition 26.6% and both axes cumulative percentages variance explained by species-environmental relationship: 49.9%. The codes of the species are the first three letters of the genus followed by the three first letters of the specific epithet (full name of the species in Table S1 [suppl.]). Invasive species are indicated in bold font.

the case of sapling species. This is common in subtropical and tropical forests, where seedling distribution is determined by the distribution of parent trees producing seeds, the seed rain, the presence of dispersers and predators and the availability of adequate sites for germination (Schupp, 1995). Furthermore, it is consistent with previous studies of laurel forest regeneration, in which human activities (wood extraction, agriculture, charcoal production, etc.) or natural disturbances have promoted the occurrence of pioneer species in the forest. Seedlings from these pioneer species only germinate under light conditions, so they cannot be found under a closed canopy (Fernández-Palacios & Arévalo, 1998; Arévalo & Fernández-Palacios, 2007). So, in spite of such differences, canopy and sampling composition are characterized by the same dominant species: *Quercus suber* and *Laurus novocanariensis* favouring also *Olea cersiformis*.

Adult trees of pioneer species are likely remnants of early successional stages of the forest, mainly related to human management. These trees may persist within the forest for decades, *Erica arborea*, or other introduced species such as *Pinus halepensis*, *Myoporum laetum* of *Eucalyptus camaldulensis* among others, unable to establish under a close canopy (Fig. 4). After several decades, the canopy composition cannot be totally explained by regeneration, but the most dominant species will persist in the canopy. Pioneer species are now excluded from the regeneration, and they will need natural or anthropogenic disturbances to become established in order to persist in the present canopy species composition.

The understory community, with a high number of exotic species (around 20%; (Table S1 [suppl.])), is another indicator of the disturbance level of the area, with high variability depending on the microsite variability in nutrient composition and environmental conditions, with some species present in all the plots as *Quercus suber* or *Oxalis pes-caprae* (Fig. 3).

The laurel forest of the Canary Islands is the most emblematic community of the Canary Island Archipelago. Thus, restoration programs are being developed to increase the laurel forest area on the islands, such as on Tenerife. Today less than 1% of the original laurel forest on Gran Canary Island remains unaltered (Santos, 1990). Based on these results, we suggest the management of the *Quercus suber* stand, since there is no evidence of a recovery of the native plant community or of a "catalytic" effect in this exotic stand.

## Conclusions

Although the management of these areas is not an urgent task, we propose some management practices to favor the regeneration of native species. Treatments of thinning in the *Quercus suber* stand should be carried out, because plantations' closed canopies are preventing the establishment of shade-intolerant species (Ashton *et al.,* 1997). Other *Quercus* species have been identified as invasive (Lemke *et al.,* 2013), and will require some monitoring. The ability of the natural forest to dominate the stand should also be promoted with stand management activities, followed by enrichment with plantations of containerized individuals of laurel forest, especially the more heliophytic species (*Erica arborea*, *Morella faya* and *Ilex canariensis*). Continuous monitoring of the area will also be required to ensure the establishment of native species.

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