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Original article

Gradient analysis of exotic *Pinus radiata* plantations and potential restoration of natural vegetation in Tenerife, Canary Islands (Spain)

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Abstract

Afforestation on the island of Tenerife has been carried out mainly with the native species of pine *Pinus canariensis* Chr. Sm. Ex DC. However, the exotic pine *Pinus radiata* D. Don has been introduced in some areas. Several studies have shown that plantations of exotic species facilitate forest succession in their understories on sites where disturbances prevent the recolonization by native forest species. We randomly located 250 plots in stands of *P. radiata*, on the island of Tenerife and recorded species. Abiotic characteristics of the plots were also noted. We evaluated the regeneration of potential vegetation of the laurel forest and pine forest under a canopy of an exotic pine species. Analysis of the species composition, resulted in four well defined groups: advanced laurel forest group (ALF), undeveloped laurel forest group (ULF), ruderal group (RU) and Canarian pine stand group (CPS). These groups can also be discriminated base on altitude, slope or canopy cover. For ALF and ULF we propose thinning restoration management and the planting of new individuals of laurel forest species. For RU and CPS, because they are potentially *P. canariensis* stands, we propose continuous elimination of *P. radiata* and enrichment with new individuals of *P. canariensis*.

Keywords: Laurel forest; *Pinus radiata*; Plantation; Regeneration; Restoration

1. Introduction

Forest restoration is considered the restitution of natural vegetation in disturbed areas and the improvement of the health of a stand (Anderson, 1995). The use of silviculture to restore degraded stands ("naturalistic silviculture", Edminster and Olsen, 1996) has become very popular in the last decade. Afforestation with exotic species can have both negative and positive effects on the environment (e.g. Geldenhuys, 1997), such as an increase in the use of water but protection from soil erosion. In some specific areas and communities, exotic afforestation could also provide better conditions for the establishment of the native shade-tolerant species without threatening native forests, which have proven resilient to invasion by exotic species (Geldenhuys, 1996). Several studies showed that plantations of exotic species have facilitated forest succession (favouring germination of native species) in their understories on sites where disturbances prevented recolonization by native forest species (e.g. Parrotta, 1995; Fimbel and Fimbel, 1996; Loumeto and Huttel, 1997).

To generate management proposals of exotic plantations, The World Bank, the Institute for Tropical Forestry (USDA Forest Service) and the British Overseas Development Authority (ODA) initiated a global research network in 1994 to evaluate the role of plantations in rehabilitating native forests (Parrotta et al., 1997).

Afforestation on the island of Tenerife (Spain) has been carried out mainly with native species. The main objective of the plantations in Tenerife is to restore vegetation in areas that were heavily disturbed by logging and intensive human use during the last five centuries after European colonization (Parsons, 1981). The main species used was *Pinus canariensis* Chr. Sm. Ex DC.

However, some areas were planted with the exotic species *Pinus radiata* D. Don (approximately 2200 ha). Natural vegetation was Canarian pine forest, but some of the areas

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were dominated by laurel forest (depending on altitude and aspect). In the last 60 years, large areas of Tenerife have been reforested, but with a lack of subsequent management or monitoring. In recent years authorities have re-considered the use of plantations, moving away from the idea of using them solely as exploitable natural resources and towards the idea of managing them in order to restore natural forests.

The objectives of this study were to examine the establishment of native vegetation under closed canopies of exotic pine species, and to gain a better understanding of what environmental conditions (altitude, canopy cover or slope) facilitate establishment of native vegetation (laurel or Canarian pine forest).

2. Material and methods

2.1. Study site

The study was conducted on the north-east slope of the Corona Forestal Natural Park and Reserva Especial de las Palomas, Tenerife (28°19′N, 16°34′W), Canary Islands, Spain (Fig. 1). The park comprises 200,000 ha, and 25% has been reforested with *P. canariensis*, with minor plantings of *P. radiata*. Most afforestation was done between 1930 and 1940 (Del Arco et al. 1992). The sites selected for our study were planted between 1948 and 1952.

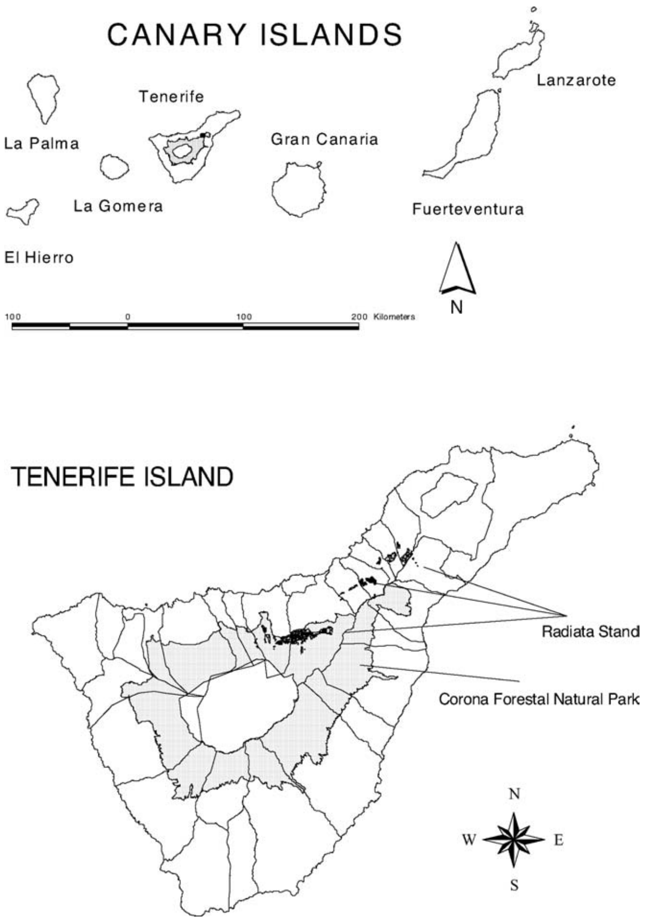

Fig. 1. Map of the Canary Islands, indicating Corona Forestal Natural Park on Tenerife. Darker marked areas of the park are indicating the *P. radiata* stands.

The annual precipitation of the park reaches 900 mm but fog drip can supplement inputs (Kämmer, 1974). The mean annual temperature is 15 °C. Frost events may occur a few days a year at high altitude, but not in the study area. Because all the plots are in a gradient of 350 m of difference in altitude, differences in temperature are not over 2 °C (as well for maximums and minimums), and in the case of the rain differences are around 90 mm (Marzol, 2001).

Soils at the study site have been classified as Entisols (suborder Orthents) (Fernández-Caldas et al., 1985).

The canopy height of the laurel forest is 10–20 m, depending on the slope, and distributed between 600 and 900 m altitude. Maximum heights are found at basin bottoms decreasing progressively towards the basins' borders. The laurel forest of Anaga contains a total of 19 tree species (Santos 1990). Dominant species include *Laurus azorica*, *Erica scoparia*, *Erica arborea*, *Ilex canariensis*, *Prunus lusitanica*, *Myrica faya* and *Viburnum tinus*. The dominance of a given species depends on site conditions. For example, *E. scoparia* dominates in forest ridges, *L. azorica* in mesic zones and *E. arborea* in more disturbed areas (Anon, 1973). Further information on stand composition, structure and environment in the study sites can be found in Arévalo (1998), Arévalo et al. (1999).

In the pine forest, distributed mainly between 1000 and 2000 m altitude, *P. canariensis* is the dominant species, a shade intolerant and high potential area of distribution in Tenerife (Del Arco et al., 1992). The dominant shrub species in the windward site are *Erica arborea*, *Adenocarpus viscosus* and *Chamaecytisus proliferus*. A high number of annual and ruderal species are present at both sites, especially in the plots close to trails or those affected by other disturbances (Ceballos and Ortuño 1974). Laurel forest and pine forest potential vegetation is base in altitude and aspect. *P. canariensis* is not considerer a previous stage to the laurel forest succession due to anthropogenic disturbances or fire (Del Arco et al., 1992). Nomenclature follows Hansen and Sunding (1985).

2.2. Vegetation sampling

We randomly selected 250 plots (10 × 10 m quadrat) in the *P. radiata* stands of Tenerife Island. Sampling was conducted between October 1999 and March 2000. Cover for species at ground level was estimated and noted on a scale of 1–10 (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%, 10: 100%). In each plot we measured altitude and slope, and estimated canopy cover of the stand using a convex spherical densiometer (Lemmon, 1957). Estimated rock, bare soil, and litter cover was determined in each plot using a scale of 1–10 (as used for species cover).

2.3. Statistical methods

Two way indicator species analysis (TWINSPAN; Hill, 1979) was applied to the data. TWINSPAN classifies plots by species composition and constructs an ordered two-way table from a site-by-species matrix (Van Tongeren, 1995). TWINSPAN, in which samples are divided according to their signs along the first correspondence analysis axis (Legendre and Legendre, 1998), has been criticized because of the assumed existence of a strong gradient and problems with large gaps in the data matrix (Belbin and McDonald, 1993). Our study was located in an Atlantic island, where we expected strong gradient effects (due to altitude or coastal distance) over small distances, and we assumed that our data did not contain large gaps in the data matrix. We considered TWINSPAN the best suited classification analysis for our data.

TWINSPAN uses the quantitative information of the cover for the classification, but we can emphasize the differences in the same species covering 1% of the plot or 50% of the plot creating "TWINSPAN pseudospecies" (Hill 1979). We used four categories for the species in relation to their cover at the plot: category 1 for species "a" means that the species is between class 0 and 1 of cover; category 2 for species "a" is more than cover class 1 and less than class 2; category 3 more than class 2 and less than 4; and category 4 means more than class 4 of cover. In our case, we emphasized differences at low cover percentages to increase the calculated dissimilarities. Classes 2 and 3 were given twice the weight of class 1, while class 4 was three times the weight of class 1 and twice that of classes 2 and 3. We reduced the importance of rare species (those with few presences), giving them less weight than other species in higher cover classes.

Ordination techniques help to explain community variation (Gauch, 1982) and they can be used to evaluate trends through time as well as space (Franklin et al., 1993; Ter Braak and Šmilauer, 1998; Arévalo et al., 1999). We used detrended correspondence analysis (DCA; Hill and Gauch, 1980) of CANOCO (Ter Braak and Šmilauer, 1998) to examine how species composition changed through space and whether different classes could be extrapolated from the analyses. Analyses were based on the 10 cover classes.

Although principal components analysis (PCA) is the most adequate technique to compare environmental factors across plots, the low number of factors in this analysis made it undesirable. Environmental characteristics (altitude, slope and canopy cover) of the groups defined by TWINSPAN were analysed using an analysis of variance (ANOVA, $P < 0.05$). Differences in litter, soil, and rock were analysed using the Kruskal–Wallis test ($P < 0.05$). Normality of the data was checked with the Shapiro–Wilk test, and homoscedasticity of the data was examined with a multiple F test. We used post-hoc Tukey tests to detect significant differences among groups found different overall. Basic statistical methods followed Zar (1984) and were applied with the SPSS statistical package (SPSS, 1997).

3. Results

Eighty species occurred in the plots in this study (Table 1). However, only 17 species were present in more than 20% of the plots. The more frequent species of the plots are mainly trees of the native laurel forest such as *Laurus azorica*, *Erica arborea*, *Ilex canariensis*, *Viburnum tinus* and *Myrica faya*, indicating that regeneration of native vegetation is present in the majority of the plots (Fig. 2). *P. radiata* did not show regeneration because it is shade intolerant. A high number of annual and ruderal species are present (Table 1), especially in the plots close to trails or those affected by other disturbances (Anon, 1973; Ceballos and Ortuño, 1974).

TWINSPAN analysis revealed four species groups (we did not consider more hierarchical groups by TWINSPAN). These groups were characterized by species at different levels of cover class.

We provided names for the groups defined by TWINSPAN based on the characteristic species of each one : (a) advanced laurel forest (ALF) : laurel forest species (*Laurus azorica*, *Ilex canariensis*, *Viburnum tinus*) dominated the understory of the pine stand ; (b) undeveloped laurel forest (ULF) : laurel forest species present but ruderal species also important. *Galium scabrum* and *Brachypodium sylvaticum* are also present ; (c) ruderal understory (RU) : understory dominated by a group of ruderal species (species of severely disturbed environments, mainly annuals) ; and (d) Canarian pine stand (CPS) : *P. canariensis* is present together with *P. radiata.*

Environmental characteristics of the groups are shown in Fig. 3. Mean altitude of the plots of the different groups was significantly different among all the groups ($F_{3,245} = 141.17$, $P < 0.01$, Fig. 3a), as well as the other environmental characteristics (Fig. 3b–d): slope ($F_{3,245} = 14.62$, $P < 0.01$), canopy cover ($F_{3,245} = 8.69$, $P < 0.01$), litter ($F_{3,245} = 57.71$, $P < 0.01$), rock ($F_{3,245} = 10.56$, $P < 0.01$) and soil cover ($F_{3,245} = 17.82$, $P < 0.01$).

Fig. 4 shows the DCA site scores (for axes I and II) and polygons containing the plots assigned to each group defined by TWINSPAN (minimum area polygons containing 95% of the plots). There is a clear ALF-ULF-RU gradient determined by the first axis, but CPS appears to be separated from the others by the second axis. A different gradient is separating CPS from the other groups, although we consider RU highly related with CPS.

Species scores in the DCA (Fig. 5) showed a more complex gradient than that revealed by TWINSPAN. Laurel forest species are dominant in the ALF group (i.e., trees and understory species such as *Phyllis nobla*, *Ranunculus cortusifolius*, *Isoplexis canariensis*, as the most important). In the ULF group there was an important presence of ruderal species (e.g. *Galium scabrum*, *Origanum vulgare*, *Viola odorata*, *Oxalis pes-caprae*, *Geranium dissectum*), but laurel forest species were also important. The RU group is discriminated by high species richness (mostly ruderals or annuals, indicating a high level of disturbance). The CPS was dis-

Table 1
Species found in the *P. radiata* stands studied on Tenerife, indicating life form and preferential habitat (Bramwell and Bramwell 1994)

Species	Life Form	D [a]	SS [b]	Preferential habitat	Species	Life form	D [a]	SS [b]	Preferential habitat
Adenocarpus viscosus	shrub	a	m	Pine forest	*Myrica faya*	tree	a	b	Laurel forest
Aeonium s.p.	crassulacea	w	s	Clift and disturbed areas	*Neotinea maculata*	forb	w	s	Pine forest
Ageratina adenophora	forb	w	s	Pine and laurel forest	*Origanum vulgare*	forb	w	s	Forested areas
Anagallis arvensis	forb	w	s	Ruderal	*Ornitopus compresus*	grass	w	s	Ruderal
Arisarum vulgare	forb	w	s	Laurel forest	*Oxalis pes-caprae*	forb	w	s	Ruderal
Asparragus umbelatus	forb	a	m	Ruderal	*Pericallis cruentus*	forb	w	s	Forested areas
Asplenium onopteris	fern	w	s	Forested areas	*Pericallis echinata*	forb	w	s	Forested areas
Brachypodium sylvaticum	forb	w	s	Laurel forest	*Phyllis nobla*	forb	w	s	Laurel forest
Briza maxima	grass	w	s	Ruderal	*Picconia excelsa*	tree	a	s	Laurel forest
Bromus s.p.	grass	w	s	Ruderal	*Pinus canariensis*	tree	w	b	Pine forest
Carex canariensis	grass	w	s	Ruderal	*Pinus radiata*	tree	b	m	Pine forest
Cedronella canariensis	forb	w	s	Laurel forest	*Prunus lusitanica*	tree	a	m	Laurel forest
Cerastium glomeratum	forb	w	s	Ruderal	*Pteridium aquilinum*	fern	w	s	Forested areas
Cistus symphytifolius	shrub	a	m	Pine forest	*Pterocephalus lasiospermus*	forb	w	s	Pine forest
Cynosorus echinatus	forb	w	s	Ruderal	*Ranunculus cortusifolius*	forb	w	s	Forested areas
Cheirolophus teydis	forb	w	S	Mountain vegetation–pine forest	*Rubia peregrina*	forb	w	s	Ruderal
Daphne gnidium	forb	a	m	Pine forest	*Rubus inermis*	forb	a	b	Ruderal
Erica arborea	tree	w	s	Laurel forest	*Rumex acetocella*	forb	w	s	Pine forest
Erodium s.p.	forb	w	s	Ruderal	*Rumex mauritanica*	forb	w	s	Ruderal
Eucaliptus glandulosus	tree	b	b	Introduced	*Scrophullaria smitti*	forb	w	s	Pine forest
Fumaria officinalis	forb	w	s	Ruderal	*Sherardia arvensis*	forb	w	s	Ruderal
Galium aparine	forb	w	s	Ruderal	*Silene gallica*	forb	w	s	Ruderal
Galium parisine	forb	w	s	Ruderal	*Smilax aspera*	forb	a	m	Forested areas
Galium scabrum	forb	w	s	Ruderal	*Sonchus*	forb	w	s	Ruderal
Geranium dissectum	forb	w	s	Ruderal	*Sonchus asper*	forb	w	s	Ruderal
Geranium molli	forb	w	s	Ruderal	*Sonchus oleraceus*	forb	w	s	Ruderal
Gram	grass	w	s	Ruderal	sp1				
Grennovia aurea	crassulacea	w	s	Clift	sp2				
Hypericum canariense	forb	b	m	Laurel forest	*Stachys arvensis*	forb	w	s	Ruderal
Hypericum grandifolium	forb	b	m	Forested areas	*Stellaria media*	forb	w	s	Ruderal
Hypericum reflexum	forb	b	m	Forested areas	*Tamus edulis*	forb	w	s	Ruderal
Ilex canariensis	tree	a	b	Laurel forest	*Teline canariensis*	tree	a	b	Pine—laurel forest borders
Ilex perado	tree	a	b	Laurel forest	*Torilis arvensis*	forb	w	s	Ruderal
Isoplexis canariensis	forb	b	m	Laurel forest	*Trifolium arvense*	forb	a	m	Ruderal
Laurus azorica	tree	a	b	Laurel forest	*Trifolium glomeratum*	forb	a	m	Ruderal
Linum bienne	forb	w	s	Laurel forest	*Tuberaria guttata*	forb	w	s	Ruderal
Lotus s.p.	forb	w	s	Ruderal	*Veronica s.p*	forb	w	s	Ruderal
Lotus angustissimus	forb	w	s	Ruderal	*Viburnum tinus*	tree	a	b	Laurel forest
Luzula s.p.	grass	w	s	Ruderal	*Vicia lutea*	forb	a	m	Pine forest
Micromeria varia	forb	w	s	Ruderal	*Viola odorata*	forb	w	s	Pine forest

[a] Dispersion = w: anemochorous, a: zoochorous, b: barochorous.
[b] Seed size = <1 mm: s, 1 mm–1 cm: m, >1 cm: b.

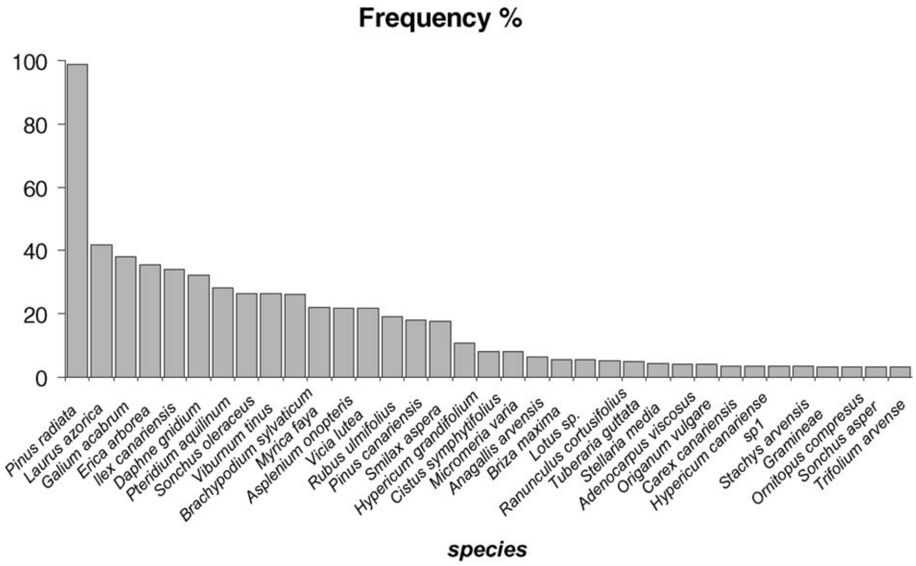

Fig. 2. Percentage presence (frequency) of species in the plots over a value of 5%.

criminated by the presence of Canarian pine forest species such as *P. canariensis* and a typical understory for a Canarian pine stand (e.g. *Neotinea maculata*, *Cistus symphytifolius*, *Cheirolophus teydis*, and *Erica arborea*). The latter species are found in areas of forest transition between Canarian pine and laurel forest (Blanco et al., 1989).

4. Discussion

Classification and ordination analysis of the data revealed four species groups that differed in environmental characteristics (altitude, canopy cover, and slope).

The plantations of *P. radiata* had an original restoration purpose, but some areas similar to those analysed in this study lacked a restoration objective. Those areas remaining on the island with currently no forest but with forest potential, suffer widespread soil loss, high levels of disturbance (Arévalo, personal observation), including high recurrence of fire (Arévalo et al., 2001), and are dominated by shrub stands of fayal-brezal (*Erica arborea* and *Myrica faya*).

The results indicate that the ALF and ULF groups include almost all the species of the laurel forest. The laurel forest is considered the most representative of all Canarian ecosystems (Arévalo 1998). Although *P. radiata* is a pioneer tree in its natural environment (California, USA), no evidence of regeneration for this species was found. However, herbs and other species of the laurel forest (which are mainly shade-tolerant) were able to establish in the plots.

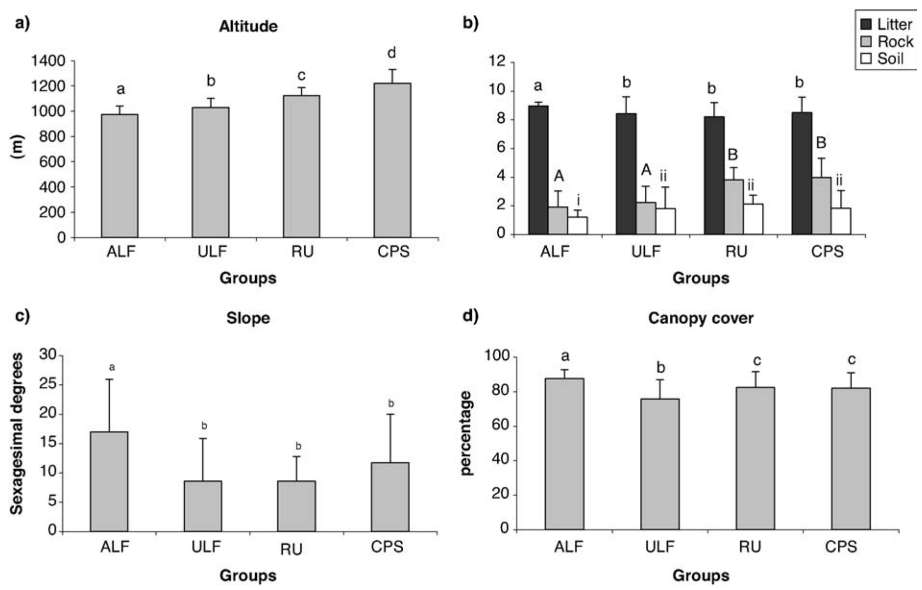

Fig. 3. Mean values and standard deviations for (a) altitude (metres); (b) litter, rock and soil cover (mean of cover classes for the plots); (c) slope (sexagesimal degrees) and (d) canopy cover (mean of the percentages) of the different groups of plots discriminated by TWINSPAN. Identical letters above the bars indicate non-significant differences (ALF: Advance laurel forest, ULF: Undeveloped laurel forest, RU: Ruderal understory and CPS: Canarian pine stand).

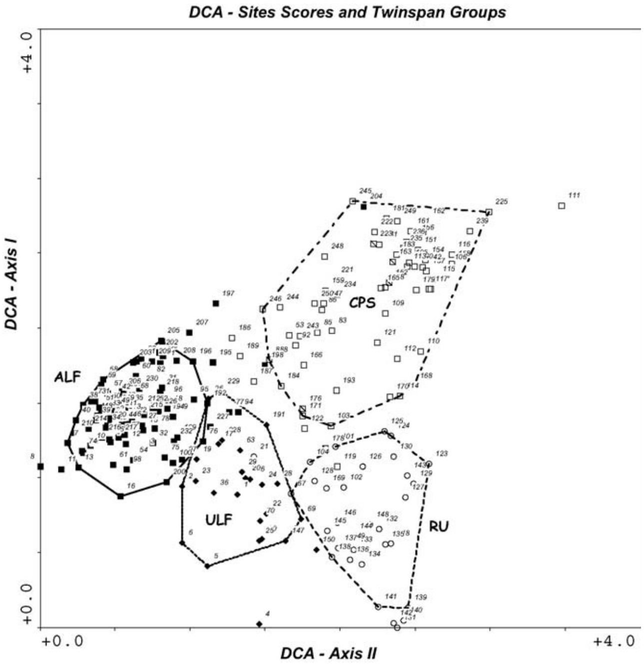

Fig. 4. Plot scores in the space defined by axis I and axis II of the DCA. Polygons enclose 95% of the plots of the different TWINSPAN groups, polygon of solid lines for ALF, dotted lines for ULF, slashed lines for RU and dotted and slashed lines for CPS. (Eigenvalues of axes I and II were 0.462 and 0.346 and the cumulative percentage of variance of both axes was 14.2%). ALF: Advance laurel forest, ULF: Undeveloped laurel forest, RU: Ruderal understory and CPS: Canarian pine stand.

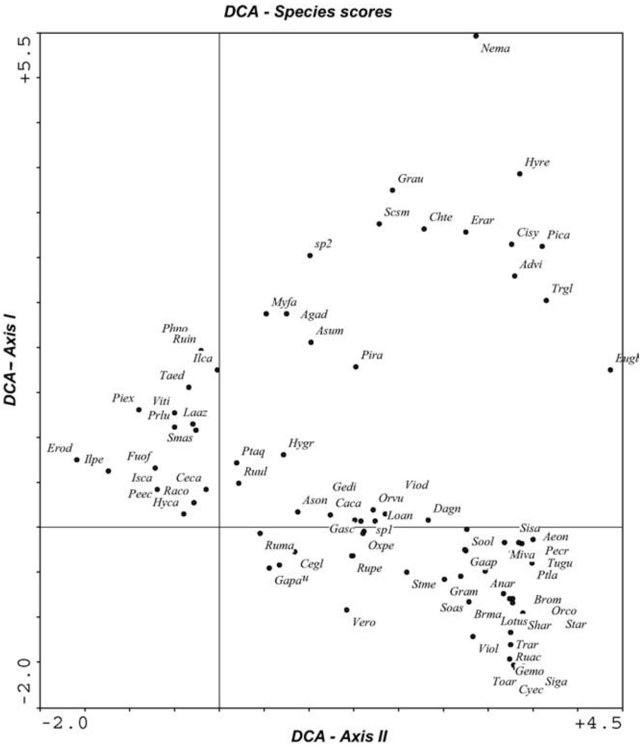

Fig. 5. DCA species scores for axes I and II. Species names are indicated with the four first letters of genus and species. Abbreviations for species are, *Adenocarpus viscosus (advi) ; Aeonium* sp. *(aeon) ; Ageratina adenophora (agad) ; Anagallis arvensis (anar) ; Arisarum vulgare (arvu) ; Asparagus umbellatus (asum) ; Asplenium onopteris (ason) ; Brachypodium sylvaticum (brsy) ; Briza maxima (brma) ; Bromus* sp., *(brom) ; Carex canariensis (caca) ; Cedronella canariensis (ceca) ; Cerastium glomeratum (cegl) ; Cistus symphytifolius (cisy) ; Cynosorus echinatus (cyec) ; Cheirolophus teydis (chte) ; Daphne gnidium (dagn) ; Erica arborea (erar) ; Erodium* sp. *(erod) ; Eucalyptus globulus (eugl) ; Fumaria officinalis (fuof) ; Galium aparine (gaap) ; Galium parisiense (gapa) ; Galium scabrum (gasc) ; Geranium dissectum (gedi) ; Geranium molle (gemo) ; Gramineae (gram) ; Greenovia aurea (grau) ; Hypericum canariense (hyca) ; Hypericum grandifolium (hygr) ; Hypericum reflexum (hyre) ; Ilex canariensis (ilca) ; Ilex perado (ilpe) ; Isoplexis canariensis (isca) ; Laurus azorica (laaz) ; Linum bienne (libi) ; Lotus* sp. *(lotu) ; Lotus angustissimus (loan) ; Luzula sp (luzu) ; Micromeria varia (miva) ; Myrica faya (myfa) ; Neotinea maculata (nema) ; Origanum vulgare (orvu) ; Ornithopus compressus (orco) ; Oxalis pes-caprae (oxpe) ; Pericallis cruentus (pecr) ; Pericallis echinata (peec) ; Phyllis nobla (phno) ; Picconia excelsa (piex) ; Pinus canariensis (pica) ; Pinus radiata (pira) ; Prunus lusitanica (prlu) ; Pteridium aquilinum (ptaq) ; Pterocephalus lasiospermus (ptla) ; Ranunculus cortusifolius (raco) ; Rubia peregrina (rupe) ; Rubus inermis (ruin) ; Rubus ulmifolius (ruul) ; Rumex acetosella (ruac) ; Rumex mauritanica (ruma) ; Scrophularia smithii (scsm) ; Sherardia arvensis (shar) ; Silene gallica (siga) ; Smilax aspera (smas) ; Sonchus (sonc) ; Sonchus asper (soas) ; Sonchus oleraceus (sool) ;* sp1 (sp1*) ;* Sp2 (Sp2*) ; Stachys arvensis (star) ; Stellaria media (stme) ; Tamus edulis (taed) ; Teline canariensis (teca) ; Torilis arvensis (toar) ; Trifolium arvense (trar) ; Trifolium glomeratum (trgl) ; Tuberaria guttata (tugu) ; Veronica* sp. *(vero) ; Viburnum tinus (viti) ; Vicia lutea (vilu) ; Viola odorata (viod) ; Viola* sp. *(viol).*

The ULF and RU groups showed many ruderal and annual species, common indicators of disturbance in these specific locations of the island. For these areas, laurel forest regeneration is hindered and management activities will be required to promote successful regeneration.

The CPS group occurred in areas where the environmental altitude potentially favours Canarian pine (Del Arco et al., 1992) (Fig. 3). Common herbs and shrubs present in these plots are typical species of the Canarian pine forest.

P. canariensis and *P. radiata* were planted together in CPS plots. The lack of fire had a negative effect on the regeneration of endemic *P. canariensis* because *P. radiata* dies after fire, whereas *P. canariensis* is highly resistant. Fire will have a positive effect, eliminating the exotic pine that is not adapted to fire and opening new areas for the establishment of new stands of Canarian pine. Fire is a natural force in the dynamics of the Canarian pine community (Arévalo et al., 2001), similar to other pine species in other areas (Huffman and Werner, 2000) and it is necessary to maintain the potential distribution of the *P. canariensis* forest.

Intense human disturbances (e.g., litter removal, trampling, logging of small trees etc.) have increased the number of ruderals species in RU, because it is at low altitude and closer to populations that have been traditionally carrying out sustainable use of the forest (e.g., timber, recovery of litter, etc ...).

P. radiata has been acting as a nurse plant providing favourable environmental conditions for the establishment of the native species. Soil protection and shade can be considered the main factors responsible for the establishment of native species. Similar ecological functions by exotic species have been reported in other studies (e.g. Parrotta, 1995). Ecological functions of non-native species should be analysed before starting any control of the species as some degraded areas may benefit from exotic species (Williams, 1997).

In light of our results, we suggest the following two management recommendations: (a) the promotion of laurel forest establishment by thinning treatments in the ALF and ULF groups. The elimination of the pine canopy should be done slowly, especially in the latter group. We suggest a thinning of not more than 50% (thinning more than 50% has been found to promote heliophitic species; Smith et al., 1997) of the total density of pines at first, then total elimination after monitoring changes in the stand after the first thinning. Since environmental conditions are not as favourable for the development of the laurel forest and because of a higher disturbance level in the later years, more time will be required for the facilitation of laurel forest regeneration. A much closed canopy has negative effects on the establishment of shade-tolerant species (Ashton et al., 1998). The ability of native forest to dominate the stand should be promoted with these subsequent stand management activities (Lugo et al., 1993; Haggar et al., 1997; Smith et al., 1997); (b) facilitation of Canarian pine establishment. Competition occurs between both species of pine and which is dominant is determined mainly by human intervention. Although prescribe fire can be a excellent tool to favour *P. canariensis*, it is difficult to apply in the studied areas due to the topography (Arévalo et al., 2001). We propose the elimination of *P. radiata* trees. The human population could use the wood from this logging for traditional activities or other purposes; however, the use of wood for traditional activities has largely decreased in the last decade. Fire cannot be successfully used as a restoration tool in the Canary Islands due to the difficulties in controlling its behaviour.

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