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ORIGINAL PAPER

A tool set for description and mapping vegetation on protected natural areas: an example from the Canary Islands

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Abstract The Canary Islands belong to Mediterranean basin hotspot, especially because their rich endemic flora. Nearly 40% of the total archipelago area is protected through protected natural area network. However, some plant communities show high degree of disturbance or they develop in unprotected zones. So, multivariate analysis combined with vegetation mapping can be useful for identify, describe and protect the main plant communities. These tools have been applied in Caldera de Taburiente national park (La Palma. Canary Islands). An actual vegetation map of this park is showed and its major natural vegetation units are described. These tools could be applied to other protected and unprotected areas, especially for planning, management and conservation purposes.

Keywords Vegetation map · National park · Aerial photographs · Classification · Ordination · ANOSIM · SIMPER

Introduction

The Canary Islands (27°37′–29°25′N and 13°20′–18°10′W), are part of one of the most remarkable biodiversity hotspots on the planet, the Mediterranean basin (Médail and Quézel 1997; Myers et al. 2000). These include 539 endemic vascular plants, almost 40% of the native flora and more than 25% of the total flora (Acebes et al. 2010). Accordingly, vegetation communities have an important endemic element (Del Arco et al. 2006). The

Nomenclature: Taxonomical nomenclature according to Acebes et al. (2010); Syntaxonomical nomenclature according to Rivas-Martínez et al. (2001), (2002), and Del Arco et al. (2006)

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Canary Islands endemic flora is highly vulnerable to environmental change (Reyes-Betancort et al. 2008). For this reason, nearly 40% of the total archipelago area is now protected, through local network of 146 protected areas (Gobierno de Canarias 2000) and also through European legislation (Annex 2 of the EU Habitats Directive 92/42/CEE), preserving this richness and floristic singularity. Despite this, some plant communities like *Euphorbia* scrubs, thermo-sclerophyllous woodland and laurel forest have greatly retreated, sometimes with little possibility of recovery (Del Arco et al. 2010).

Vegetation mapping is a good tool to identify the main plant communities, as well as to understand their relationships with environmental factors (Faber-Langendoen et al. 2007). This valuable information is essential to analyze and establish conservation priorities (Franklin 1995; Blasi et al. 2005; Hoagland 2000; Biondi et al. 2011).

The aim of this study was to map and describe at a detailed scale the vegetation of Caldera de Taburiente national park using a particular tool set. There are some general maps of the island (Ceballos and Ortuño 1976; Santos 1983; Del Arco et al. 2006), but no maps of Caldera at this scale.

Methods

Study area

Caldera de Taburiente national park is located on the island of La Palma, in the northwest portion of the Canary archipelago. This young island (1.6 Ma) (Carracedo 1980) includes a gigantic volcanic feature (caldera) measuring 8 km in diameter. The latter has about 2,000 m depth, from its highest point (Roque de los Muchachos, 2,426 m a.s.l.) to the lowest (Dos Aguas, 430 m a.s.l.), with a steep terrain. Its basic characteristics include a rough topography, with deep precipices, slopes of greater than 50° inclination, and many near-vertical rocky walls (Afonso 1988). The climate is Mediterranean, with a warm and dry summer. The annual average temperature varies between 15.6°C in Taburiente (820 m a.s.l.) and 9.5°C in Roque de los Muchachos (2,426 m a.s.l.). Winters are cool, with an average temperature of 11.6°C in January in Taburiente. At the higher elevations, there are nighttime frosts in the autumn, winter and spring. Most rainfall occurs in autumn and winter, varying between 498 mm in Mirador de las Chozas (1,380 m a.s.l.) and 978.2 mm in Tenerra (1,070 m a.s.l.). At the summit of Roque de los Muchachos annual precipitation can reach 869.3 mm, sometimes in the form of snow (Del Arco et al. 1999). From a bioclimatic point of view, Canary Islands belong to Mediterranean macrobioclimate (Rivas-Martínez 1997; 2007). Within it, several bioclimatic belts have been defined by using a combination of thermotype and ombrotype. Bioclimatic belts are the successive types or groups of physical media along an altitudinal or latitudinal cliseries in which plant communities are integrated. Thermotypes are the spaces within an "Itc" (Compensated thermicity index) gradient. Ombrotypes are the spaces within an "Io" (Ombrothermic index) gradient (Table 1).

Twelve bioclimatic belts exist within the Caldera de Taburiente. These include combinations of infra-, thermo-, meso- and supramediterranean thermotypes, with dry, subhumid and humid ombrotypes (Del Arco et al. 2009). Regarding to flora, the park includes about 390 plant species. Of these, 86 are Canary endemisms, 28 of which are restricted to La Palma, and 18 Macaronesian endemisms (Santos 2004).

Caldera de Taburiente has suffered different human impacts like fires or grazing. The latter has been especially harmful (Garzón-Machado et al. 2010). Despite of this, some

Table 1 Threshold values for thermotypes and ombrotypes present in Caldera de Taburiente, according to Rivas-Martínez (1997)

Thermotype	Itc[a]
Inframediterranean	580–450
Thermomediterranean	450–350
Mesomediterranean	
Lower	350–280
Upper	280–210
Supramediterranean	210–80
Ombrotype	**Io[b]**
Dry	
Lower	2.0–2.5
Upper	2.5–3.0
Subhumid	3.0–5.5
Humid	5.5–11

[a] $Itc = [(T + M + m) \times 10] \pm C$, where *T* mean annual temperature, *M* and *m* mean maximum and minimum temperatures in the coldest month, *C* compensation value

[b] $Io = (Pp/Tp) \times 10$, where *Pp* (Positive rainfall) annual rainfall in mm, taking into account only the months with mean temperature higher than 0°C, and *Tp* (Positive temperature) value in tenths of degrees resulting from the sum of the mean temperatures of the months with a mean higher than 0°C

sectors have been relatively well preserved. In 1954 this area was classified as a national park, and incorporated to national park's Network of Spain. Recently it has been transferred to the Canary Government (Gobierno de Canarias 2011).

Data collection

The methodology used for data collection was divided into the following phases:

- Physiognomic analysis of vegetation at 1:10.000 scale, using aerial photographs (2009 flight). For this purpose, the vegetation map of La Palma was used as a guideline (Del Arco et al. 2006).
- Field exploration to confirm the previous analysis and register other types of vegetation not registered in that map and unrevealed through aerial photographs.
- Location of sampling plots. 147 of these plots were located at random, covering all vegetation types identified earlier. The number of plots for each vegetation type varied according to the respective area and accessibility. Later, 37 plots were added from sources in the literature (Pérez-de-Paz et al. 1994; Martín et al. 2007). In all plots, abundance-cover index of all vascular plant species was measured following the method of Braun-Blanquet (1979). Phytosociological nomenclature follows Rivas-Martínez et al. (2001); (2002), and Del Arco et al. (2006). The ranks of subassociation, association and alliance were used to delimit the map units, as they have been proved very useful for describing vegetation (Biondi et al. 2004; Biondi et al. 2011). Altitude, slope, aspect and UTM coordinates of each location were also recorded. The latter was used to subsequent position in digital cartography, and extract bioclimatic and geological variables for each studied place from their respective maps

Table 2 Ranges of environmental variables

Environmental variables	Values
Altitude	430–2375 m a.s.l.[a]
Slope	5–90°[a]
Aspect	N, S, W, E, NE, SE, NW, SW
Thermotype	Inframediterranean
	Thermomediterranean
	Lower-Mesomediterranean
	Upper-Mesomediterranean
	Supramediterranean
Ombrotype	Lower-dry
	Upper-dry
	Subhumid
	Humid
Geology	Alluvial
	Rock falls
	Basaltic lava flows
	Phonolitic lava flows
	Colluvial and landslide deposits
	Gabbros
	Basaltic pyroclasts
	Sediments, agglomerates and breccias

[a] The variable takes value within the range shown

(Del Arco et al. 2009 and Carracedo et al. 2001). The bioclimatic variables used in this study were thermotype and ombrotype. Table 2 shows these environmental variables.

Data analysis

Vegetation and related environmental factors were analyzed using multivariate techniques (classification and ordination analyses). A data matrix plots-versus-species was created using a transformed Van der Maarel cover-abundance scale (Van-der-Maarel 2005) (Table 3). The matrix was subjected to the hierarchical agglomerative clustering method to

Table 3 Transformation of Braun-Blanquet cover-abundance scale to Van der Maarel cover percentage

BrBl	Ord%
r	0.5
+	1
1	2
	4
2	8.5
	17.5
3	35
4	70
5	140

BrBl Original Braun-Blanquet scale, *Ord%* ordinal transform scale % approximation from 1981, see van der Maarel (2005) separate out the major groups of vegetation. Complete linkage was used as the method for grouping under Euclidean distance as similarity coefficient (Leps and Smilauer 2003). Natural vegetation units were identified as homogeneous groups in the dendrogram.

One-way analysis of similarity (ANOSIM) (Clarke 1993) was used for the interpretation of the optimal level of clustering. It compares average rank similarities within preselected homogeneous groups to average rank similarities between groups and yields a measure statistic (R) ranging from 0 to 1, with values larger than 0.75 indicating a strong separation. A significance level of 0.001 was used to distinguish between communities. A similarity percentage analysis (SIMPER) (Clarke 1993) was used to evaluate the major species contributing to the similarities within communities previously detected by cluster and ANOSIM analyses. These species were used to describe the plant communities. The software used for all these analyses was Community Analysis Package 3.11 (Seaby et al. 2004).

Ordination techniques were performed in order to help to explain differences on plant communities and to evaluate the influence of environmental factors on species composition and distribution of vegetation. We used detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) (Ter Braak and Smilauer 1998). CCA was performed in a set of environmental variables (Table 2) treated by a manual selection procedure simultaneously applying the Monte Carlo test (999 permutations under full model). This test confirms that the sub-set of environmental variables selected significantly explains (P-value < 0.01) a representative part of the floristic composition (Mwavu et al. 2008). The software used was CANOCO 4.5 for Windows.

Mapping

Once the plant communities were checked and the environmental variables determining them established, a Geographic Information System (Environmental Systems Research Institute 2006) was used to draw an actual vegetation map, at a scale of 1:10.000. Digital color aerial photographs (GRAFCAN 2009) were the base to delimit polygons on it. A digital elevation model (DEM) to obtained altitude, aspect and slope data (GRAFCAN 2009), and geological (Carracedo et al. 2001), and bioclimatic maps (Del Arco et al. 2009) were the main auxiliary layers used. Chorological taxonomic maps of differential species, provided for the national park, also were used. The associated database included the following fields: community code, legend code, area and perimeter. Patch analyst extension (Elkie et al. 1999) was used to analyze the surface of each natural vegetation unit.

Results and discussion

A total of 129 species were recorded throughout this study. Canary endemic species showed the highest proportion of them (66 species, 24 of them are exclusive endemic to La Palma) (Acebes et al. 2010). The others are native species, except for 11 non-native species, of which three are invasive species (Sanz-Elorza et al. 2004). Regarding to flora conservation, 17 species are included in the red list of Spanish Vascular Flora (Moreno 2008) (Fig. 1).

Classification analysis

The cluster analysis yielded five main plant groups (Fig. 2) based on the structure and floristic composition of the data, nominated A, B, C, D and E, and four subgroups: A1, A2,

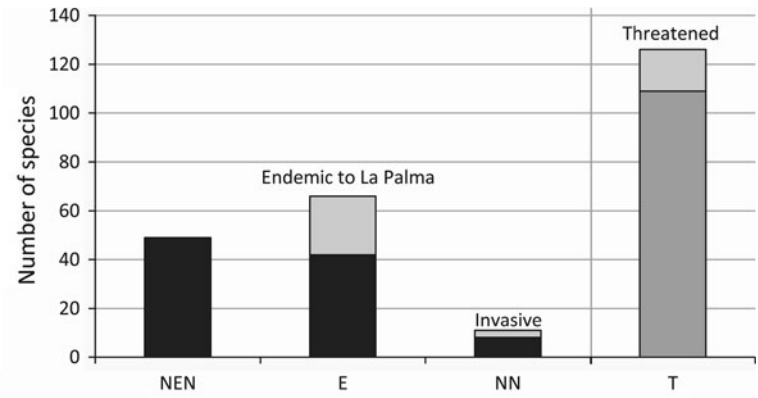

Fig. 1 Status flora recorded throughout this study. Categories shown are NEN (non-endemic natives); E (endemic); NN (non-native); T (total) (Moreno 2008; Acebes et al. 2010)

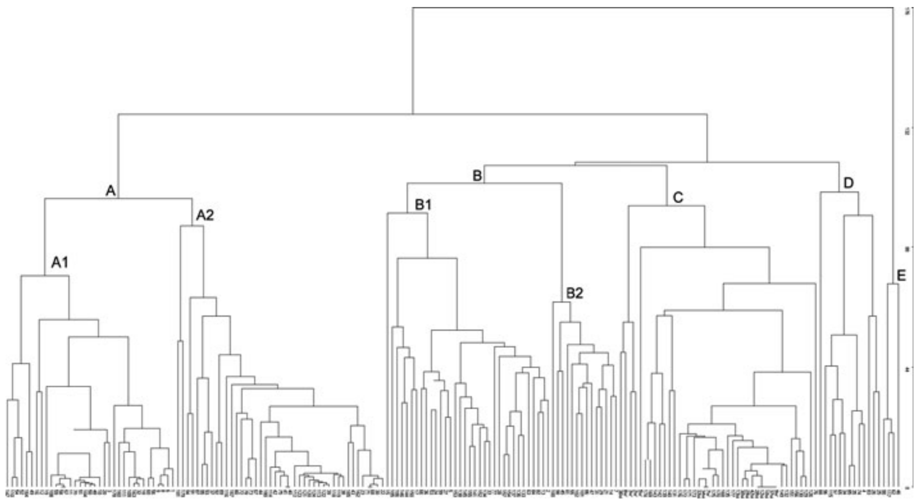

Fig. 2 Cluster analysis dendrogram obtain from 184 plots and 126 species. *Group A*: Canary pine forest, *B*: rock communities, *C*: summit broom scrub and Canary cedar woodland fragments, *D*: Canary willow and hydrophytic communities and *F*: grasslands. *Subgroups A1*: typical pine forest, *A2*: thermophilous pine forest, *B1*: summit rock communities and *B2*: pine forest rock communities

B1 and B2. The ANOSIM test revealed significant differences for the five major groups ($R = 0.93$, $P = 0.001$) and also for all groups (major groups and subgroups) ($R = 0.84$, $P = 0.001$). These results indicate a significant separation of the plant groups previously selected by cluster analysis.

SIMPER analysis was performed at subgroups level. The results showed dominant species of each plant community, more or less exclusive for each group except for subgroups B1 and B2 with some shared species, although with a differential percentage contribution (Table 4). All species were considered to describe the plant communities.

The groups and subgroups according their dominant species were classified as: (A) "Canary pine forest", (B) "rock communities", (C) "summit broom scrub and Canary

Table 4 Natural vegetation units: main contributor species, syntaxonomic name and conservation codes

Natural vegetation unit	Main contributor species and percentage contribution (SIMPER analysis)	Syntaxonomic name	Natura 2000 code (Habitats Directive 92/43/EEC) (1)	Code according to "Atlas y Manual de los Hábitat de España" (2)
Canary willow and hydrophytic communities	*Salix canariensis* (45.02)	*Rubo-Salicetum canariensis*	92A0	82A071
	Ageratina adenophora (44.89)	*Molinio-Holoschoenion vulgaris*	6420	542010
	Equisetum ramossisimum (3.34)	*Mentho-Juncion inflexi*	6420	542040
Typical pine forest	*Pinus canariensis* (53.77) *Cistus symphytifolius* (41.07)	*Loto hillebrandii-Pinetum canariensis* subass. *cistetosum symphytifolii*	9550	855012,856511
Thermophilous pine forest	*Pinus canariensis* (91.53)	*Loto hillebrandii-Pinetum canariensis* subass. *spartocytisetosum filipis nom. prov.*	9550	855012, 856511
Summit broom scrub and Canary cedar woodland fragments	*Adenocarpus viscosus* ssp. *spartiodes* (85.41)	*Genisto benehoavensis-Adenocarpetum spartioidis*	4090	3090D3
	Juniperus cedrus ssp. *cedrus* (10.85)	*Adenocarpo spartioidis-Juniperetum cedri*	9560	856510, 856520
Pine forest rock communities	*Aeonium canariense* (42.31)	*Soncho-Aeonion*	8320	732010
	Greenovia diplocycla (12.44)			
	Tolpis calderae (6.93)			
	Carlina falcata (5.25)			
	Sonchus hierrensis var. *benehoavensis* (4.79)			
	Lobularia canariensis ssp. *palmensis* (3.54)			

Table 4 continued

Natural vegetation unit	Main contributor species and percentage contribution (SIMPER analysis)	Syntaxonomic name	Natura 2000 code (Habitats Directive 92/43/EEC) (1)	Code according to "Atlas y Manual de los Hábitat de España" (2)
Summit rock communities	*Greenovia diplocycla* (24.04)	*Greenovion aureae*	8320	732020
	Senecio palmensis (14.80)			
	Micromeria lasiophylla ssp. *palmensis* (9.91)			
	Pimpinella dendrotragium (4.95)			
	Tolpis grex *lagopopda* (3.85)			
	Aeonium canariense (3.75)			
	Festuca agustinii (3.74)			
Grasslands	*Hyparrhenia sinaica* (94.62)	*Cenchro-Hyparrhenietum sinaicae*	6220	522245
Other communities		*Artemisio-Rumicetum lunariae*	5330[a]	146020

(1) Bartolomé et al. (2005); Rivas-Martínez & Penas (2003); Vera et al. (2008); (2) Rivas-Martínez & Penas (2003)

[a] Canary Infra-Thermomediterranean substitutional community

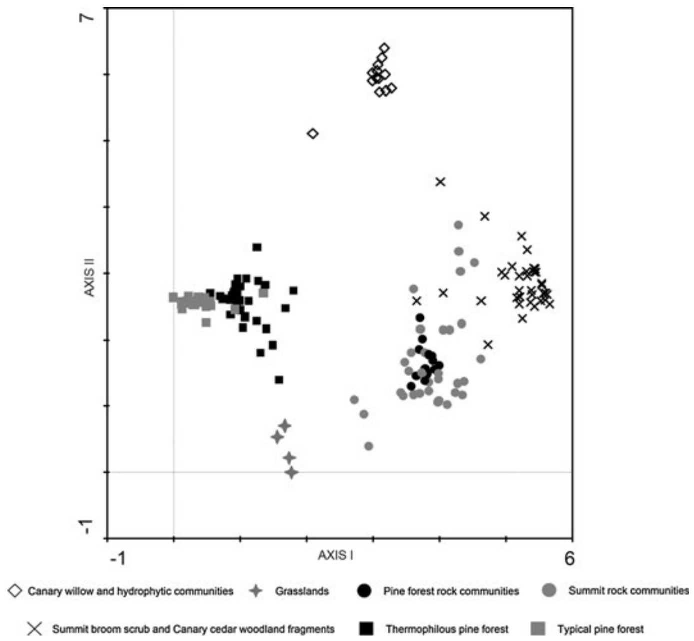

Fig. 3 DCA ordination diagram of plant communities occurring in the plots selected. Symbols shows the classification obtained in the dendrogram (*Eigenvalues* for axis I: 0.885, axis II: 0.440 and axis III: 0.307; sum of all canonical *eigenvalues* and total inertia: 8.106)

cedar woodland fragments", (D) "Canary willow and hydrophytic communities" and (E) "grasslands". Some of them were divided into subgroups: A (A1: "typical pine forest"; A2: "thermophilous pine forest") and B (B1: "summit rock communities"; B2: "pine forest rock communities").

Ordination analysis

DCA analysis confirmed the major groups shown by cluster and ANOSIM analysis (Fig. 3). "Pine forest", "rock communities" and "summit broom scrub" were shown as clearly differentiated groups along axis I, probably indicative of an altitudinal gradient. As for the subgroups, "typical pine forest" was separated from the "thermophilous pine forest"; "summit rock communities" was not clearly separated from "pine forest rock communities". Two other groups completely separate from the rest were shown on separate areas of the axis II ("Canary willow and hydrophytic community" and "grasslands"). This axis separated slightly to the other groups.

The influence of environmental factors on species composition and distribution of vegetation was inferred from CCA analysis (Fig. 4). All factors were used and then only were taken into account the ones that the Monte Carlo test yielded as significant (Table 5). Altitude ($F = 5.56$, $P = 0.001$) and ombrotype variation (humid) ($F = 16.36$, $P = 0.001$) were the most important determining variation in species composition along axis I. "Summit broom scrub" and "summit rock communities" are positively correlated with these variables. The axis II is related with slope ($F = 17.39$, $P = 0.001$). Both rock communities are in its positive sector. The other less important variables were rock falls

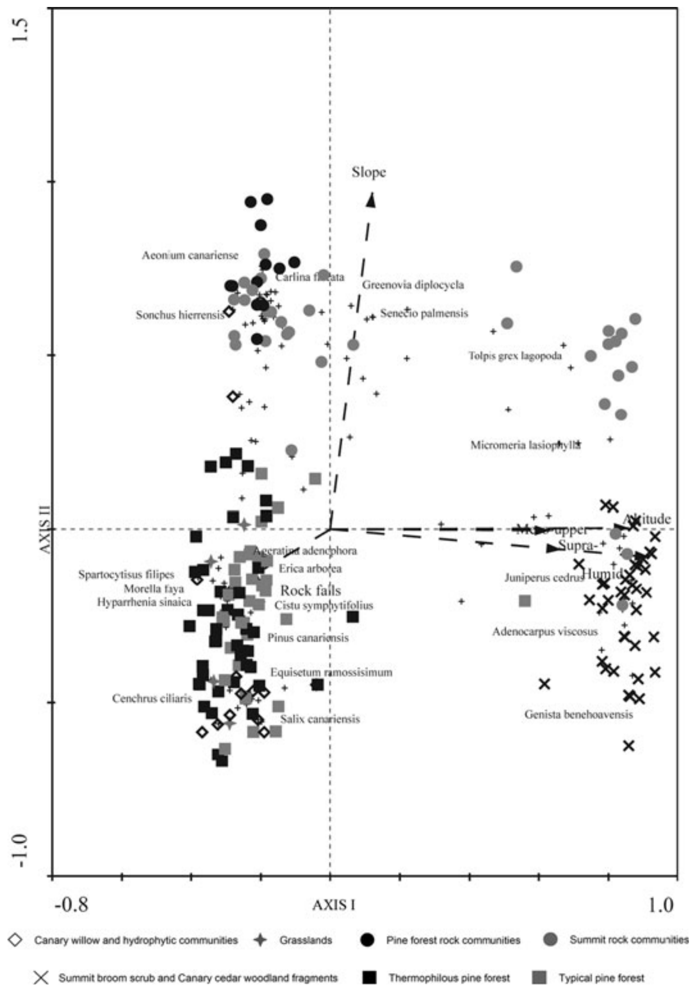

Fig. 4 CCA ordination diagram showing the correlation between species, plots and environmental variables. Only the most characteristic species and environmental factors are showed (*Eigenvalues* for axis I: 0.766, axis II: 0.660) and axis III: 0.169; sum of all canonical *eigenvalues*: 1.766; total inertia: 8.106)

($F = 2.24$, $P = 0.001$) and supramediterranean ($F = 1.90$, $P = 0.009$) and upper-mesomediterranean thermotype ($F = 2.56$, $P = 0.01$). The other environmental variables not clearly contribute to the separation of the groups.

Map units

The dominant vegetation in Caldera de Taburiente is the "Canary pine forest", but apart from it, different environmental factors as altitudinal difference, slope and rainfall, etc. allow the development of other plant communities. The Table 7 shows these communities in a synoptical table of the relevés made in the sampling plots, by using presence classes of Braun-Blanquet (1979) and Alcaraz (1999).

Table 5 Canonical coefficients of sub-set of environmental variables, the correspondent *t* value (Student's statistic) and their correlations for the two first axes

Sub-set of environmental variables	Axis I			Axis II		
	CC	*t*	Corr.	CC	*t*	Corr.
Altitude	0.1327	2.9071	0.8226	−0.2031	−2.9228	0.0487
Slope	−0.0137	−0.5405	0.0712	1.0040	26.0586	0.8862
Upper-Mesomediterranean	0.4913	10.3423	0.6048	0.0874	1.2082	0.0294
Supramediterranean	0.4853	9.1907	0.6375	0.1030	1.2805	−0.0194
Humid	0.2549	4.7340	0.8806	−0.0497	−0.6059	−0.0257
Rock falls	−0.0395	−1.4604	−0.2852	−0.0731	−1.7732	−0.1820

CC Canonical coefficients, *t t*-values and *Corr.* correlations for sub-set of environmental variables

Canary willow (Rubo-Salicetum canariensis) and hydrophytic communities (Molinio-Holoschoenion vulgaris; Mentho-Juncion inflexi)

The Canary willow is a heliophilous community, typical of springs, and banks of ravines that flow most of the year. It is characterized by *Salix canariensis*, which forms small groves that can be occasionally destroyed by water force in winter. *Morella faya* (*Myrica faya*) is the only tree species accompanying the Canary willow. *Equisetum ramossisimum* and *Scirpus holoschoenus* ssp. *globiferus* are common and the invasive *Ageratina adenophora* widespread. Eradication actions have been carried out for the latter without success.

The hydrophytic communities are present in many water sources or sharing biotope with the Canary willow community, where there is a high phreatic level most of the year. *Mentha longifolia, Equisetum ramosissimum, Epilobium hirsutum, E. parviflorum, Rorippa nasturtium-aquaticum, Veronica anagallis-aquatica*, *Scirpus holoschoenus* ssp. *globiferus,* etc., are common plants within these communities. Other species as the ferns *Adiantum capillus-veneris, Pteridium aquilinum* and *Pteris vittata* are frequent in their vicinity.

Canary pine forest of La Palma (Loto hillebrandii-Pinetum canariensis)

The mature Canary pine forest is a more or less open formation characterized by *Pinus canariensis,* a species of ancient Mediterranean affinity and wide ecological range (Millar 1996). The pine forest is the climatophilous vegetation of dry infra-, dry-subhumid-humid thermo- and subhumid-humid mesomediterranean territories inside the park, between 600 and 2,000 m (Del Arco et al. 2009) and outside the influence of trade-wind clouds.

Pine forest is the most widespread community of Caldera de Taburiente, contacting to summit vegetation in the highest elevations; however it is poor in understory species, probably due to the strong negative effect of alien herbivores (Garzón-Machado et al. 2010). The most characteristic plants, apart from *Pinus canariensis* are *Cistus symphytifolius* var. *symphytifolius, Chamaecytisus proliferus* ssp. *proliferus* and *Lotus hillebrandii*. Within the national park, several types of pine forest can be distinguished according to specific environmental conditions involving the presence of some species:

– Thermophilous pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *spartocytisetosum filipis* nom. prov.), present in the southwest sector of the park, in the dry infra- and thermomediterranean belts (Del Arco et al. 1999). It is floristically characterized by the presence of the endemic broom *Spartocytisus filipes,* mixed with the pines. Some endemic shrubby species of the lowest belts such as *Kleinia neriifolia* and *Globularia salicina,* and vines as *Periploca laevigata* and *Rubia fruticosa* are also found.

– Typical pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *cistetosum symphytifolii*) is the poorest type, with a few species. Pine trees can grow in diverse topographical conditions, from very steep slopes with scarse soil, to areas with smooth topography and deep soil, forming a dense and continuous forest (Pérez-de-Paz et al. 1994). It is widely distributed inside the park, in the dry, subhumid and humid thermomediterranean belts, reaching the subhumid lower-mesomediterranean (Del Arco et al. 1999).

Summit broom scrub (Genisto benehoavensis-Adenocarpetum spartioidis) and Canary cedar woodland fragments (Adenocarpo spartioidis-Juniperetum cedri)

Summit broom scrub is a community adapted to the extreme conditions of the high mountain. It extends above the pine forest on subhumid-humid supramediterranean territories of the north, in the summits of La Palma, inside and outside of the park (Del Arco et al. 1999). It is a low and dense scrubland dominated by *Adenocarpus viscosus* ssp. *spartioides* and accompanied with an important number of endemisms such *Spartocytisus supranubius*, *Descurainia gilva, Plantago webbii, Erysimum scoparium, Pterocephalus porphyranthus*, etc. In addition, *Viola palmensis*, *Lactuca palmensis* and *Genista benehoavensis* are endemic threatened species of this community. The latter could be more abundant in the past, forming the dominant scrub with *A. viscosus* ssp. s*partioides*. Overgrazing by goats and fires were the main causes of retreat (Del Arco 1982). Fire threat still persists and also the grazing effect of introduced wild herbivores. The national park is currently carrying out recovery plans for this and other rare endemic species (Palomares 2004). It has been described as the summit potential climatophilous vegetation of the island.

Canary cedar woodland is today a very diffuse community characterized by *Juniperus cedrus* ssp. *cedrus*. This rare species is more or less spread on the upper part of the pine forest belt and above it (Del Arco et al. 1999) mainly in rocky outcrops, in vegetation fragments that probably are relicts of ancient sparse woodland (Höllermann 1978). This probably had wider abundance and distribution in the past, and it was disturbed and destroyed by human activities (Francisco-Ortega et al. 2009; Rumeu et al. 2009). The typical accompanying species of the Canary cedar in the outcrops are pines and the rupicolous plants of the summit; apart from them the typical plants of the summit broom scrub are added. Because of that it is very difficult to characterize Canary cedar woodland except for the sporadic presence of Canary cedar (Höllermann 1978). This juniper woodland has been proposed as the summit potential edaphophilous-rupicolous vegetation of the island (Martin et al. 2007).

Rock communities (Soncho-Aeonion; Greenovion aureae)

Communities of high floristic diversity and endemicity are developed in the cliffs, deep precipices, and many near-vertical rocky walls, naked or with a thin soil layer. This floristic richness probably is due to the high slope which makes them inaccessible to herbivores (Garzón-Machado et al. 2010). They include several chasmophytic and comophytic communities in which two families are remarkable for their richness: Crassulaceae (mainly the genera *Aeonium* and *Greenovia*) and Asteraceae (genera *Sonchus, Senecio, Tolpis, Carlina*, etc.).

– Pine forest rock communities (*Soncho-Aeonion*): it constitutes the most thermic rock community group. *Aeonium canariense* is the most characteristic species at the lower altitudes of the park, on thermic areas belonging to infra- and thermomediterranean belts (Del Arco et al. 1999). Others endemic species such *Greenovia diplocycla, Sonchus hierrensis, Carlina falcata, Tolpis calderae, Lobularia canariensis* ssp. *palmensis, Sideritis barbellata,* etc., are common in the community.
– Summit rock communities (*Greenovion aureae*): it constitutes the colder rock community group. The endemic *Greenovia diplocycla* is the dominant species within the meso- and supramediterranean belts (Del Arco et al. 1999). Others endemic species such *Senecio palmensis, Micromeria lasiophylla* ssp. *palmensis, Tolpis* grex *lagopoda* and *Festuca agustinii* are common on the northern cliffs up to 2,400 m. At this altitude, some endemic species with conservation problems such *Pimpinella dendrotragium* and *Cerastium sventenii* grow.

Grasslands (Cenchro-Hyparrhenietum sinaicae)

The most characteristic grassland is *Cenchro-Hyparrhenietum sinaicae*, a mainly hemicryptophytic community characterized by *Cenchrus ciliaris, Hyparrhenia sinaica, Aristida adscensionis* ssp. *coerulescens* and *Bituminaria bituminosa*. Some thermic shrub species such *Lavandula canariensis*, *Kleinia neriifolia* and *Rubia fruticosa* are commonly spread in the grassland. The grassland develops in areas cleared for grazing, particularly on slopes with well-developed soil. It is also common at the edges of paths, making it a pathway to the introduction of invasive plant species such *Pennisetum setaceum* and *Opuntia tomentosa* (Pérez-de-Paz et al. 1999).

Other plant communities

Three types of pine forest were not recognized by the classification analysis:

– Humid pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *ericetosum arboreae*), developed in slopes and ravines facing northeast where atmospheric and soil humidity is high due to northerly aspect and frequent presence of convective clouds (Del Arco et al. 2006). It includes some characteristic cold and drought tolerant species belonging to evergreen laurel forest, such *Morella faya, Erica arborea* and *Phyllis nobla*. *Persea indica*, representative of humid evergreen laurel forest, can occasionally grow in some ravines.
  This forest has a good representation on the cloudy windward slopes of La Palma, above evergreen laurel forest, outside Caldera de Taburiente. Although *Erica arborea* and *Morella faya* are typical elements of this type of pine forest and they are present in the sampling plots, their presences have not been enough to generate a statistically representative group. In Caldera, "humid pine forest" is poorly represented and in a fragmentary way and it could be the cause. In general, a factor influencing the growing of this community is the presence of clouds, which happens in their stands. Covered in floristic background, cloud factor, and general distributions in the island, we have decided to consider this unit in the map.

- Pine forest with summit broom (*Loto hillebrandii-Pinetum canariensis* subass. *adenocarpetosum spatioidis*). It is a small and sparse community in contact with the summit scrub, where mainly *Adenocarpus viscosus* subsp. *spartioides* has a significant presence in the undergrowth (Del Arco et al. 2006). It has scarce presence within the park, and is very well showed at the highest altitudes of the pine forest outside Caldera de Taburiente.
- Pine forest with Canary cedar (*Loto hillebrandii-Pinetum canariensis* subass. *juniperetosum cedri*). At about 1,600 m up to 2,000 m a.s.l., in the inner cliffs of Caldera is more and more frequent the presence of *Juniperus cedrus* ssp. *cedrus* together with *Pinus canariensis* (Del Arco et al. 1999). This could be interpreted as the contact between pine forest and possible primitive summit cedar woodland as explained above.
  The samples of "pine forest with summit broom" and "pine forest with Canary cedar" appear spread within "summit broom scrub and Canary cedar woodland fragments" and "summit rock communities". This could be derived from an almost similar floristic composition and scarce presence of pine and cedar in the sampling plots due to steepness or disturbance as it was already described which results in a low weight of these species in the analysis. Despite this, we have considered convenient to map both units. "Pine forest with summit broom" as it has good presence outside the park (Del Arco et al. 2006), and "pine forest with Canary cedar" mainly based in the chorological maps of *J. cedrus* ssp. *cedrus*.
- Alluvial *Rumex lunaria* community, and *Artemisio-Rumicetum lunariae*. A special pioneer species-poor community characterized by *Rumex lunaria* settles on holocene alluvial soils at the main ravine head of Caldera. It shares territory with the substitutional community *Artemisio-Rumicetum lunariae*. This community was identified through aerial photographs and field exploration.

Rural area

Only a small portion of Caldera is considered rural area. It corresponds to some culture lands and houses of owners of Caldera. Rural area was identified through aerial photographs.

Vegetation map

The national park occupies 4,690 ha according to the latest law (Gobierno de España 1981). However, the current analysis using GIS techniques shows that the real area is 4,379 ha. About half of it, is occupied by "typical pine forest", followed by the other types: "pine forest with Canary cedar" and "thermophilous pine forest", with 13 and 11% of total area, respectively (Table 6). "Summit broom scrub and Canary cedar woodland fragments" also has a large area, occupying about 11% of total area. "Pine rock communities" and "summit rock communities", occupying 1% ha and 10% respectively, are fragmented into many small patches that correspond to the cliffs and vertical rocky walls. A 3D analysis probably would reveal more area of these. The others plant communities cover a smaller area (Table 6). The actual vegetation map is showed in Fig. 5.

Conclusions

Aerial photographs analysis and the methodology of Braun-Blanquet combined with the latest classification and ordination techniques (Clustering, ANOSIM, SIMPER, DCA and

Table 6 Surface analysis of each natural vegetation units obtained using patch analyst extension

Natural vegetation units	Area (ha)	Number of patches	Mean patch area (ha)	% of total
Typical pine forest	2122.34	23	92.28	48
Pine forest with Canary cedar	559.13	55	10.17	13
Thermophilous pine forest	500.79	15	33.39	11
Pine forest rock communities	50.85	68	0.75	1
Summit rock communities	446.60	119	3.75	10
Summit broom scrub and Canary cedar woodland fragments	467.68	8	58.46	11
Canary willow and hydrophytic communities	81.56	17	4.80	2
Pine forest with summit broom	68.36	12	5.70	2
Humid pine forest	53.59	3	17.86	1
Rumex lunaria community	11.91	1	11.91	0.3
Grasslands	4.53	1	4.53	0.1
Rural area	11.72	5	2.34	0.3
Total	4379			

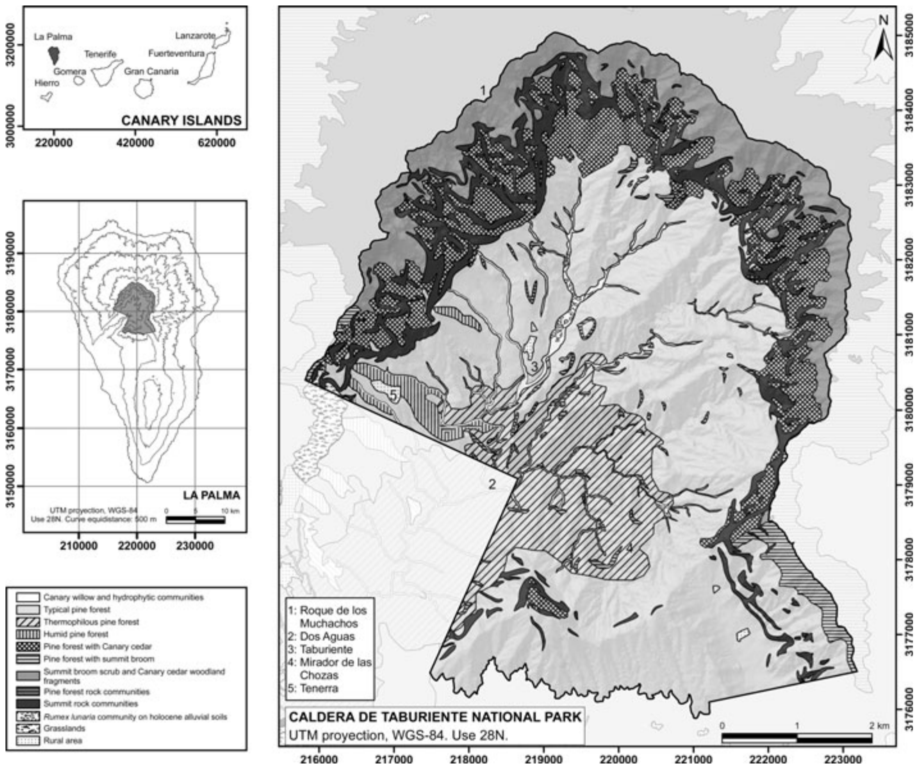

Fig. 5 Actual vegetation map of Caldera de Taburiente national park (La Palma. Canary Islands)

CCA) is a good and powerful tool for identification and description of major plant communities and the environmental factors affecting them.

This tool set has proven useful for characterizing and checking the identity of the vegetation units of Caldera de Taburiente national park; also for linking them with environmental variables, for a quantitative (area in ha) and qualitative (floristic composition and character species) evaluation, and for mapping. DEM and bioclimatic maps were the main auxiliary layers along the mapping process, as they consider the most influential variables detected by CCA analysis (altitude, slope and ombrotype). Automatic selection of slope ranks from DEM allowed a good location of rock community stands.

These tools can be also useful for the characterization of the habitats where threatened species grow and to develop effective strategies for their conservation. Besides, floristic composition allows to establish in which vegetation units the introduced and invasive species have preferential development, and to be prepared against future expansion. It can also help to eradicate current invasive plant species within the national park, such *Ageratina adenophora* or *Pennisetum setaceum* (nowadays in the borderline of the park), which is a priority of the policy of the park (Gobierno de Canarias 2005).

These tools, together with GIS techniques for mapping vegetation, could be applied to other protected areas in the Canary Islands, especially for planning, management and conservation purposes (Dias and Melo 2010), and to determine the effectiveness of the protected area network for conserving diversity (Reyes-Betancort et al. 2008). In addition, since a large part of this network corresponds to highest parts of the islands, these techniques can be good to study and preserve others communities (e.g. laurisilva, thermo-sclerophyllous woodland, and *Euphorbia* scrub) in unprotected zones, with a high degree of disturbance (Del Arco et al. 2010).

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Appendix

See Table 7 for Appendix.

Table 7 Appendix. Synthetic table of the natural vegetation units. Presence classes according to Braun-Blanquet (1979), and Alcaraz (1999)

	Natural Vegetation Units				
	A	C	E	D	B
Canary pine forest of La Palma (A) (Loto hillebrandii-Pinetum canariensis)					
Typical pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *cistetosum symphytifolii*)					
Pinus canariensis (A)	V	II	*2*	I	III
Pinus canariensis (B)	V		*2*		r
Cistus symphytifolius ssp. *symphytifolius*	IV	r		+	II
Lotus hillebrandii	II				
Chamaecytisus proliferus var. *calderae*	I	+		II	II

Table 7 continued

	Natural Vegetation Units				
	A	C	E	D	B
Bystropogon origanifolius ssp. *palmensis*	I	+			I
Chamaecytisus proliferus var. *palmensis*	I			+	r
Humid pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *ericetosum arboreae*)					
Erica arborea	+				+
Persea indica	r			+	
Thermophilous pine forest (*Loto hillebrandii-Pinetum canariensis* subass. *spartocytisetosum filipis* nom. prov.)					
Spartocytisus filipes	I		1		I
Kleinia neriifolia	+		3		r
Rubia fruticosa	+		1		r
Globularia salicina	r				+
Cistus monspeliensis	r				
Euphorbia lamarckii	r				
Juniperus turbinata ssp. *canariensis*	r				
Periploca laevigata	r				
Summit broom scrub (C) (*Genisto benehoavensis-Adenocarpetum spartioidis*) and Canary cedar woodland fragments (*Adenocarpo spartioidis-Juniperetum cedri*)					
Adenocarpus viscosus ssp. *spartioides*	r	V			I
Juniperus cedrus ssp. *cedrus*	r	IV			II
Descurainia gilva	r	II			I
Genista benehoavensis		II			
Lactuca palmensis		II			
Erysimum scoparium	r	I			II
Arrhenatherum calderae		I			r
Echium wildpretii ssp. *trichosiphon*		I			+
Plantago webbii		I			r
Poa cf. *leptoclados*		I			r
Pterocephalus porphyranthus		I			+
Spartocytisus supranubius	r	+	1		r
Viola palmensis	r	+			r
Echium gentianoides		r			+
Grasslands (E) (*Cenchro-Hyparrhenietum sinaicae*)					
Hyparrhenia sinaica	II		4		I
Aristida adscensionis ssp. *coerulescens*	r		2		
Cenchrus ciliaris			1		
Canary willow (*Rubo-Salicetum canariensis*) and hydrophytic communities (*Molinio-Holoschoenion vulgaris; Mentho-Juncion inflexi*) (D)					
Ageratina adenophora	I			V	II
Salix canariensis				IV	
Scirpus holoschoenus ssp. *globiferus*				IV	+
Equisetum ramosissimum				IV	
Morella faya	r			II	r
Pteridium aquilinum	I			II	

Table 7 continued

	Natural Vegetation Units				
	A	C	E	D	B
Mentha longifolia				II	
Rorippa nasturtium-aquaticum				I	
Dittrichia viscosa			1	+	
Veronica anagallis-aquatica				+	
Rock communities (B) (*Soncho-Aeonion; Greenovion aureae*)					
Greenovia diplocycla	r				V
Senecio palmensis	r				IV
Pimpinella dendrotragium	r	+			III
Tolpis calderae	r	I			III
Aeonium canariense	r				III
Carlina falcata	r				III
Sonchus hierrensis var. *benehoavensis*	I				III
Lobularia canariensis ssp. *palmensis*					III
Aeonium davidbramwellii	r				II
Argyranthemum haouarytheum	r				II
Teline stenopetala ssp. *sericea*	r	r		+	II
Festuca agustinii	r	I			II
Micromeria lasiophylla ssp. *palmensis*	r	II			II
Echium webbii	r				II
Paronychia canariensis	+				II
Sideritis barbellata	r				II
Silene italica	r				II
Tolpis grex *lagopoda*					II
Andryala webbii	+			+	I
Phagnalon saxatile	+		2		I
Phyllis nobla	r			+	I
Asplenium onopteris	r				I
Davallia canariensis	r				I
Polypodium macaronesicum	r				I
Tinguarra cervariaefolia	r				I
Gonospermum canariense	r			+	+
Rosa canina		r		+	+
Cerastium sventenii		r			+
Pericallis papyracea	r				+
Ceropegia dichotoma ssp. *dichotoma*	r				r
Dactylis smithii	r				r
Companion species					
Hypericum grandifolium	r	I		II	+
Rumex lunaria	+		2	+	II
Lavandula canariensis	+		3		II
Micromeria herpyllomorpha	I		2		III
Asphodelus ramosus ssp. *distalis*	+				+

Table 7 continued

	Natural Vegetation Units				
	A	C	E	D	B
Bromus tectorum		I			r
Chenopodium ambrosioides				+	r
Hypericum canariensis		+			II
Hypochoeris cf. *glabra*				+	r
Opuntia tomentosa	r		1		
Vulpia myuros		r			r

Other taxa. In *A Adenocarpus foliolosus × viscosus (r), Cicer canariense (r), Polycarpaea aristata (r), Todaroa aurea* ssp. *suaveolens (r); in C Lactuca viminea (+), Nepeta teydea (r); in D Adiantum capillus-veneris (II), Pteris vittata (II), Brachypodium sylvaticum (I), Epilobium hirsutum (I), Polypogon viridis (I), Arundo donax (+), Pennisetum setaceum (+), Ricinus communis (+); in B Arabis caucasica (II), Descurainia millefolia (II), Reichardia ligulata (II), Polycarpaea smithii (I), Aeonium spathulatum (I), Notholaena marantae (I), Todaroa montana (I), Adiantum reniforme (+), Aichryson laxum (+), Asplenium trichomanes (+), Bupleurum salicifolium* ssp. *aciphyllum (+), Aeonium arboreum (r), Aichryson* cf. *palmense (r), Asplenium septentrionale (r), Bencomia caudata (r), Ceterach aureum (r), Cheirolophus arboreus (r), Convolvulus floridus (r), Cosentinia vellea ssp. bivalens (r), Hypericum grex grandifolium (r), Monanthes polyphylla (r), Opuntia maxima (r), Pancratium canariense (r), Rumex maderensis (r), Sorbus aria (r), Umbilicus gaditanus (r), Umbilicus heylandianus (r)*

References

Acebes JR, León MC, Rodríguez ML, Del Arco MJ, García-Gallo A, Pérez-de-Paz PL, Rodríguez-Delgado O, Martín VE, Wildpret W (2010) Pteridophyta, Spermatophyta. In: Arechavaleta M, Rodríguez S, Zurita N, García A (eds) Lista de especies silvestres de Canarias. Hongos plantas y animales terrestres. Gobierno de Canarias, Tenerife, pp 119–172

Afonso L (ed) (1988) Geografía de Canarias 2nd edn. Interinsular Canaria, SC de Tenerife

Alcaraz FJ (1999) Manual de Teoría y Práctica de Geobotánica. ICE, Universidad de Murcia, Spain

Bartolomé C, Álvarez J, Vaquero J, Costa M, Casermeiro MA, Giraldo J, Zamora J (2005) Los tipos de hábitat de interés comunitario de España. Guía básica. Ministerio de Medio Ambiente, Madrid

Biondi E, Feoli F, Zuccarello V (2004) Modelling environmental responses of plant associations: a review of some critical concepts in vegetation study. Crit Rev Plant Sci 23(2):149–156

Biondi E, Casavecchia S, Pesaro S (2011) Phytosociological synreleves plant and landscape mapping: from theory to practice. Plant Biosys 145(2):261–273

Blasi C, Capotorti G, Frondoni R (2005) Defining and mapping typological models at the landscape scale. Plant Biosys 139(2):155–163

Braun-Blanquet J (1979) Fitosociología. Bases para el Estudio de las Comunidades Vegetales. Blume, Madrid

Carracedo JC (1980) Geología. Atlas básico de Canarias. Interinsular Canaria, Barcelona, pp 17–27

Carracedo JC, Badiola R, Guillou H, de-la-Nuez H, Pérez-Torrado FJ (2001) Geology and volcanology of La Palma and El Hierro, western Canaries. Estud Geol 57:175–273

Ceballos L, Ortuño F (1976) Estudio sobre la Vegetación y la Flora Forestal de las Canarias occidentales. Reedición corregida. Excmo. Cabildo Insular de Tenerife, Santa Cruz de Tenerife

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143

Gobierno de Canarias (2000) Decreto 1/2000, de 8 de mayo, por el que se aprueba el Texto Refundido de las Leyes de Ordenación del Territorio de Canarias y de Espacios Naturales de Canarias. Boletín Oficial de Canarias 60:5989–6307

Gobierno de Canarias (2005) Decreto 27/2005, de 1 de marzo, por el que se aprueba el Plan Rector de Uso y Gestión del Parque Nacional de la Caldera de Taburiente. Boletín Oficial de Canarias 52:4106–4139

Gobierno de Canarias (2011) Decreto 70/2011, de 11 de marzo, por el que se crea la Red Canaria de Parques Nacionales. Boletín Oficial de Canarias 59:6094–6100
Gobierno de España (1981) Ley 4/1981 de 25 de de reclasificación del Parque Nacional de la Caldera de Taburiente. Boletín Oficial del Estado 90:8153–8155
Del Arco MJ (1982) Sobre la presencia de Genista L en la isla de La Palma (I. Canarias): Genista benehoavensis (Bolle ex Svent.) M. del Arco, comb. nov. (Fabaceae-Genisteae). Vieraea 11:267–282
Del Arco MJ, Acebes JR, Pérez-de-Paz PL, Marrero MC (1999) Bioclimatology and climatophilous vegetation of Hierro (part 2) and La Palma (Canary Islands). Phytocoenologia 29(2):253–290
Del Arco MJ, Wildpret W, Pérez-de-Paz PL, Rodríguez-Delgado O, Acebes JR, García-Gallo A, Martín VE, Reyes-Betancort JA, Salas M, Bermejo JA, González R, Cabrera MV, García S (2006) Mapa de Vegetación de Canarias. GRAFCAN, Santa Cruz de Tenerife
Del Arco MJ, Garzón-Machado V, Pérez-de-Paz PL (2009) Estudio bioclimático del Parque Nacional de la Caldera de Taburiente. La Palma. Islas Canarias. Poster presented at the XXII Jornadas Internacionales de Fitosociología: Bioclima Mediterráneo y Vegetación, University of Alicante, pp 23–25
Del Arco MJ, González R, Garzón-Machado V, Pizarro B (2010) Actual and potential natural vegetation on the Canary Islands and its conservation status. Biodivers Conserv 19:3089–3140
Dias E, Melo C (2010) Factors influencing the distribution of Azorean mountain vegetation: implications for nature conservation. Biodivers Conserv 19:3311–3326
Elkie PC, Rempel RS, Carr AP (1999) Patch analyst user's manual, a tool for quantifying landscape structure. Northeast Science & Technology, Ontario
Environmental Systems Research Institute (2006) ESRI ArcGIS 9.2, Environmental Systems Research Institute Ltd., USA
Faber-Langendoen D, Aaseng N, Hop K, Lew-Smith M, Drake J (2007) Vegetation classification, mapping, and monitoring at Voyageurs national park, Minnesota: an application of the U.S. national vegetation classification. Appl Veg Sci 10:361–374
Francisco-Ortega J, Santos-Guerra A, Bacallado JJ (2009) Canary Islands, Biology. In: Gillespie RG, Clague DA (eds) Encyclopedia of Islands. University of California Press, Berkeley, pp 127–133
Franklin J (1995) Predictive vegetation mapping: geographic modelling of biospatial patterns in relation to environmental gradients. Prog Phys Geogr 19(4):474–499
Garzón-Machado V, González-Mancebo JM, Palomares-Martínez A, Acevedo-Rodríguez A, Fernández-Palacios JM, Del Arco MJ, Pérez-de-Paz PL (2010) Strong negative effect of alien herbivores on endemic legumes of the Canary pine forest. Biol Conserv 143:2685–2694
GRAFCAN (2009) Cartográfica de Canarias S.A. http://www.grafcan.com. Cited 19 Sep 2010
Hoagland B (2000) The vegetation of Oklahoma: a classification for landscape mapping and conservation planning. Southw Natural 45(4):385–420
Höllermann PW (1978) Geoecological aspects of the upper timberline in Tenerife, Canary Islands. Arctic Alpine Res 10:365–382
Lepš J, Šmilauer P (2003) Multivariate analysis of ecological data using canoco. University Press, Cambridge
Martín VE, Wildpret W, Del Arco MJ, Pérez-de-Paz PL, Hernández B, Rodríguez-Delgado O, Acebes JR, Gallo AG (2007) Estudio Bioclimático y Fitocenótico comparativo de la alta cumbre canaria: Tenerife-La Palma, Islas Canarias. Phytocoenologia 37:663–697
Médail F, Quézel P (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Ann Missouri Bot Gard 84:112–127
Millar C (1996) Impact of the Eocene on the evolution of Pinus L. Ann Missouri Bot Gard 80:471–498
Moreno JC (ed) (2008) Lista Roja 2008 de la flora vascular española. Dirección General de Medio Natural y Política Forestal, Madrid
Mwavu EN, Witkowski ETF, Mucina L (2008) Plant communities of a semi-deciduous tropical rainforest in north-western Uganda: role of soil and anthropogenic factors. Phytocoenologia 38(3):193–211
Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858
Palomares A (2004) Flora Amenazada. In: García Canseco V (Coord.) Parque Nacional de la Caldera de Taburiente. Canseco editores. pp 129–142
Pérez-de-Paz PL, Del Arco MJ, Rodríguez-Delgado O, Acebes JR, Marrero MV, Wildpret W (1994) Atlas Cartográfico de los pinares canarios: III. La Palma. Viceconsejería de Medio Ambiente. Gobierno de Canarias La Palma, Santa Cruz de Tenerife
Pérez-de-Paz PL, García-Gallo A, Heene A (1999) Control y erradicación del "rabo-gato" (Pennisetum setaceum) en la isla de La Palma. Excmo. Cabildo Insular de La Palma, Sta. Cruz de la Palma
Reyes-Betancort A, Santos A, Rosana I, Humphries CJ, Carine MA (2008) Diversity, rarity and the evolution and conservation of the Canary Islands endemic flora. An Jard Bot Madrid 65(1):25–45

Rivas-Martínez S (1997) Syntaxonomical synopsis of the North American natural potential vegetation communities I. Itinera Geobotanica 10:5–148 (Bioclimatic classification system of the World: 10–11)
Rivas-Martínez S (2007) Mapa de series, geoseries y geopermaseries de vegetación de España. Memoria del Mapa de Vegetación de España. Parte I. Itinera Geobotanica 17:5–436
Rivas-Martínez S, Penas A (2003) Atlas y Manual de los Hábitat de España. Dirección General de Conservación de la Naturaleza. Ministerio de Medio Ambiente, Madrid
Rivas-Martínez S, Fernández-González F, Loidi J, Lousa M, Penas A (2001) Syntaxonomical checklist of vascular plant communities of Spain and Portugal to association level. Itinera Geobotanica 14:5–341
Rivas-Martínez S, Díaz TE, Fernández González F, Izco J, Loidi J, Lousa M, Penas A (2002) Vascular plant communities of Spain and Portugal. Addenda to the syntaxonomical checklist of 2001. Itinera Geobotanica 15 (1):1–432, 15(2):433–922
Rumeu B, Padilla DP, Nogales M (2009) The key role of a Ring Ouzel Turdus torquatus wintering population in seed dispersal of the endangered endemic Juniperus cedrus in an insular environment. Acta Ornithologica 44(2):199–204
Santos A (1983) Vegetación y Flora de La Palma. Editorial Interinsular Canaria, S.A. Santa Cruz de Tenerife
Santos A (2004) Flora y Vegetación. In: García-Canseco V (ed) Parque Nacional de la Caldera de Taburiente. Canseco editores. pp 69–104
Sanz-Elorza M, Dana-Sánchez ED, Sobrino-Vesperinas E (eds) (2004) Atlas de las Plantas Alóctonas Invasoras en España. Dirección General para la Biodiversidad, Madrid
Seaby R, Henderson P, Prendergast J (2004) Community Analysis Package, version 3.11. Searching for structure in community data. PISCES Conservation Ltd., Lymington, UK
Ter Braak CFJ, Smilauer P (1998) CANOCO: software for canonical community ordination, version 4. Wageningen, Holanda
Van-der-Maarel E (2005) Vegetation ecology–an overview. In: Van-der-Maarel E (ed) Vegetation ecology. Blackwell, Oxford, UK, pp 1–51
Vera A, Samarín C, Viera G, Delgado G (2008) Natura 2000 en Macaronesia. Guía Técnica. Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias