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Phytogeographic characterization of Gran Canaria Island (Canary Islands, Spain)

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Abstract: Salas-Pascual, M., Quintana-Vega, G. & Fernández-Negrín, E. *Phytogeographic characterization of Gran Canaria Island (Canary Islands, Spain). Lazaroa 36: 9-20 (2015).*

Studies on the flora and fauna of the Canary Islands show that this Archipelago is one of the planet's diversity hot spots. However, an analysis of the differences in the phytogeographic characteristics of each of the islands that make up this Archipelago is lacking. This article focuses on the phytogeographic characterization of the island of Gran Canaria. This island exhibits geological and climatic characteristics resulting in a rich vascular flora, including endemic species and genera that are significantly different from the other islands of the Archipelago. These differences are verified through statistical analysis of the existing similarity between the floras of the members of the Canary Islands. This study also analyses the subdivision of Gran Canaria Island, indicating that there are three well-differentiated areas on the island itself. Finally, this study argues that these areas, themselves, should be considered biogeographic sectors.

Keywords: Phytogeography, Canary Islands, Gran Canaria, biogeographic typology.

Resumen: Salas-Pascual, M., Quintana-Vega, G. & Fernández-Negrín, E. Caracterización fitogeográfica de la isla de Gran Canaria (Islas Canarias, España). *Lazaroa 36: 9-20 (2015).*

El estudio de la flora y fauna de las Islas Canarias ha permitido considerar este Archipiélago como uno de los puntos calientes de diversidad del Planeta. Sin embargo, poco se han analizado las características fitogeográficas diferenciales de cada una de las islas que configuran esta región insular. En el presente artículo se intenta una caracterización fitogeográfica de la isla de Gran Canaria. Esta isla presenta aspectos geológicos y climáticos que le hacen ser poseedora de una rica flora vascular con géneros y especies endémicas, lo que le confiere diferencias significativas con el resto de islas del Archipiélago. Estas diferencias se verifican tras el análisis de la semejanza estadística existente entre las floras de las diferentes islas que configuran las Canarias. A su vez, se analiza la sectorización de la isla de Gran Canaria, concluyéndose en la presencia de tres zonas bien diferenciadas en la propia isla, discutiéndose finalmente su posible consideración como sectores biogeográficos, propiamente dichos.

Palabras clave: Fitogeografía, Islas Canarias, Gran Canaria, tipología biogeográfica.

INTRODUCTION

While the Canary Islands are an undeniable biogeographic unit from a floristic point of view, it is clear that there are differences among the various islands of the Archipelago. These differences are sufficient to merit an analysis of the degree of floristic similarity between the islands as well as between the different natural regions of Gran Canaria Island itself. This study aims to assess the botanical affinities of the islands composing the Canary Archipelago, seeking affinities and dissimilarities that will contribute to the phytogeographic and biogeographic typology of the Canary Islands. A further aim of this work is to conduct a sectoral floristic

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analysis of Gran Canaria Island, with the purpose of analysing the presence or absence of areas within the island that present sufficient individual characteristics to be interpreted as phytogeographic units.

Each of the Canary Islands presents notable differences in terms of its dimensions, geographic location, geological age and climate, allowing different biota to be noted on each island. Table 1 highlights the differences in the various geographical and ecological characteristics of each island.

Table 1
Geographic characteristics of the Canary Islands.

Islands	Surface area (km^2)	Elevation (m.a.s.l.)	Distance to Africa (km)	Maximum age (Millions of years)
Tenerife	2,034	3,718	284	11.5
Fuerteventura	1,655	807	95	20.5
Gran Canaria	1,560	1,948	196	14.5
Lanzarote	807	670	125	15.5
La Palma	708	2,426	416	1.7
La Gomera	370	1,487	333	12
El Hierro	269	1,501	383	1.1
Islas Canarias	7,447	3,718	95	20.5

Despite the Canary Islands being unanimously considered one of the areas with the greatest plant biodiversity on the planet, little research has focused on the possible floristic relationships that may exist between the islands of the Archipelago itself. Questions of a geographical and descriptive nature are easily analysable and have been addressed on multiple occasions (e.g., Fernández-Palacios & Whittaker, 2008: 382; Nicolás & *al*, 1998; Fernández-Palacios & Martín-Esquivel, 2001; Guerrero & *al*., 2005).

Traditionally, these differences have led to a separation of the Archipelago into two or three island biogeographic groups according to different authors. The broadest reported divisions are as follows:

- Eastern Canaries (Lanzarote and Fuerteventura) and Western Canaries (the remainder) (Rivas-Martínez & *al*., 2001 and 2007; De Nicolás & *al*., 1989)
- Eastern islands (Lanzarote and Fuerteventura), central islands (Gran Canaria, Tenerife and La Gomera) and western islands (La Palma and El Hierro) (Sanmartín & *al*., 2008)

Other divisions are not exclusively biogeographic but, rather, geographical or administrative. Thus, other classifications used in studies related to the flora and fauna of the Archipelago are as follows:

- Eastern (Lanzarote, Fuerteventura and Gran Canaria) and Western Canaries (Tenerife, La Gomera, La Palma and El Hierro) (Esteve, 1968).
- Eastern (Lanzarote and Fuerteventura), Central (Gran Canaria and Tenerife) and Western Canaries (La Gomera, La Palma and El Hierro) (Ibarrola, 1970: Blanco & González, 1992).

According to the most widely accepted biogeographic approaches (Meusel & Jaeger, 1989, Rivas-Martinez & *al*., 2001, Rivas-Martínez, 2007), the Canary Islands form part of the Holarctic Kingdom, Mediterranean region, Canaria sub-region. Within this sub-

region is the Canarian superprovince, which is divided into two provinces: Western Canaria (El Hierro, La Gomera, La Palma, Tenerife and Gran Canaria) and Eastern Canaria (Fuerteventura and Lanzarote). Within this division, every island represents a sector, except for Lanzarote, which is considered to be a district of the Lanzarote sector. The Lanzarote sector includes the Savage Islands and the Chinijo Archipelago, in addition to the aforementioned island of Lanzarote. Only Fuerteventura has two currently defined districts: Jandiense and Majorero.

As indicated in previous classifications, Gran Canaria Island appears to be most closely related to Tenerife and, to a lesser extent, to the rest of the western islands. Only in administrative divisions is Gran Canaria Island related to the Eastern islands of Fuerteventura and Lanzarote, as they are part of the same administrative province as Las Palmas. This disparity of groupings is largely due to the subjectivity of the methods used in most of the studies addressing this issue.

The botanical differences between Gran Canaria and the rest of the Archipelago have been indicated on other occasions. The palm botanist A. Santos explains it perfectly when he writes

"Dentro de la provincia florística occidental, Gran Canaria, con una riqueza de endemismos de 84 especies, muestra algunas particularidades propias e independientes del resto de las islas…..La presencia en Gran Canaria de un importante conjunto endémico con una personalidad propia (*Dracaena tamaranae*, *Globularia ascanii*, *G. sarcophylla*, *Scrophularia calliantha* o *Tanacetum* spp.) hace pensar en algunos procesos de colonización o evolutivos independientes del resto de las islas, o una mejor conservación debido a la antigüedad y estabilidad geológica de, al menos, una parte de la isla." (Santos, 2001: 190)

["The western floristic province, Gran Canaria, with a richness of 84 endemic species, has some of its own peculiarities that are independent from the rest of the islands …..The presence of a significant endemic array with its own personality on Gran Canaria (*Dracaena tamaranae*, *Globularia ascanii*, *G. sarcophylla*, *Scrophularia calliantha* or *Tanacetum* spp.) suggests colonization or evolutionary processes that are independent from the other islands, or better conservation due to the geological age and stability of at least part of the island."]

Outside of phytosociological studies and the traditional biogeographic divisions mentioned above, the only work that has sought to separate Gran Canaria into different biogeographic zones is that of the geographers A. Santana and E. Pérez-Chacón (1991), who considered three biogeographic units: the trade wind-canarian, xero-canarian and summit zones. The first zone includes the N and NE, from Agaete Canyon to Guayadeque; the second presents the same boundaries, with extension along the south and southwest slopes; finally, the summit zone includes the central cap of the island, from an elevation of approximately 1,200 m to a maximum height of 1,994 m.a.s.l in the Pozo de las Nieves. In his thesis published in 2001, Antonio Santana divides these three «large units», as he calls them, into several regions separated by the amount of «natural resources» they harbour. These «natural resources» are considered to be vegetation, soil, relief, climate, and agricultural resources. The separation of these zones and regions combines ecological and human criteria and, thus, is of little use for the purposes of this study.

In summary, this study aims to expand existing knowledge of the phytogeographic relationships between the various islands of the Canary Archipelago, using the flora of each island to reveal these affinities. This analysis will ultimately focus on Gran Canaria Island, given its particular ecological characteristics and uniqueness compared with the rest of the Archipelago.

MATERIALS AND METHODS

Because the purpose of this study was to compare the floristic catalogues of each of the Canary Islands, it was based on the work published by Acebes & *al*. (2009), which is considered the "official" list of terrestrial vascular plant species. This list has undergone several revisions in recent

years, and the most recent edition is the most complete. The applied method was hierarchical ascendant classification (HAC) based on the Jaccard similarity index. The list used in this work classifies each species as either native or introduced, and it indicates the island in the Archipelago upon which it occurs. For this analysis, introduced species were excluded because they do not provide biogeographic information, as they are exclusively related to varying degrees of human activity and are associated with other areas of the planet. An example of this situation comes from the large number of introduced species from the Americas on the Canary Islands, which is explained by the significant relationship that these islands have had with the New World since its discovery, rather than by any climatic, edaphic, or other similarity.

To calculate the degree of proximity of the island floras, a mathematical tool known as the Jaccard index was used, providing a quantitative view of their similarity.

The Jaccard index (I_j) measures the similarity, dissimilarity, or distance between two samples. The equation for calculating the index is as follows:

$$I_j: c/(a+b+c)$$

where:

a is the number of taxa present on island or territory A that are not present on island or territory B.

b is the number of taxa present on another island or territory (B) that are not present on island or territory A.

c is the number of taxa present on both islands or territories

The similarity index makes it possible to perform an HAC, which provides a meaningful analysis of the relationships between the flora of two islands or territories. The HAC was carried out using the XLSTAT data analysis program, version 2015.2.02, which works in an Excel environment.

This methodology has been used by other authors to configure floristic sectors in other regions near the Canary Islands (Galán de Mera & *al*., 2003, for the south-western areas of the Iberian Peninsula and northwest of Morocco) and even when searching for floristic relationships between the Macaronesian Archipelagos (De Nicolás & *al*., 1989). This most recent attempt was based on the list of plants from Macaronesia compiled by Hansen and Sunding in 1985. This check-list did not distinguish between introduced and native species nor did it indicate which species were endemic, and their results were therefore not highly significant. As mentioned previously, including species introduced by humans, which are more closely related to historical or social aspects than to biogeographical characteristics, distorts an analysis that would allow us to determine the degree of phytogeographic affinity between two territories. Biogeographic modelling studies take the same considerations into account when calculating the species richness of native species on oceanic islands (Whittaker & *al*., 2008; Steinbauer & *al*., 2013).

Because the endemic component of the flora presents the highest biogeographic value (Fernández-Palacios & Dias, 2001; Ferreras & Fidalgo, 1991; Moreno-Saiz & Sainz-Ollero, 1997), using species that exhibit such characteristics is essential for understanding the phytogeographic relationships that exist between the various Canary Islands and even more so for evaluating the subdivisions of Gran Canaria island, which are the two objectives of this study.

The second analysis aimed to subdivide Gran Canaria, confirming the presence or absence of notable differences between the different quadrants that geographically separate Gran Canaria Island.

The most common division of the island is carried out by establishing a diagonal from the NW end, at Punta de Sardina del Norte, to Arinaga Point at the SE end. Thus, two well-differentiated geological and climatic zones are obtained. The Northeastern half, known as Neocanaria or Neotamaran, is geologically younger and is influenced by trade winds, while the Southwestern half, known as Tamarán, Paleocanaria or Paleotamaran, is much older

and is not influenced by trade winds (Hausen, 1962; Salas & García, 2003; Fernández-Palacios, 2009). These two primary units are separated according to a lithochronological axis proposed by the makers of the National Geological Map (MAGNA-I.T.G.E., 1990). To increase the number of proposed sectors in the analysis, these two regions were subdivided by drawing another diagonal perpendicular to the first, from the NE end, at La Isleta, to Punta de Veneguera at the SW end (Figure 1). Each of the quadrants presents different characteristics, as quadrant W (4) is sometimes influenced by trade winds when they overflow through the central peaks, and its geological age is greater than that of quadrant S (3). In the north, quadrant E (2) is drier than quadrant N (1), being protected from storms from the west and winds from the north, in addition to being strongly influenced by trade winds in this area when they blow with great strength, which increases the evapotranspiration of vegetation.

The geological information used in the present study for Gran Canaria Island was based on Fuster & *al*. (1968), Hausen (1962), and Schmincke & Sumita (1998) as well as 1:25,000 geological maps and annotations edited by the Geomining Technological Institute of Spain (Instituto Geominero de España - I.T.G.E) in 1990.

Bioclimatic and climatic features were based on data reported in the work conducted by Del Arco & *al.* (2002) in addition to data from several manuals on the climate of the Canary Islands, especially those by Martín-Ruiz (1994) and Marzol (2001).

The distribution of endemic species on Gran Canaria island was gathered from countless sources of documentation and databases, including ATLANTIS 3.1, the Canary Islands biodiversity data bank maintained by the Government of the Canary Islands, and the web page http://www.jardincanario.org/web/viera-y-clavijo/busqueda-de-la-flora-de-gran-canaria,

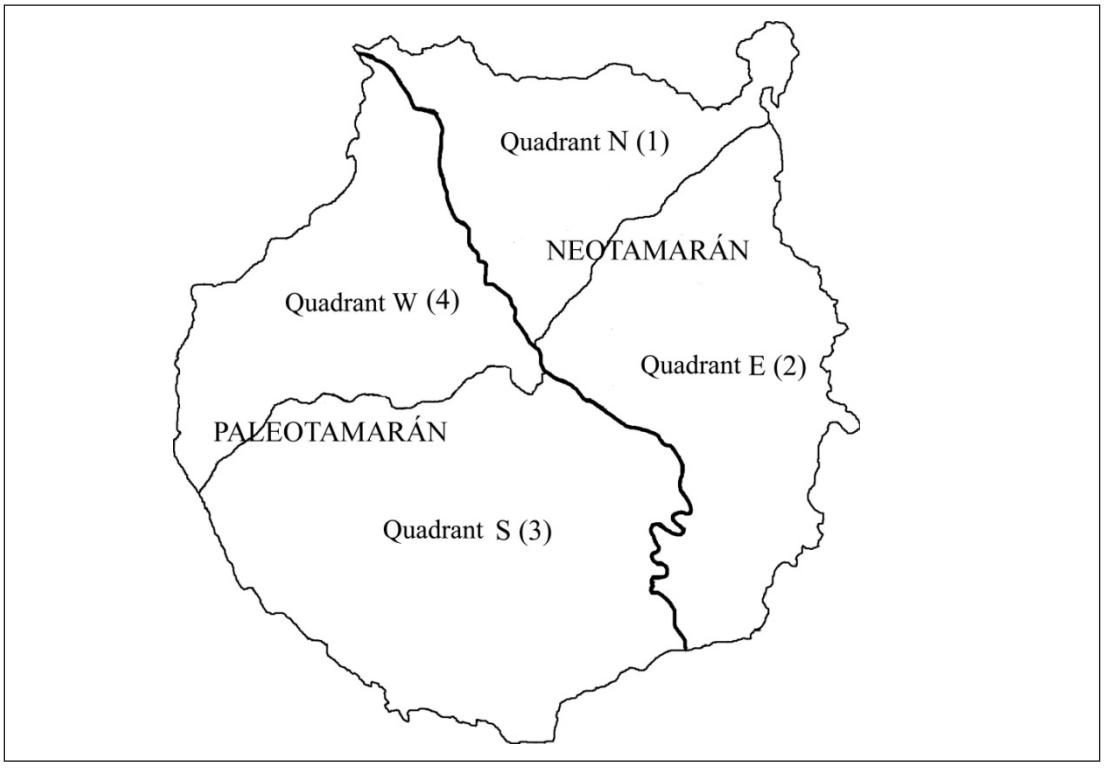

Figure 1. — Zone divisions of Gran Canaria.

administered by the staff of the Viera and Clavijo Botanical Garden, including 1,437 references to the flora of Gran Canaria.

RESULTS

Characterization of Gran Canaria Island compared with the rest of the Archipelago.

The number of species and subspecies present on each island of the Archipelago is shown in Table 2. The table also quantifies the native, endemic, and exclusive endemic species and subspecies.

A presence-absence table was produced for all of these species and subspecies, indicating presence with the value 1 and absence with 0. It was not possible to present the entire table here due to its dimensions, and only the first 10 cases are shown as an example of how Table 3 was produced.

Similarity matrices and the corresponding dendrograms are shown in Table 4 and Figure 2.

Table 2
Number of species and subspecies on each of the Canary Islands, according to its typology

Species and subspecies	H	P	G	T	C	F	L	Total
Total	719	930	928	1,519	1,338	766	724	2,233
Native	551	661	676	1,008	871	561	541	1,516
Endemic	138	195	204	339	242	84	79	643
Exclusive endemic	25	43	56	133	107	12	15	390

Table 3
First 10 examples of the table used for the phytogeographic characterization of the Canary Islands
(N=native; E=endemic; Ex=exclusively endemic to one island)

Taxon	Category	H	P	G	T	C	F	L
Aaronsohnia pubescens ssp. *maroccana*	N	0	0	0	0	0	1	1
Adenocarpus foliolosus	E	1	1	1	1	1	0	0
Adenocarpus ombriosus	Ex	1	0	0	0	0	0	0
Adenocarpus viscosus ssp. *spartioides*	Ex	0	1	0	0	0	0	0
Adenocarpus viscosus ssp. *viscosus*	E	0	0	1	1	0	0	0
Adiantum capillus-veneris	N	1	1	1	1	1	1	1
Adiantum reniforme	N	1	1	1	1	1	1	1
Aegilops geniculata	N	0	1	1	1	0	0	1
Aegilops lorentii	N	0	0	1	0	0	0	0
Aegilops neglecta	N	0	0	0	0	0	0	1

The obtained dendrograms show that if the native species of the Canarias are taken into account, three different classes are observed, consisting of the Eastern Islands (Fuerteventura and Lanzarote), the Central Islands (Tenerife and Gran Canaria), and the Western Islands (La Gomera, La Palma and El Hierro). In contrast, if only the species endemic to the Canary Islands are considered, while three classes are maintained, their composition is not, as one class clearly consists of the Eastern Canarias (Fuerteventura and Lanzarote), whereas another includes the islands of Tenerife, La Gomera, La Palma and El Hierro, and Gran Canaria forms its own disconnected class (see Figure 3). This classification is repeated if we use the 23

Table 4
Proximity matrices based on the Jaccard similarity index
a) Native or autochthonous species; b) endemic species

	H	P	G	T	C	F	L
H	1						
P	0.57	1					
G	0.57	0.57	1				
T	0.45	0.51	0.53	1			
C	0.46	0.48	0.51	0.57	1		
F	0.38	0.35	0.39	0.37	0.43	1	
L	0.36	0.33	0.35	0.36	0.40	0.70	1

a

	H	P	G	T	C	F	L
H	1						
P	0.40	1					
G	0.37	0.36	1				
T	0.26	0.34	0.33	1			
C	0.24	0.25	0.27	0.29	1		
F	0.17	0.14	0.15	0.12	0.15	1	
L	0.12	0.11	0.11	0.10	0.11	0.53	1

b

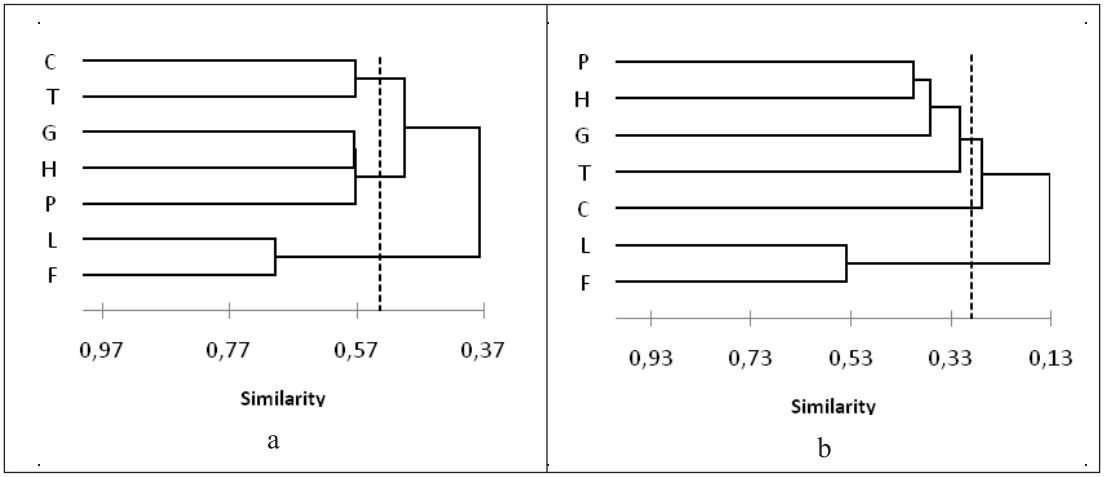

Figure 2. — Dendrograms based on the Jaccard similarity index. a) Native or autochthonous species; b) endemic species.

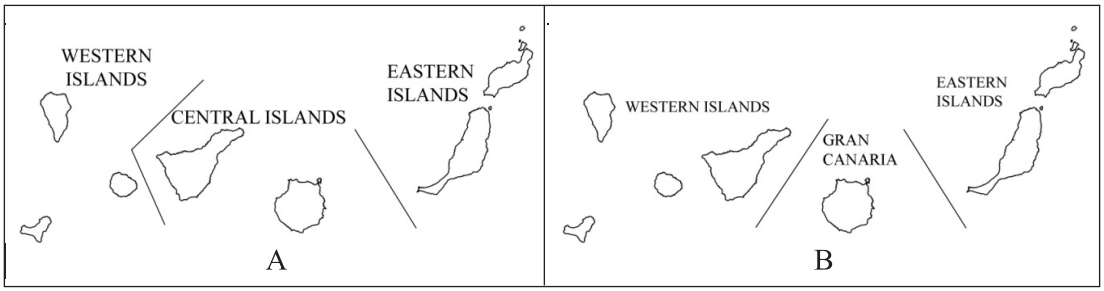

Figure 3. — Phytogeographic zones of the Canary Archipelago: A. Considering native species; B. considering endemic species.

endemic genera of the Archipelago: *Dicheranthus*, *Greenovia*, *Dendriopoterium*, *Spartocytisus*, *Neochamaelea*, *Kunkeliella*, *Rutheopsis*, *Tinguarra*, *Todoroa*, *Parolinia*, *Navaea*, *Pleiomeris*, *Ixanthus*, *Plocama*, *Ceballosia*, *Allagopappus*, *Atalanthus*, *Babcokia*, *Chrysoprenanthes*, *Gonospermum*, *Lactucosonchus*, *Sventenia* and *Vieria*, as shown in Figure 4. Among these genera, 4 are endemic genera exclusive to Gran Canaria: *Babcokia*, *Chrysoprenanthes*, *Dendriopoterium* and *Sventenia*. Among the remainder of the Canaries, only Tenerife and La Palma exhibit endemic island genera: *Navaea* and *Vieria* on Tenerife and *Lactucosonchus* on La Palma.

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To complete this analysis, the list of the various endemic species of Gran Canaria present in each of the quadrants referred to above (quadrant N (1), quadrant E (2), quadrant S (3) and quadrant W (4)) was used, and the indices of similarity between these quadrants were calculated, leading to the following tables and graphs included in Figure 5.

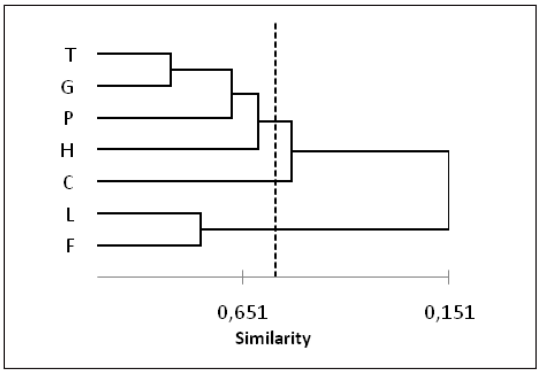

Figure 4. — Dendrogram obtained using the similarity index from the analysis of the endemic genera of terrestrial vascular plants of the Canary Islands.

A

	N	E	S	W
Canarian endemics	146	142	111	167
Gran Canarian endemics	40	41	50	73
Local endemics	9	9	12	28

B

	N	E	S	W
N	1			
E	0.65	1		
S	0.33	0.40	1	
W	0.50	0.50	0.50	1

C

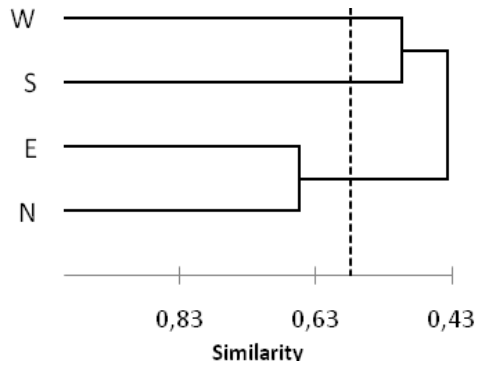

Figure 5. — A) Number of endemic species in each of the quadrants considered. B) Matrix showing the similarity index (Jaccard) for each quadrant obtained through the analysis of Gran Canarian endemics. C) Dendrogram showing the degree of endemic similarity (Jaccard similarity index) of the considered Gran Canarian quadrants.

As expected, there are major differences between the N-E and S-W halves. The climatic and geological differences are sufficient to cause the flora of the two regions to be very different, but the similarity between the N and E quadrants is sufficiently great that it is not convincing to separate the two phytogeographic regions. In contrast, relatively low similarity values were obtained for the S-W quadrant, making it possible to differentiate the southern and western quadrants as individual phytogeographical zones. The number of species exclusive to the two regions is of great importance, not only in terms of species, as two entire genera are exclusive to the Gran Canarian western zone: *Dendriopoterium* and *Sventenia*. Among the species present, there are 28 exclusive endemics of this western region of Gran Canaria, while there are nine exclusive species in the N and E quadrants and 12 in the S quadrant.

According to this analysis, there appear to be three phytogeographic zones in Gran Canaria, which are also very likely biogeographic zones, as observed in Figure 6. Hence, each of these zones is proposed as a biogeographical district, as described in the following concluding section: The North-East district, characterized by an almost constant influence of trade winds and a young geology, mostly consisting of basic basalt, is occupied by flora and vegetation similar to those present on the western islands. The South district, which is not subject to the influence of trade winds and is geologically older, presents conditions that are in some ways similar to those of the eastern islands. Finally, the West district is unique in its climate (with occasional, but highly thermal influences from the sea of clouds), its geology (an old territory, without modern material contributions, with steep conditions) and its flora.

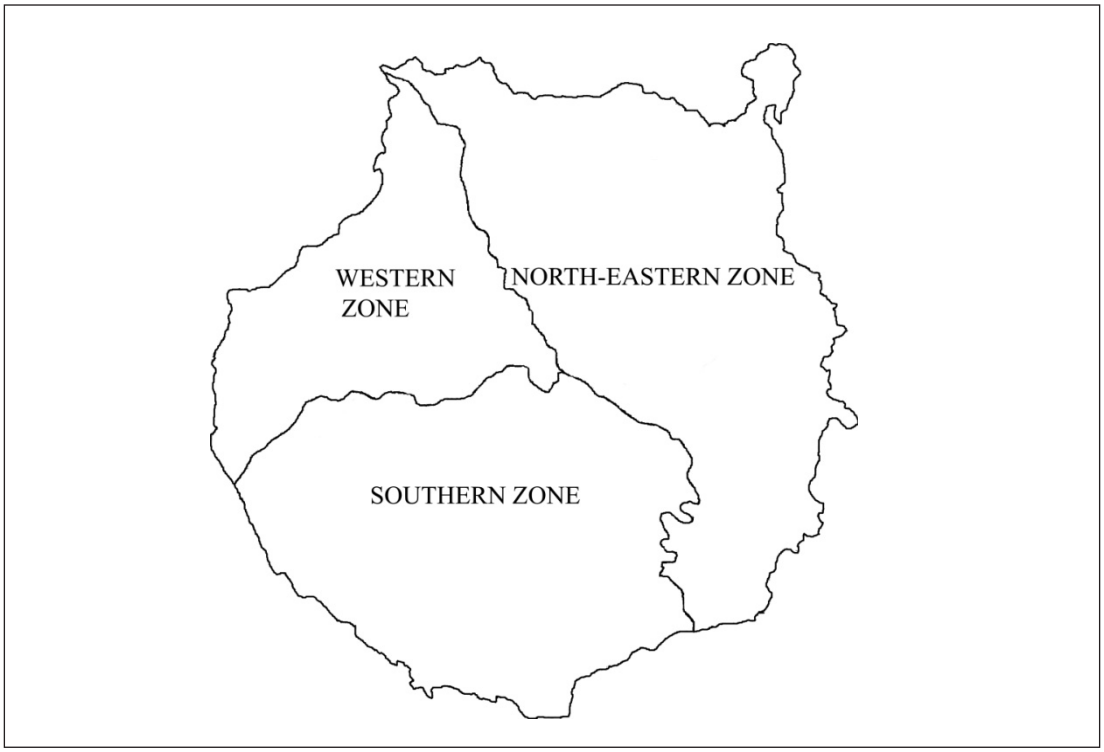

Figure 6. — Phytogeographical subdivisions of Gran Canaria.

DISCUSSION AND CONCLUSIONS

The phytogeographical affinities of the Canary Island Archipelago are a poorly discussed subject in the scientific botanical literature. This is so much the case that to date, except for Fuerteventura, no island has previously been subjected to biogeographic subdivision into districts. A significant methodological feature is not including introduced species in the analysis because they do not provide biogeographic information that helps to clarify the phytogeographic relationships between territories, even if they do provide information on factors such as the climate or historical links. In territories where introduced species are especially numerous, as is the case for the Canary Islands, these species alter the results of comparative analyses and lead to erroneous conclusions. Thus, it is analyses of endemic species that provide reliable and verifiable results. In the Canary Islands, the number of endemic species is sufficiently high to conduct this type of study. This is not the case in continental territories, where the degree of floral endemism is much lower; therefore, studies should be supported by the affinities of native or autochthonous flora.

Based on the results obtained in the present study, it is not possible to establish sufficient differences between the floristic components of the eastern islands (Fuerteventura and Lanzarote) and the western islands (Gran Canaria, Tenerife, La Palma, La Gomera and El Hierro). However, the western group appears to present sufficient differences to separate Gran Canaria Island from the rest. The unique geological features of Gran Canaria, along with its climatic and geomorphological characteristics, have resulted in unique flora, including several exclusive genera, characterized by their age or relictual character. This distinction between Gran Canaria and the other western and central islands was also noted in a group of Canaries reptiles (Guerrero & *al*., 2005), reinforcing the biogeographically differentiated character of Gran Canaria.

This analysis of Gran Canaria island distinguishes three distinct phytogeographic zones on the island: the North-East half is characterized by the influence of trade winds, geological youth and a basaltic substrate; the Southern quadrant, which is sheltered from the trade winds and Atlantic storms from the west, is of moderate geological age, representing the most xerophytic part of the island, dominated by acidic phonolitic substrates; and the Western quadrant, which is subject to the occasional influence of trade winds and is vulnerable to storms from the west, represents the oldest part of the island and is alternately dominated by highly altered phonolitic and basalt rocks. This last zone exhibits a very distinctive flora with a large number of exclusive endemic species and even endemic genera.

The age of the area and the number of endemics are two factors that are closely linked. Geological stability enables longer and more stable adaptation processes, resulting in a greater number of endemic species.

It is worth noting some features related to the effect of these results on the biogeographic typology of the analysed territory. The separation of a territory into biogeographic units continues to be relatively subjective because there is no unanimity regarding what qualifies a region as a sector, district or any other unit. For a more accurate determination of this biogeographic typology, a much wider study would be necessary, involving not only the flora but also vegetative formations and vegetation and fauna series for the territory. The results of this study do, however, allow us to propose a division of the Canary Archipelago based on previous work and new ideas arising from the floristic analysis carried out here. In this biogeographical subdivision, the phytogeographic territories observed on Gran Canaria Island correspond to three different biogeographic districts. The following is the proposed biogeographic characterization:

HOLARCTIC KINGDOM
MEDITERRANEAN Region
CANARIAN-MADEIRIAN Subregion
CANARIAN Province
Western Central Canarian Subprovince
GRAN CANARIAN Sector
North-East District
South District
West District
WESTERN CANARIAN Sector
Tinerfeño Subsector
Gomero Subsector
Herreño Subsector
Palmero Subsector
Eastern Canarian Subprovince
LANZAROTEÑO Sector
Islas Salvajes District
Chinijo District
Conejero District
FUERTEVENTUREÑO Sector
Majorero District
Jandiense District

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