The Vegetation Landscapes of a Oceanic Recent Volcanic Island

Esther Beltrán-Yanes and Isabel Esquivel-Sigut

The islands that underwater fire has raised above the waves,gradually become overgrown with vegetation, but oftenthese newly formed lands are torn apart by the action of thesame forces that made them emerge from the bottom of the oceans.Perhaps certain islets that today are no more than heaps of slagand volcanic ash were once as fertile as the hills of Tacoronte and El Sauzal.

Alexander von Humboldt, Voyage aux régions équinoxiales du Noveau Continent fait en 1799, 1800, 1801, 1802, 1803 et 1804. I. Paris,1816, p.113

Abstract

The aim of this chapter is to characterise the vegetation landscapes of El Hierro's Geopark, highlighting the important role played by the island's volcanic morphology in the richness and diversity of its landscapes. To this end, some of its most representative vegetation landscapes have been selected at various spatial scales, recognising their main discontinuities and internal organisation, and identifying the integrated combinations of the geographical factors that determine them have been identified, with special interest in the volcanic morphostructural conditioning factors. This work has required photointerpretation of aerial images and consultation of the WMS (*Web Map Service*) of IdeCanarias, as well as field work for the preparation of vegetation profiles and floristic-physiognomic inventories. Active volcanic areas are distinguished by being some of the most dynamic types of landscape on the planet. In this sense, the study of the vegetation landscapes of the small island of El Hierro allows us to discover how volcanic morphogenesis can extraordinarily diversify island landscapes.

Keywords

Vegetation landscapes • Volcanic rift • Geography of the vegetation • Post-eruptive plant colonisation • El Hierro's Geopark

1 Introduction

From a geographical point of view, the study of landscapes focuses on the analysis of the physiognomy of a territory and on the explanation of the interrelated forms and elements that make it up. From this point of view, the term landscape is inherent to any territory, though depending on its main element—natural, agricultural, urban, etc.—the techniques of analysis and information sources consulted will vary, the results of which must always be interpreted from a common approach inspired by the geographical foundation. Moreover, the territorial organisation that characterises a landscape is distinguished by a hierarchical structure of interdependent spatial units organised according to the spatial scale of study. It is important, therefore, to emphasise that each territorial organisation of a landscape is unique. Indeed, no two landscapes are exactly alike because their spatial structures are always different (Arozena Concepción and Beltrán-Yanes 2001; Bertrand and Bertrand 2006; Martínez de Pisón 2009; de Bolós i Capdevila and Gómez Ortiz 2009).

If the term 'landscape' is added to the term 'vegetation', the relevance of vegetation in the territorial organisation of the physiognomy of a space is highlighted. Vegetation's role tends to be very important, except in very cold or very dry

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places, since, together with the relief, vegetation is the main element in landscape characterisation, both because it contributes to its formal configuration, and because it is the component that best synthesises the interactions between the inert and the living. From this perspective, the plant component is fundamental for the identification of predominantly natural landscapes. Furthermore, the study of landscapes' territorial structure at different scales allows us to understand the spatial dimension of the interrelated factors that condition the geography that sustain landscape appearance. In short, in Biogeography from the perspective of Geography, the interest in knowing the living beings is inseparable from the territories of which they form part, because from this approach their knowledge allows the characterisation of the singularity of the territories (Arozena Concepción 1992).

Based on this geographic speciality, the aim of this chapter is to characterise the vegetation landscapes of El Hierro's Geopark, highlighting the important role played by the island's volcanic morphology in the richness and diversity of its landscapes. This study, therefore, focuses on how the relief created by continuous volcanic activity has conditioned the vegetation landscapes that distinguish this Geopark. To this end, some of its most representative vegetation landscapes have been selected at various spatial scales, recognising their main discontinuities and internal organisation, and identifying the integrated combinations of the geographical factors that determine them have been identified, with special interest in the volcanic morphostructural conditioning factors. This work has required photointerpretation of aerial images and consultation of the WMS (*Web Map Service*) of IdeCanarias (OrtoExpress and hillshade, vegetation and geology maps) (https://www.idecanarias.es/), as well as field work for the preparation of vegetation profiles and floristic-physiognomic inventories. Vegetation mapping was also carried out using GIS in some of the selected volcanic areas.

2 Volcanic Relief as a Diversifier of Vegetation Landscapes in the Canary Islands

Traditionally, when we focus on the study of vegetation in the Canary Islands, the first thing that strikes us is that the islands stand out worldwide for their biodiversity are parte of one the most important biodiversity hotspots on the planet, the Mediterranean Basin, (Médail and Quézel 1997) , favoured by their location at a subtropical latitude (27° 37′ and 29° 25′ north latitude and 13° 20′ and 18° 10′ west longitude). The position of these oceanic islands between Mediterranean and Tropical worlds allows them to display a significant range of flora and vegetation types, from forests adapted to thermophilic and dry environments, such as the juniper forests, to humid environments, such as the original laurisilva or monteverde, or at higher altitudes, with the extensive Canary Island pine forests. Alongside these forest communities that occupy the midlands of the higher islands, xerophytic scrubland also grows on the coast, such as the cardonales-tabaibales, in which the floral and physiognomic affinities with the vegetation of the nearby African continent are noteworthy. In addition, on the highest peaks of the islands of La Palma (2426 m above sea level) and Tenerife (3717 m above sea level), the summit scrub has dominant connections not only to Mediterranean mountains but also has certain physiognomics links to tropical mountains.

As already mentioned, the location of the Canary Islands contributes to this range of forest and shrub plant communities. However, there is another geographical conditioning factor that determines this variety of vegetation types, which is the mountainous nature of these volcanic islands. The presence of mountainous areas that reach or exceed 1500 m above sea level on most of the islands introduces a geographical factor that causes striking variations in bioclimatic conditions. Among the main climatic consequences are the circulation of the trade winds at these latitudes in the eastern Atlantic. This means that the slopes of the highest islands, exposed to these winds, between 600 and 1500 m above sea level, receive the highest rainfall. In this altitudinal range, the "sea of clouds" also occurs, which provides notable environmental humidity due to its frequency and a considerable water volume that contributes to the survival of exuberant vegetation in these dry subtropical latitudes. For this reason, the altitude and orientation of the islands-mountains give rise to multiple environmental contrasts ranging from warm and dry local climates on the coast, to temperate and very humid on the windward slopes, cool with little rainfall on the leeward peaks and cold with irregular snowfalls on the highest peak of Tenerife (Marzol 2000, 2001).

Therefore, if we focus on the study of vegetation landscapes, the diversity of flora and vegetation is accompanied by an even more surprising wealth of plant communities. This is the result of novel environmental conditions caused by the complex volcanic orography of the islands, and which, on some of them are notably amplified by the constant rejuvenation of the relief due to volcanic activity.

In this chapter, we will focus on one of these island-mountains, built by recent volcanic activity: the island of El Hierro. The island is the smallest and most oceanic of the Canary Islands, with its highest point at the Pico de Malpaso (1501 m above sea level). El Hierro is distinguished by having the most diverse vegetation landscapes on recent volcanic morphologies at different spatial scales in the archipelago. The variety of Canary Island volcanism in terms of forms, processes, eruptive materials and chronology, interrelated with the subtropical climatic conditions of the islands, gives rise to multiple changes in vegetation landscapes over a very small and irregular island surface area. In addition, over the last few centuries, human action has also altered the natural vegetation landscapes.

3 The Vegetation Landscapes of El Hierro on an Island Scale

As already mentioned, El Hierro is one of the most recent islands of the archipelago and a large part of its territory is covered by volcanic cones and lava flows. It has traditionally been considered a dry island due to its geological youth, however, this is due more to water availability than to climatic drought. The recent nature of the volcanoes and the high porosity of the eruptive materials have not contributed to significant underground water storage, which, together with the absence of impermeable soils, has not facilitated the emergence of natural springs. However, its orography and more westerly position provide it with a generally humid environment that links El Hierro to the climatic regime of the other higher western islands.

In order to characterise the vegetation landscapes of El Hierro, it is necessary to initially distinguish the basic elements that make up its "territorial vegetation mosaics" and which correspond to the most representative plant communities of the main natural ecosystems of this island. However, these vegetation types may present internal nuances in their floristic composition and structure depending on geographical factors on a more local scale. Their unequal location, extension, distribution and continuity in the territory, as well as the spatial relationships established between them, constitute an original geography of the vegetation that distinguishes El Hierro's Geopark.

3.1 El Cardonal-Tabaibal

The cardonal-tabaibal grows between sea level and approximately 450 m above sea level (Aguilera et al. 1994) and is associated, over the first metres, with coastal halophilous scrubland in predominantly saline environments. On the island's southern slope, this vegetation unit reaches higher altitudinal levels until it meets the juniper forest (Aguilera Klink et al. 1994), and on the northern slope it extends up to 300 m above sea level. This scrub has physiognomic adaptations to a warm local climate, with average temperatures that can exceed 18 °C, and receives annual rainfall of between 150 and 250 mm (Marzol 1988; Aguilera et al. 1994). Adaptations to this climate include the development of succulent tissues, reduction of leaf area and spinescence to counteract evaportranspiration (Pérez de Paz et al. 1981; Sánchez Pinto 2005) (Fig. 1a).

The cardón (*Euphorbia canariensis*) and the sweet tabaiba *(Euphorbia baslsamifera*) are the most representative species of this plant community. Associated with this scrubland is the bitter tabaibal, which forms ecotonic zones with the juniper groves and whose most distinctive species is the bitter tabaiba (*Euphorbia lamarckii*). This floristic individual has a short, thick main trunk that branches out abundantly, giving rise to globular crowns. Accompanying species include *Kleinia neriifolia* (verode), *Periploca laevigata* (cornical), *Rumex lunaria* (vinagrera) and *Schizogyne sericea* (salado), among others. The richness and cover of this plant community can vary according to humidity conditions and the effects of human activity.

3.2 The Juniper Grove

One of the best representations of the thermophilic forest of the Canary Islands are the juniper forests of El Hierro. This open sclerophyllous forest of Mediterranean affinity receives annual rainfall totals between 200 and 500 mm and thrives at average temperatures between 17 and 19 °C (Aguilera Klink et al. 1994; Fernández-Palacios et al. 2008). In El Golfo, in the north of the island, there is a humid juniper forest located between 400 and 600 m asl, below regular contact with the sea of clouds.

To the south, El Hierro's junipers have a more open distribution and a characteristic creeping habit (Fig. 1b), arising from the adaptation of *Juniperus turbinata* subsp. *canariensis* to the frequent action of the prevailing winds at the summit. In addition to juniper, the most common species are bitter tabaiba (*Euphorbia lamarckii*), verode (*Kleinia neriifolia*), tasaigo (*Rubia fruticosa*) and salado (*Schizogyne sericea)* (del Arco et al. 2006).

3.3 The Monteverde or Laurel Forest

Above the juniper forests and on the windward slopes, under the regular effect of trade wind clouds, the monteverde forest has developed thanks to the mild temperatures between 13 and 17 °C and rainfall of around 1000 mm (Fernández-Palacios 2009). However, these laurel forests do not show mature expressions (Santos Guerra 2000), and some of the most characteristic species of this forest community are missing. In El Hierro's monteverde, mostly thermophilic species dominate, such as *Apollonias barbujana* subsp. *barbujana* (barbuzano), *Arbutus canariensis* (madroño), *Erica canariensis* (heather), *Morella faya* (faya), *Picconia excelsa* (paloblanco) and *Viburnum rugosum* (follao). These species form dense, evergreen forests (Fig. 1c) (Pérez de Paz 1990; Guzmán Ojeda et al. 2007), although when faya and heather predominate in some areas, they are mainly replacement

Fig. 1 Examples of the most characteristic plant communities of the island and which form part of the vegetation landscapes of the Geopark: **a** Cardonal-tabaibal in La Galera; **b** Juniper forest (La Dehesa); **c** Fayal-brezal (Jinamar); **d** Pine forest (El Julan). *Source* The authors

forests resulting from anthropic action and degradation. An example of this latter expression of monteverde is the fayal de La LLanía, with a floristic composition and structure that is highly conditioned by traditional livestock exploitation (Arozena Concepción et al. 2017).

3.4 The Pine Forest

Finally, the third forest community in the Geopark is the Canary Island pine forest, which is made up of stands of natural and reforested pine forest. It is located on the summit and leeward slopes of the island and is located at between 800 and 1450 m above sea level. The pine forest grows in a drier and thermally varied environment with annual rainfall above 300 mm and average annual temperatures ranging from 11 to 19 °C (Arévalo and Fernández-Palacios 2009). It is a tall, monospecific forest composed of Canary Island pine (*Pinus canariensis*) that forms an open tree canopy, with a very poor understory floristically in which *Lotus campylocladus* ssp (corazoncillo), *Trifolium* ssp., *Micromeria* ssp., *Hyparrenia hirta* and, locally, *Echium aculeatum* (ajinajo) can be found (Fig. 1d).

As has already been pointed out, these plant communities make up the main units or 'tesserae' of the different geographies that spatially articulate El Hierro's landscapes. From this point of view, a first general observation of the island reveals an altitudinal organisation of the vegetation with internal changes produced by orientation to the frequent trade winds. In the coastal sectors, a unit of xerophytic scrubland can be recognised, and as the altitude increases, there is a concentration of the forest mass up to the summit of the island, which is clearly crowned. In this forest unit, there are physiognomic and floristic differences between the thermophilus forest of the lower altitudinal areas, the monteverde forest of the higher midlands to the windward and on the summits, and the pine forests that extend along the culminating sectors and slopes on the leeward side.

This main territorial organisation of the vegetation landscape is due to the presence of a vigorous and abrupt volcanic relief with a maximum age of 1.2 Ma (Guillou et al. 1996), which at its highest point reaches 1501 m asl and is distinguished by a triangular layout, built from the triaxial system of high volcanic edifices or rifts that constitute its volcanic summits (Guillou et al. 1996; Carracedo et al. 2001). The volcanic rift is a longitudinal morphostructure characterised by volcanic activity, and whose construction is spatially organised around a main tectonic axis that accounts for the greatest number of eruptive phenomena of predominantly basaltic composition. A large volcanic construction is thus created by the superposition and juxtaposition of multiple monogenetic volcanoes (Romero 1986, 1991; Dóniz-Páez 2009). The spectacular topographic amphitheatre of El Golfo, located to the north of the island, and resulting from one of the most important gravity slides ever to have occurred on El Hierro (between 21,000 and 130,000 years ago; Carracedo 2008), gives it its characteristic crescent shape. The small surface area in relation to the maximum height of the island means that El Hierro has the steepest average slopes in the archipelago.

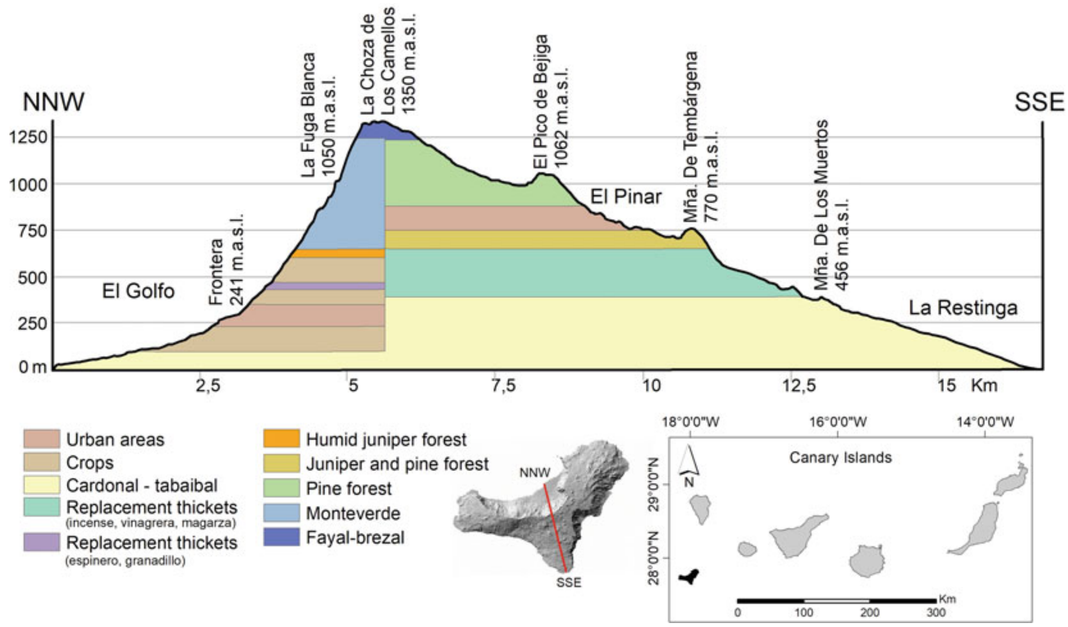

Fig. 2 NNW-SSE vegetation profile of the island of El Hierro. *Source* Idecanarias, Self-elaboration

Consequently, the altitude of El Hierro's volcanic relief explains the variety of forests it presents by hindering the circulation of oceanic winds, giving rise to environmental contrasts and the consequent discharge of abundant water resources on the windward slopes and on part of its summits. The vegetation profile that summarises this geography of the vegetation landscape runs from north to south through the central part of the Geopark (Fig. 2).

This profile begins on the coast of the Valle del Golfo, around Los Arenales, where the halophilic plant community of thyme (*Frankenia ericifolia*) and servilleta marina (*Astydamia latifolia*) grows and is in contact with the maresía, and the sweet tabaibales and cardonales typical of the coastal xerophytic environment. The extension of this part of El Golfo has facilitated greater settlement (Belguera, Tigaday, Los llanillos, etc.) and the expansion of agriculture, reinforced over the last few decades, which has profoundly altered the original geography and characteristics of the cardonales-tabaibales and the humid juniper groves. Indeed, this has left the latter plant community reduced to a small discontinuous unit at around 500 m above sea level. As we approach the escarpment of El Golfo and ascend, we can recognise different replacement thickets, such as bitter tabaibales (*Euphorbia lamarckii*), inciensales (*Artemisia thuscula*) and granadillares (*Hypericum canariense*) among the abandoned crops of the dominant detrital accumulations. However, it is from this last altitudinal level onwards, where the imposing escarpment of El Golfo, with slopes that reach a height of 1000 m in the easternmost sector, gives rise to a marked spatial change in the floristic composition and physiognomy of the vegetation.

The presence of this high wall that encloses this great depression to the south has further protected the forests from human activity and introduced a strict altitude control as an organiser of the forest landscape. The monteverde forest and fayal-brezal vegetation landscape units therefore appear territorially suspended vertically, as if they were literally ascending the slope until they reached its summit (Fig. 3).

This clear discontinuity in the landscape between scrubland and woodland in the north of the island is further reinforced by the concave and semi-circular topography of El Golfo to the NNW. This facilitates the concentration of water from the Atlantic winds, essential for the survival of the monteverde forest.

Once this great escarpment has been crossed, the vegetation landscape adapts to the presence of the N–S rift of El Pinar, which generates a volcanic alignment with a general convex topography that descends progressively to the southern tip of the island. The construction of this volcanic rift from parallel structural lines with a dominant north–south direction (Carracedo 2008) has given rise to a large longitudinal volcanic relief with a flat summit and a maximum height of approximately 1300 m above sea level.

The first thing that is striking about the vegetation on this southern slope is the spatial organisation of the forests. The flow of trade wind clouds over the summit allows the growth of fayal-brezal on the upper areas of this slope, with the pine forest (*Pinus canariensis*) below it. Only locally can this distribution be modified by the spatial discontinuities caused by the lapilli surfaces of the most recent eruptions or by the pine reforestation conducted on El Hierro during the last century (https://www.idecanarias.es/). Therefore, the pine

Fig. 3 Image of El Golfo with the dense forest cover of the monteverde on the escarpment. *Source* http://www.fotosaereasdecanarias.com

forest in its natural distribution is characterised by a forest floor on the leeward side of the slope, which currently covers large areas located between the escarpment of Las Playas and the slopes of El Julan.

As we go down this slope, the pine forest is replaced by juniper forest through an ecotonic floor. However, the flat summits of this volcanic morphostructure have been used for traditional livestock farming and agriculture, typical of the midlands of the south of the island with its water and soil resources, so that from around an altitude of 800 m, the forest is discontinuously located spatially. In this sector, areas of crops can be recognised, alternating with replacement scrubland in those plots where agriculture has ceased. Here, incense bushes (*Artemisia thuscula*) are frequent, together with other nitrophilous scrubland, which is also conditioned by grazing. Finally, from 400 to 350 m above sea level, there is a clear spatial discontinuity in the vegetation landscape, which is related to the presence of extensive, more recent volcanic surfaces corresponding to volcanic cones, badlands and coastal lajiales. This coastal sector has an open cover of dominant species, such as salado (*Schizogyne sericea*), also known on the island as irama, and tabaibas (*Euphorbia lamarckii*), in which the age of the volcanoes, the type of volcanic substrate and traditional farming uses are determining factors in interpreting the floristic changes and the structure of the vegetation.

4 The Vegetation Landscapes of the Volcanic Rifts of the Geopark

Differences in location, spatial arrangement and topography of El Hierro's rifts, originating from the recent volcanism, mean that the vegetation landscapes of these volcanic alignments present striking contrasts in their features and spatial organisation.

Thus, on the N-S southern volcanic rift, its location on the leeward side of the island gives the pine forest landscape a prominent role, whereas on the north-eastern volcanic rift, on the windward side, there is monteverde forest. This volcanic edifice, with an altitude of just over 1300 m above sea level and built from NE–SW oriented tectonic patterns (Carracedo 2008), has high humidity that promotes the development of monteverde forest at its summit, as can be seen today on some of its volcanic cones. However, much of the laurel (monteverde) forest of these mountains was ploughed up for agricultural use in the seventeenth century due to the quality of its volcanic soils (Hernández and Niebla 1985).

The exceptional conditions of humidity and the presence of this forest generated the best land on the island on a plateau, which has been given over to traditional livestock farming alternating with subsistence crops. Therefore, at present, on the north-eastern rift, an altitudinal organisation of the vegetation landscape can be identified in which there is a cardonal-tabaibal in different states of conservation on the coast, replaced from 250 to 300 m above sea level by shrub and nitrophilous formations in areas where traditional farming uses have ceased. The thickets of bitter tabaiba (*Euphorbia lamarckii)*, vinagreras (*Rumex lunaria*) and incense (*Artemisia thuscula*) alternate in the landscape depending on altitude, orientation and the time when farming or agricultural activity ceased, until they meet at the summit with fayal-brezal of the protected area of Ventejís (Fig. 4). In this sector, the fayal-brezal is spatially combined with other vegetation units such as thistle grasslands (*Galactites tomentosus*) and tagasaste crops (*Chamaecytisus proliferus* subsp. *proliferus* var. *palmensis*), which highlight the use of this mountain for preferential livestock farming. The upper forest floor of this second profile corresponds to a reforested pine forest with the foreign species *Pinus radiata*, which replaces the monteverde characteristic of this volcanic rift.

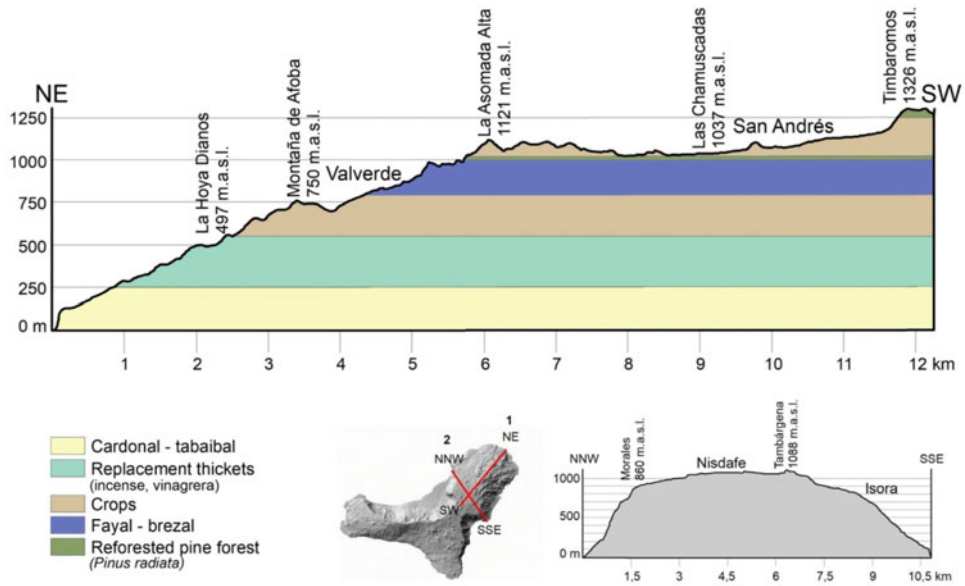

Fig. 4 NE-SW vegetation profile (1) and NNW-SSE topographic profile of the culminate plain (2) on the northeast volcanic rift. *Source* Idecanarias, Self-elaboration

By contrast, the western orientation of the island's third volcanic rift with a WNW–ESE main orientation, together with its original local topography, causes striking differences in the Geopark's vegetational landscapes. This high alignment of recent volcanoes has its highest point on the island at Pico de Malpaso (1501 m above sea level). Additionally, it has the peculiarity that the large landslides of El Golfo to the north and Julan to the south have considerably narrowed its summit. On the other hand, the summit between approximately 400 and 1000 m above sea level has a flat and more extensive topography, which descends gently until it reaches a cliffy coastline.

The vegetation landscape of this volcanic rift is organised altitudinally with a xerophytic coastal scrubland dominated today by irama (*Schizogyne sericea*), which is replaced at around 350 m above sea level by a juniper forest in the La Dehesa area, which is one of the most representative forest landscapes on the island (Fig. 5). The characteristic aerodynamic shapes of this open forest are due to the persistent action of the NE winds (Fig. 1b) at the summit. The fact that this altitudinal section corresponds to an orographic sector of considerable extension emphasises the juniper forest in the vegetation landscape of this volcanic mountain, whose regeneration, biodiversity and structure are conditioned by past use of this forest (Salvá Catarineu et al. 2012). The vegetation profile of the summit of this volcanic rift is completed at altitude by the pine forests of *Pinus canariensis*, whose surface area has been enlarged by reforestation. Alongside these forests, replacement scrub and grasslands composed of bitter tabaiba (*Euphorbia lamarckii)*, vinagreras (*Rumex lunaria*), incense (*Artemisia thuscula*) and thyme (*Micromeria hyssopifolia*) are organised spatially depending on altitude and orientation, and, once again, they reflect common livestock use on the island. However, discontinuities in the vegetation landscape caused by recent volcanic events on this rift, such as those linked to the summit pyroclast fields of the Tanganasoga volcano, also locally organise the vegetation of this volcanic mountain alignment.

5 Vegetation Landscapes on a Local Scale: The Tesoro Volcano

The analysis of vegetation landscapes on a larger spatial scale allows us to identify new vegetation landscapes in these mountains, related to the most recent volcanism. This is a typical disturbance factor in the natural dynamics of vegetation landscapes in active volcanic territories. These landscapes respond to a process of primary plant succession in which primocolonising vegetation settles on a rocky surface devoid of soil, with very low fertility and lacking in organic matter (Smathers and Mueller-Dombois 1972; Hendrix 1981).

For the study of this type of vegetation landscape, the Tesoro volcano has been selected. It is located on the north-eastern volcanic rift, in Tamaduste, a coastal rift. This Holocene volcanic edifice of monogenic character and basaltic composition presents a volcanic cone with funnel craters and basal emission centres through which most lava of different typologies flowed (Dóniz-Paez et al. 2009). The overflow of the lava along the rift generated lava deltas from the superposition of lava flows, in which lava forms aa, lava balls and lava blocks can be identified. Likewise, in the interior of the volcano, some forms of modelling can also be recognised, such as detrital fans of torrential origin, which cover certain parts of the coastal lava platform.

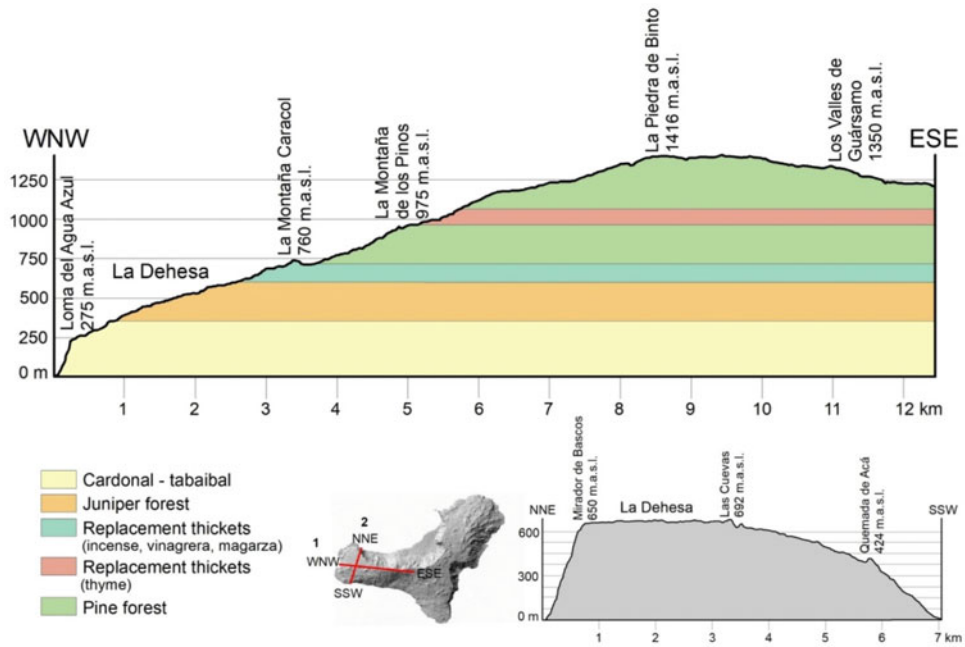

Fig. 5 Vegetation profile (1) and topographic profile of the La Dehesa sector (2) in the western rift. *Source* Idecanarias, Self-elaboration

The climatic zone in which this volcano is located is semi-arid, characteristic of Canary Island coasts, although its exposure to the humid north-easterly winds means that it receives high levels of humidity most of the year. The vegetation is therefore defined by the presence of a xerophytic scrubland made up mainly of *Rumex lunaria*, *Kleinia neriifolia, Schizogyne sericea* and various species of the genus *Aeonium* sp. accompanied by a tapestry of thallophytes, which presents varied spatial units depending on the floristic composition, size and cover of the shrub formation.

When the vegetation landscapes of the most recent volcanoes are analysed in a semi-arid environment, which is the dominant one in the Canary Island archipelago, thus conserving the original volcanic forms hardly transformed by modelling and erosion, it is surprising to see the forceful control exerted by the morphology of the Tesoro volcano in the process of plant colonisation (Beltrán Yanes 2000; Beltrán Yanes and Dóniz Páez 2009). Topography, through local environmental changes and the regulating effects of morphoclimatic processes, as well as the shapes and surface textures of the volcanic substrates, constitute the fundamental geographical determinants of the vegetation landscape. In this way, different types of scrublands can be distinguished in El Tesoro that coincide territorially with its main morphological units and present the following characteristics (Fig. 6).

On the volcanic cone and lapilli fields, in addition to accumulations of pyroclasts and lava slopes (highly fragmented lava material) that cover the cliff, there are mainly calcareous plants (*Rumex lunaria*) that form an open scrubland, affected by the lack of stability of these eruptive materials. The topography of the volcanic mountain and the cliff also accentuate the displacements of the substratum by gravity and torrentiality.

On the other hand, on the lava flows located on the cliff, and therefore in the same environmental sector as the previous unit, the more stable and continuous nature of the lava surfaces favours a significant presence of aerohygrophilous and heliophilous lichens, such as *Ramalina bourgaeana*, *Xanthoria resendei,* etc., which do not grow on the pyroclasts. Associated with the thallophytes, there is also open scrub, but more diverse, of *Kleinia neriifolia*, *Rumex lunaria*, *Aeonium* sp. and ferns, such as *Allosorus fragilis,* helped by these substrate characteristics.

On the coast, the lava flows show other local variations in vegetation, strongly influenced by the saline environment, but, above all, by the morphology of lava flows. In the thick blocky lava flows, there is a minimal presence of vegetation with isolated elements of *Kleinia neriifolia* with clear rupicolous and fissuriferous adaptations. These are very massive lavas with deep intercalated cracks that show very limited weathering processes. By contrast, on the aa lava flows located to the north of the lava delta, their more scoriaceous and vacuolar texture facilitates the disintegration of the lava substrate and, therefore, an increase in the presence of vegetation with a thicket of *Rumex lunaria, Schizogyne sericea and Kleinia neriifolia.*

However, one of the most striking vegetation units from the point of view of plant colonisation of this volcano are the dense thickets of *Schizogyne sericea* on the alluvial deposits on the lava platform. The development of detrital fans originating from the concentrated runoff through lava channels on the coastal slope has given rise to thickets with the highest cover rates on the volcano. This halophilic

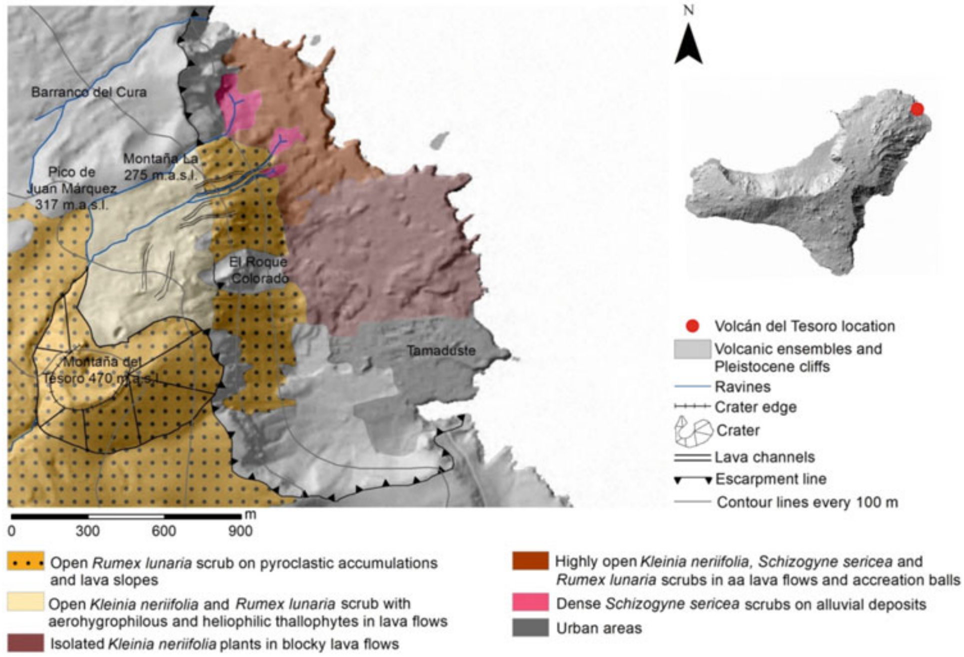

Fig. 6 Vegetation map of Volcán del Tesoro. *Source and cartographic base* Idecanarias. Self-elaboration

scrubland covers 60% of the surface with a maximum height of 1.50 m. The main floristic elements are salt cedar including *Schizogyne sericea , Rumex lunaria and Kleinia neriifolia.* The existence of this plant community constitutes a unique vegetation unit in the study of the plant colonisation of recent volcanic territories. It is associated with the allochthonous soils, which even contain their own biological capital (propagules and seeds), and are the result of a very rapid local transformation of the original morphology of the volcano (Beltrán Yanes 2000). From the perspective of the study of the influence of biotic and abiotic factors on the changes in time and space of post-eruptive colonising plant communities, there are interesting contributions made in other volcanic areas such as the Kula Volcano, Turkey (Öner and Oflas 1977), Paricutin (Mexico) (Velázquez et al. 2000) and the Tolbachinskii Dol Volcanic Plateau (Korablex and Neshataeva 2016) and Tolbachinsky Dol, in Kamchatka (Grishin 2010).

6 Conclusions

El Hierro is an excellent example of the close relationship between volcanic morphogenetic processes and the island's vegetation landscapes. The wealth of volcanic morphologies at various scales creates multiple, interdependent vegetation geographies that also contribute to defining the territorial physiognomic identity.

Thus, taking an overview, not only does the vigorous volcanic relief establish spatial contrasts in the vegetation between the windward and leeward sides of the island, but also the basic structure of its orographic framework, traced by the central crossroads of volcanic rifts with different morphology and spatial arrangement, establishes other variations in the bioclimatic conditions and vegetation landscapes. In this sense, the altitude and orientation of these mountains with respect to the trade winds determines the differentiated organisation of their plant mosaics. But also, from this perspective, it is striking how the different locations of the plateaus in these orographic elevations, sculpted by the gravitational landslides on their slopes, give rise to an unequal landscape relevance of the various forests in El Hierro. This novel volcanic relief has even conditioned the spatial organisation of the traditional uses and exploitation of the island's natural resources. Therefore, this factor is also essential for the geographical interpretation of the current state of the vegetation, reflected in the structure and floristic composition of the plant communities.

On a larger spatial scale, El Hierro's vegetation landscapes offer new characteristics and spatial structures derived from the most recent volcanic activity. This activity has introduced a factor of perturbation and renewal of the natural dynamics of the plant communities and landscapes. In these cases, the age of new structures and their morphological units are determining factors in the territorial change of the vegetation, although they are always dependent on the prevailing climatic conditions (Beltrán-Yanes 1992).

In short, active volcanic areas are distinguished by being some of the most dynamic types of landscape on the planet. In this sense, the study of the vegetation landscapes of the small island of El Hierro allows us to discover how volcanic morphogenesis can extraordinarily diversify island landscapes. There is no doubt that eruptions suddenly change, alter and destroy the vegetation, fauna and landscape of the places affected, with often catastrophic consequences for the population. However, this chapter aims to highlight another perspective of volcanism related to the renewal of landscapes and its important role in the construction of new and original territorial configurations, which, from the point of view of the study of the vegetation landscapes of oceanic volcanic islands, the Canary archipelago stand out worldwide for its diversity.

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