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Study of the current vegetation of the historical lava flows of the Arafo Volcano, Tenerife, Canary Islands, Spain

Victoria Eugenia Martín Osorio[1], Wolf-Hermann Wildpret Martín[2], Rocío González Negrín[1] & Wolfredo Wildpret de la Torre[1]

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Abstract. Vegetation research on the lava flows of the historic volcanic eruption of 1705 in Arafo, Tenerife, Canary Islands, is presented. The study area located in the 830000-year-old valley of Güímar was created after a massive landaslide 47 km^3 in volume. The research is divided into three parts, which cover an altitudinal range from around 35 to 1583 m asl from the Lower-semiarid Inframediterranean up to the Lower-dry lower-Mesomediterranean bioclimatic belts. First, a phytosociological study of the vegetation present in the area was made and concluded that richness in pioneer communities form a vegetation complex with a high degree of endemicity. Two new associations and four pioneer communities are proposed. Especially notable are the communities of *Stereocauletum vesuviani* and the pioneer communities of *Pinus canariensis*. The second part of the research was a field sampling study of 450 individuals of *Pinus canariensis*, which were measured at different altitudes to obtain data about the colonization dynamics of this species on this 300 years old substrate. We found that stem diameter seems to be a good indicator for healthy tree development at a range between 700 to 1300 m asl, which corresponds to the pine forest as potential vegetation and that many individuals show signs of nutrient deficiency. The third part consists of the publication of two new populations of the Canarian endemism *Himantoglossum metlesicsianum*, a highly endangered orchid. The monitoring of these two populations has recently begun, and further research will be conducted on all three aspects of this publication, which will be presented and expanded upon in the future.
Keywords: Historic lavas; vegetation complex; *Himantoglossum metlesicsianum*; *Pinus canariensis*.

Estudio de la vegetación actual de las coladas históricas del Volcán de Arafo, Tenerife, islas Canarias, España

Resumen. Se presenta un estudio de la vegetación vascular que coloniza, en la actualidad, las coladas históricas del Volcán de Arafo, situado al sureste de la isla de Tenerife, que originó una colada lávica basáltica “*aa*” con olivinos en el año 1705. El volcán está situado en una ladera formada por un megadeslizamiento gravitacional de hace 830.000 años con un volumen de 47 Km^3 de lava deslizada en una superficie de 130 Km^2. El estudio está dividido en tres partes realizado a través de un gradiente altitudinal desde los 35 hasta los 1583 m snm perteneciente a un Macrobioclima Mediterráneo con pisos bioclimáticos, desde el Inframediterráneo semiárido inferior, hasta el Mesomediterráneo inferior seco inferior. La primera parte es un estudio fitosociológico de la vegetación actual que se corresponde con un complejo de vegetación formado por comunidades primocolonizadoras, en fase de progresión, caracterizadas por comunidades liquénicas de *Stereocauletum vesuviani* y por pinares de *Pinus canariensis*. Se describen 2 nuevas asociaciones fitosociológicas y 4 nuevas comunidades de vegetación primocolonizadoras. La segunda parte es un estudio de muestreo de campo de 450 individuos de *Pinus canariensis*, situados a diferentes altitudes para obtener datos sobre la dinámica de colonización de esta especie en este sustrato de 300 años. Descubrimos que el diámetro del tallo parece ser un buen indicador del desarrollo óptimo de los árboles en un rango entre 700 y 1300 m snm que corresponde con el pinar como vegetación potencial, también que muchos de ellos muestran signos de deficiencia de nutrientes. La tercera parte consiste en la cita de dos nuevas poblaciones para la isla de Tenerife del endemismo canario *Himantoglossum metlesicsianum*, una orquídea en peligro de extinción. El monitoreo de estas dos poblaciones, ha comenzado recientemente y se realizarán más investigaciones sobre los tres aspectos de esta publicación, que se presentarán y ampliarán en el futuro.
Palabras clave: Lavas históricas; complejo de vegetación; *Himantoglossum metlesicsianum*; *Pinus canariensis*.

Introduction

The study of the current situation of plant colonization Güímar process by vascular plants in historic lava flows in the Güimar valley, Tenerife, is provided. We have chosen stretches almost intact, or slightly damaged by the anthropogenic action, of the “malpaíses” originated during the eruption of the historic Arenas Negras volcano. This eruption began on February 2nd, 1705, and ended on March 27th of that year. This volcanic episode lasted for 54 days and is, to this day, the most destructive event on the history of the municipalities of Güímar and Arafo, as it threatened to destroy both villages. Luckily several publications were made relatively soon after the eruption and up to this day in which several aspects of the lava flows, like vegetation or form of agricultural use, and different authors comment on the areas around them. Then, we have a glimpse of how this novel ecosystem, as well as the surrounding ones, have

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[1] Botany, Ecology and Plant Physiology Department, La Laguna University. Apto. 456. E-38200, Tenerife, Spain. Email: vemartin@ull.edu.es
[2] Fakultät für Biologie Schänzlestraße 1. 79104 Freiburg Albert-Ludwigs-Universität Freiburg. Deutschland.

evolved with time and changing anthropogenic use as well as climate, albeit with some limitations.

The first of these descriptions that we know of, about the colonization of the historic lava flows by plants was made 71 years after the eruption by Viera y Clavijo (1776). He describes how a 'white liquid' is the only vegetation that can be observed on top of the black lava. This observation probably referred to the lichen *Stereocaulon vesuvianum* (Laur.) Pers., which can be abundantly found there nowadays. Further down, he notes: "*pero cerca de la costa, los euforbios, los prenantos y los kleinios ha empezado ya a desarrollarse…*" which translates to "*but near the coast, the euphorbia, the prenates, and kleinia have already begun to develop*".

Twenty years after Viera y Clavijo, in 1796, the french naturalist André Pierre Ledrú visits the town of Güímar and points out that in the flows which destroyed the crops of sugarcane new wine plantations are already present (Ledrú, 1982). This switch to winegrowing is still present today. It consists of one of the fundamental aspects of why the area has been declared a protected space, together with the interest of preserving the vegetation units currently in the process of colonizing the "malpaíses".

Nearly a century later, in 1894, the german geographer, and professor from the Leipzig University, Hans Meyer wrote on the sizeable individuals of *Chamaecytisus proliferus.* It is Canarian endemism associated with *Pinus canariensis*, growing atop the lava fields. In the south base of the volcanic cone, at around 1270 m asl, there was a single pine of about 15 meters in height. He also noted a water flow that descended rapidly and where he found an increasing number of *Pinus canariensis* reaching a fully-fledged forest. This final element is already outside of our study area. On the lower side of the volcano, at around 1260 m asl, he described a chestnut (*Castanea sativa)* plantation consisting of saplings around 30 centimeters in height and planted in 10-meter intervals in all directions. Such, now fully grown trees, can still be found today. Mayer continued his descend, noting the presence of *Erica canariensis* and *Adenocarpus foliolosus,* at around 1167 m asl, before heading away of the lava flows and describing a mature pine forest with sizeable trees of about a meter in diameter at around 1085 m asl. Wine and cereal crops were observed at around 900 m asl followed by the first *Opuntia sp.* fields at around 700 m asl and the first potato fields around 628 m asl, showing the diversity of use and crops utilized in this region in this period (Mayer, 1896).

In the 20th Century, more interventions were carried out in and around the lava flows. Following a forest fire in "Lomo de Abarzo" in 1910, subsequent reforestation efforts took place in the 1920s coordinated by the teachers of Arafo and Güímar (Rodríguez Delgado, 2013) which were followed in 1939 by the planting of over 3000 saplings of *Pinus canariensis* on the margins of the lava flows (Ayuntamiento de Arafo, 2020). The area in which this reforestation took place is probably inside the natural distribution area of *Pinus canariensis*, as noted in Ceballos & Ortuño (1951). They described in a map of the currently ongoing plantations in Tenerife the area between the municipalities of El Rosario, Candelaria, Arafo and Güímar are detailed to house a belt of naturally occurring pine forest with an upper zone with vast areas that could be repopulated.

This territory offers the possibility of studying the dynamics of the colonization processes which have been taking place for the last 300 years and analyzing the influence of climate change on this process. There are several vegetation studies of global character in this area (Viera y Clavijo, 1776; Ledrú, 1982; Mayer, 1896; Rivas-Martínez *et al.*, 2005; Del Arco *et al.*, 2006; Rodríguez Delgado, 2013). Therefore being of great interest to be able to precisely study the diverse communities which conform the vegetation landscape of this lava flows and being able to know about their successional dynamics.

The studied tree, *Pinus canariensis*, has a lot of outstanding properties, which make it an interesting study object. It is naturally occurring in nearly all of the seven Canary Islands, excluding Fuerteventura and Lanzarote. It played a vital role in the economy of the Canary Islands as a building material and fuel. The needles were and still are, regularly collected as sleeping ground for domestic farm animals, and afterward, as a fertilizer for crops. It is also widely known for its fire resistance and thick bark. All of this provides the Canarian pine the possibility to resprout after forest fires, which is a very beneficial development in geography prone to volcanic eruptions and extended drought periods in the summer (Climent *et al.*, 2004). Its long needles also help it cope with that last aspect, as it has been shown to be able to capture considerable amounts of water out of fog clouds, being even considered for implementation in suitable arid regions as a method to gain access to freshwater (Groth, 2010). A study by Aboal *et al.* (2000) in northern Tenerife demonstrated that throughfall under a canopy of *Pinus canariensis* represented up to 2.2 times the incident rainfall captured by a pluviometer in an open field at the same site. This capability, combined with its long and very deep roots and special physiological adaptations of the needles to resist drought, contributes to the ample distribution range of *Pinus canariensis* (Grill *et al.*, 2004). For instance, in the study area, we find natural pines occurring from 350 to 1500 m asl and many more above 2000 m asl as a result of the reforestation efforts cited above. Its ability to grow on the bare rock of the lava flows just 300 years after the initial eruption made us decide that it was necessary to study this phenomenon from a phytoecological and phytosociological perspective. This example for a colonization process underway through a tree species on recently developed soils could be of interest for understanding the dynamics which develop after landscape altering phenomenons such as a volcanic eruption in territories where such events are the norm.

The present publication has three distinct parts, coinciding with the objectives of the project: i) the study of the current vegetation which colonises the lava flow; ii) a morphometric and statistical study of 450 individual samplings of *Pinus canariensis*, to get a glimpse of the parameters which may influence the colonization process; iii) the cite of two new populations of *Himantoglossum metlisicsianum* for the island of Tenerife which was discovered during the field sampling process. Until now, the populations of this orchid for Tenerife were limited to north-western parts of the island; further populations can also be found on the island of La Palma and Gran Canaria (Mesa Coello, 2006; Acebedo & Mesa, 2013; Marrero *et al.*, 2019).

Material and Methods

Study area

The Arafo volcano is the result of several eruption episodes with different characteristics. In the first phase, it behaved in an explosive manner in which the actual volcanic structure, of around 100 meters in height, was formed and the posterior outpouring of the lava flows downhill which was a couple of meters short of reaching the Atlantic Ocean (ID Canarias, 2020) (Figure 1).

The new volcanic structure is organized in 9 distinct material strata, consisting, from the lower levels to the upper levels, of columnar basalts (3 meters), alluvial deposits, lapillis with bombs (50 cm), slag, slag with lapillis, lapillis without bombs, a newer lapillis and bombs strata and a final upper stratum of lapillis and fine material (Romero Ruiz, 1991) (Figure 2). This distinct stratification is expected to have an impact on the vegetation, depending on which stratum is present at the surface level in the different areas.

The study area belongs to the Canary Network of Protected Natural Areas (Legislative Decree, 2000) with two categories, the Corona Forestal Natural Park and the Siete Lomas Protected Landscape. It also belongs to the Natura 2000 Network (BOC, 2010) with the categories of Special Conservation Zone (ZEC) and Special Bird Protection Zone (ZEPA).

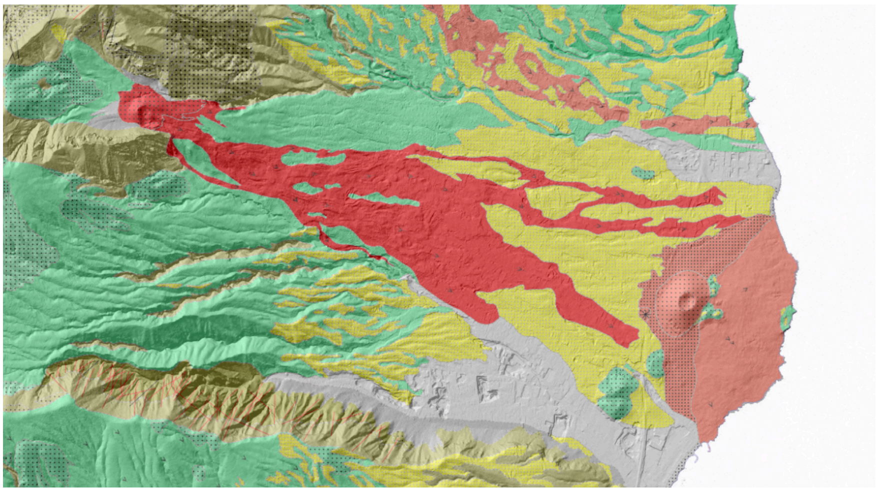

Figure 1. Arafo Volcano and lava flows formed after the 1705 eruption. (ID Canarias, 2020).

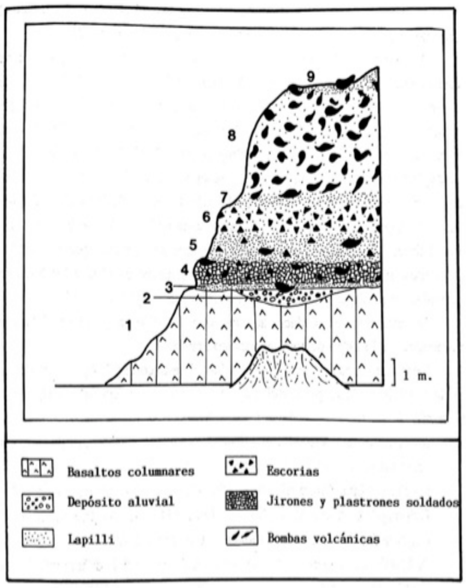

Figure 2. Profile with the nine types of strata of the Arafo volcano, according to Romero Ruiz (1991).

Bioclimatic study

For the bioclimatic study of the territory, the meteorological stations of Mena (Güímar), Barranco de Badajoz (Güímar), Topo (Güímar) and Barranco de Añavingo (Arafo) of the Agro-Cabildo (2020) agrometeorological network have been consulted.

Barranco de Badajoz (Güímar), situated at 340 m asl, has an annual precipitation of around 254 mm and a mean annual temperature of 18,8°C. The second station is the

Barranco de Añavingo (Arafo) station, located at 700 m asl with annual precipitation of 290 mm and a mean annual temperature of 16.4°C. From sea level to mountain tops, the climate corresponds to a Mediterranean macrobioclimate and the Bioclimatic Belts, Lower-semiarid Inframediterranean, Upper-semiarid Inframediterranean, Lower-dry Thermomediterranean and Lower-dry lower-Mesomediterranean (Rivas Martínez, 2009; Del Arco *et al.*, 2006; Del Arco & Rodríguez, 2018). It is important to note the frequent formation of a cloud belt ("mar de nubes"), which covers the Güímar valley in SE orientation and oscillates between 700 and 1200 m asl. In the SE-oriented territory, it is produced by the effect of overflow of trade fog and the valley effect that originates a particular microclimatic zone with the generation of a protective cover that moderates evaporation and generates an increase in atmospheric humidity. At an altitude of 700 m asl the Añavingo (AgroCabildo, 2020) meteorological station data shows between 0h and 14h a mean relative monthly humidity readout always above 55%, being the month of July the one where the minimum of 55% is registered and the month of June where a maximum of 83% is reached. In the period between 14- 24h, readouts are always above 65%, with a maximum also in June of 88% mean monthly relative air humidity.

Vegetation and flora survey

An altitudinal transect from 35 m to 1583 m asl was sampled. An undetermined number of phytosociological relevés (plots) were collected. The georeferenced disposition of the characteristic species of the main vegetation units, representing the potential vegetation of the territory were also recorded. The so-called "malpaíses" formed by relatively well-preserved lava flows of type "*aa*" located in the municipal areas of the towns of Güímar and Arafo included in the "Protected Landscape of the Seven Hills" ranging at an altitude between 800 and 1300 m asl.

The Canary Islands Biodiversity Data Bank (BDBC, 2020) has been used for the taxonomic study of flora. The phytosociological research was done following the Braun-Blanquet (1979) methodology. The first phase of analytical analysis through vegetation sampling on the field and the next synthetic step through the creation of phytosociological data tables. Afterward, the Geobotany Information System GBOTIS (Martín Osorio *et al.*, 2005) was used, through the ArcGis program, to georeference the phytosociological plots and the elaboration of maps.

During the field study, two new populations of the "orchid of Tenerife," *Himantoglossum metlesicsianum,* which is considered as "endangered," were found. Its locations have been georeferenced, and a morphometric study of each present at the populations was carried out.

Because of the inaccessibility of some places of the study area, a DJI Model Mavic 2 Zoom Drone was used to obtain information through images and videos of significant parts of the lava fields.

Measures of morphometric parameters

Four hundred fifty randomly chosen individuals of *Pinus canariensis* between 350 and 1567 m asl (Figure 3) were analyzed. The height and DBH (Diameter at breast height) of the trees were measured as well as the UTM coordinates and elevation above sea level.

Coordinates and elevation above sea level were logged in with a Garmin eTrex10 GPS, and the DBH measurements were used using a Richter fiberglass diameter measuring tape. Tree height was measured with said tape for the measurable trees and a BOSCH Professional GLM 50C laser distance measurer for the taller ones as well as the mobile app Arboreal.se for tree measurement, which was previously tested for accuracy. The data was subsequently analysed with statistical analysis program R Studio 1.2.1335 (R Core Team 2019) and Microsoft Excel for the digitalization of the data frames.

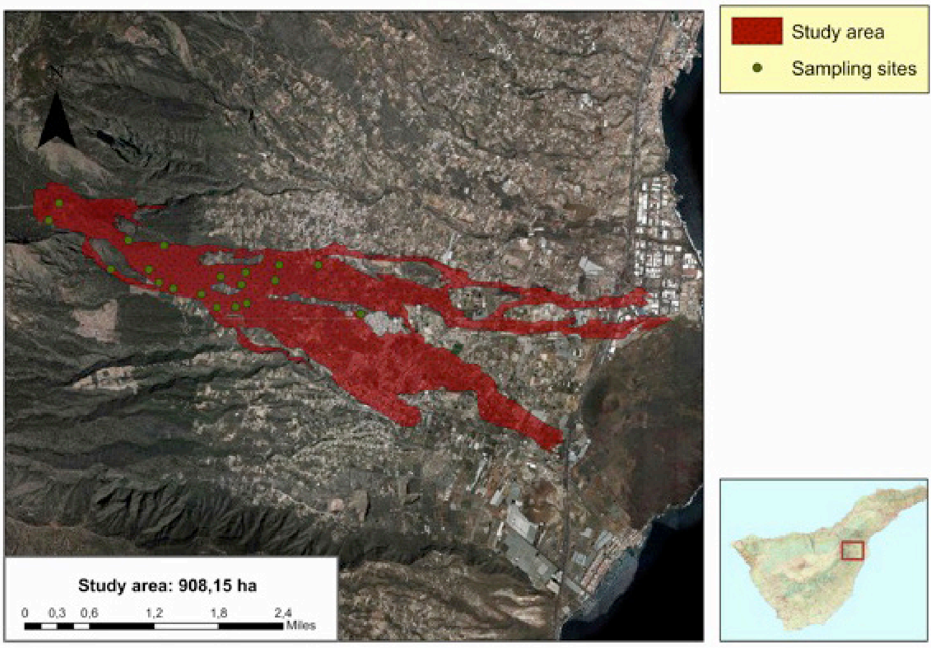

Figure 3. Approximate sampling points of *Pinus canariensis* (green circles).

Results and Discussion

Flora and vegetation survey

The floristic study of the territory shows the high level of existing endemicity, highlighting the pteridophytes group (Table 1). Of the total taxa cited in the text, 60% are endemic, with seven taxa are endemic of Tenerife island (Appendix 1).

The landscape is made out of a group of series (geosigmeta) and group of permaseries or permanent communities (geopermaseries), a set of communities concatenated across a framed altitudinal gradient; in this case, in a valley formed through a gravitational slide which has been filled by a basaltic lava flow. In some cases, it can constitute a vegetation complex, meaning a grouping of plant communities that share the same territory, or else, of several neighboring vegetation series, which are defined as a subserial geocomplex (Rivas Martínez, 2007).

Table 1. Main taxons of endemic macaronesian and canarian ferns.

Taxa	Distribution
Asplenium aureum Cav.	Macaronesian endemism
Allosorus fragilis Christenh. (=*Cheilanthes pulchella* Bory ex Willd.)	Macaronesian endemism
Consentinia vellea (Aiton) Tod. subsp. *bivalens* (Reichst.) Rivas-Martínez & Salvo	Endemic Canarian subspecies
Paragymnopteris marantae (L.) K.H. Shing subsp. *subcordata* Benl & Poelt var. *subcordata*	Tenerife and Hierro endemism

Taking this into mind, it is important to stress out that the vegetation which can be currently found on top of the recent lava flows is heavily influenced by that which is directly adjacent to such fields, thus being able to state that the landscape of the lava flows is made out of primo-colonizing communities and fragments of the communities around the lava streams. The pioneer community of *Pinus canariensis* is the most notable because of its high amplitude, ranging from around 393 to 1567 m asl in a surface of 908,15 ha aprox. Due to its abundance, the presence of lichens and rupicolous pteridophyte and *Crassulaceae* communities is also very remarkable. It can be precise, that the surrounding vegetation communities, which function as a species reservoir for the ongoing colonization of the lava flows are made out of the following vegetation series and seral stages:

Vegetation Series

- Cardón shrubland: *Periploco laevigatae-Euphorbio canariensis* S.
    - ○ Periploco laevigatae-Euphorbietum canariensis (Tenerife cardón spurge shrubland)
    - ○ Euphorbietum lamarckii (Wild spurge shrubland)
    - ○ Cenchro ciliaris-Hyparrhenietum sinaicae (Hemicriptophytic grassland)
    - ○ Artemisio thuscula-Rumicetum lunariae (Nitrophilous shrubland community)
- Canary pine forest: *Sideritido solutae-Pino canariensis* S. *ericetosum canariensis*
    - ○ Sideritido solutae-Pinetum canariensis ericetosum canariensis (Humid pine forest)
    - ○ Chamaecytisetum angustifolii (Retamoid mantle)
    - ○ Telinetum canariensis (Broom schrub community, dry-subhumid areas)
    - ○ Rumici maderensis-Pimpinelletum dendrotragii (Semi-sciophilous fringe community)
    - ○ Erysimo scoparii-Pterocephaletum lasiospermi (Lithosols and lapilli pioneers)
    - ○ Cistetum symphytifolii-canariensis (Lithosols. Thermic faciation)
    - ○ Hypochoerido glabrae-Tuberarietum guttatae (Non-nitrophilous therophytic community)
    - ○ Soncho microcarpi-Rumicetum lunariae (Humid nitrophilous shrubland community)
- Summit broom schrubland: *Descurainio bourgeauanae-Spartocytiso supranubii* S.
    - ○ Descurainio bourgeauanae-Spartocytisetum supranubii (Teide broom shrubland, lapilli recent volcanic)
    - ○ Erysimo scoparii-Pterocephaletum lasiospermi (Pioneer community on lithosol and lapilli)
    - ○ Arrhenathero calderae-Plantaginetum webbii (Pioneer community on scree and gelifracted roks)

Up next, we describe the new phytosociological associations and plant communities which make up the landscape of the territory:

Pioneer community of *Pinus canariensis* on historic lava flows

This pioneer community develops between 393 and 1567 m asl through the Infra-, Thermo- and Mesomediterranean bioclimatic belts and constitutes the most characteristic landscape of the lava flow (Figure 4). A deposit of pine needles litter (“pinocha”) allows other species to grow, similarly in the succession dynamic of the *Sideritido solutae-Pino canariensis* vegetation series where *Cistus symphytifolius* Lam. var. villosus Demoly and *Cistus monspeliensis* L. subsp. *canariensis* Rivas-Mart., Martín Osorio & Wildpret grow. This layer of pine needles, which can be up to several decimetres thick, helps maintain soil humidity thus also allowing elements of other communities, like the pioneer *Davallia canariensis* (L.) Sm. community to establish. Floristic elements such as *Erica canariensis* Rivas-Mart., Martín Osorio & Wildpret are found in the areas influenced by the sea of clouds, participating in the community *Sideritido-Pinetum canariensis ericetosum canariensis*.

Figure 4. Pioneer community of *Pinus canariensis* on historic lava flows.

***Cosentinio bivalentis-Paragymnopteretum subcordatae* ass. nova hoc loco**

Holotypus: Table 2, relevé 1.

Ultramafic (igneous rocks with low silica content) rupicolous community made out of pteridophytes, most of them canarian or macaronesian endemisms, on the recent lava flows in the Dry Thermo-Mesomediterranean belts. It is a non-nitrophilous community which develops on small grooves and narrow fissures where humidity is able to accumulate and last longer after rainfall. This community belongs to the *Cheilanthion pulchellae* alliance, which groups the canarian Infra-Mesomediterranean arid-dry chasmophytic ultramafic pteridophytic associations. It is characterised by *Consentinia vellea* (Aiton) Tod. subsp. *bivalens* (Reichst.) Rivas-Martínez & Salvo (Figure 5) and *Paragymnopteris marantae* (L.) K.H. Shing subsp. *subcordata* Benl & Poelt var. *subcordata* (=*Notholaena marantae* subsp. *subcordata* var. *subcordata*) (Figure 6) an endemic Canarian subspecies and endemic variety of the islands of El Hierro and Tenerife respectively. Described by Benl (1967) it has fronds of over 15 cm in length and paleas of a dirt to rust brown color. In 1983 Santos describes for the island of La Palma a community of *Cheilanthes marantae*, a chasmophytic vegetation of “malpaíses” (recent lava flows) accompanied by *Aeonium spathulatum* (Hornem.) Praeger in the territory belonging to a potential vegetation of *Cisto-Pinion canariensis*, the canarian pine forests. We consider that this community described for La Palma could be similar to the association hereby described. This community is distinguished from the *Adianto pusilli-Cheilanthetum pulchellae* Saenz & Rivas Martínez 1979 community by the absence of *Adiantum reniforme* subsp. *pusillum* and because the latter develops mainly on shady walls, sometimes oozing, from the domain of Monte Verde.

In this area, influenced by the sea of clouds, the presence of the association *Stereocauletum vesuviani* Klem. (*Stereocaulion ramulosi* Matt.) is frequent, covering the volcanic rocks in NE orientation.

Figure 5. *Consentinia vellea* subsp. *bivalens* and *Allosorus fragilis.*

Figure 6. *Cosentinio bivalentis-Paragymnopteretum subcordatae.*

Table 2. *Cosentinio bivalentis-Paragymnopteretum subcordatae* ass. nova
(*Cheilanthion pulchellae*, *Notholaeno maranthae-Cheilanthetalia maderensis*, *Asplenietea trichomanis)*

Altitude (m asl)	1140	1144	1150	1140	1144	1151	1037	1149	793
Plot size (m^2)	50	20	20	50	20	20	10	20	20
Total cover (%)	85	90	90	85	90	90	90	90	10
Inclination (%)	30	30	30	30	30	30	30	30	20
Exposure	SE	NE	NE	SE	NE	NE	SE	NE	NE
Species N.	11	10	10	8	8	7	6	5	4
Relevé N.	1	2	3	4	5	6	7	8	9
Characteristics of association									
Cosentinia vellea subsp. *bivalens*	2	2	+	1	3	+	2	1	3
Paragymnopteris marantae subsp. *subcordata* var. subcordata	4	3	1	1	2	2	3	3	.
Characteristics of *Cheilanthion pulchellae*									
Allosorus fragilis	1	2	2	3	3	2	.	3	1
Characteristics of *Aeonietea*									
Aeonium arboreum subsp. *holochrysum*	1	+	1	1	1	1	1	+	.
Aeonium spathulatum	.	.	.	.	1	.	2	.	.
Asplenium aureum	.	.	.	1	.	.	.	.	.
Companions									
Stereocaulon vesuvianum	3	4	5	3	2	5	5	3	.
Umbilicus gaditanus	1	+	1	+	.	2	.	.	.
Cladonia rangiferina gr.	1	3	+	.	.	1	.	.	2
Cladonia pixidata gr.	2	1	+	.	.		.	.	.
Bryophytes	3	2	1	.	.	.	.	.	.
Davallia canariensis	.	.	.	.	.	.	3	.	3
Polypodium macaronesicum	.	.	3	.	+	.	.	.	.

Companions: *Sideritis oroteneriffae* and *Pterocephalus lasiospermus* + in 1; *Rumex lunaria* + in 4; *Sonchus acaulis* 1 in 5.

Localities: All plots are from Lava flows Arafo volcano (Tenerife, Spain). UTMs and date are: 1: 28R0359280/3134834, 15/12/19, *holotypus ass.*; 2: 28R0357571/3134850, 15/2/20; 3: 28R0357569/134864; 4: 28R0359280/3134834, 15/12/19; 5: 28R0357567/3134851, 15/2/20; 6: 28R0357571/3134846, 15/2/20; 7: 28R0358357/3135190, 29/12/19; 8: 28R0357568/3134856, 15/2/20; 9: 28R0359205/31134744, 8/1/20.

Soncho microcarpi-Rumicetum lunariae ass. nova hoc loco

Holotypus: Table 3, relevé 2.

Shrubby pioneer community in Thermo-Mesomediterranean zones under the influence of the "mar de nubes", a fog belt which fluctuates between 700-1200 m asl and which is fairly consistent appearing all year round in the Semiarid-Dry Thermo- and Mesomediterranean belts. It replaces the *Artemisio thusculae-Rumicetum lunariae* community at this higher altitude. The characteristic species are *Sonchus microcarpus* (Boulos) U. Reifenb. & A.

Reifenb., insular endemism, and *Rumex lunaria* L. The first species, although being a species-typical for *Kleinio-Euphorbietea* has been recorded up to a height of 1150 m asl on SE orientations. The other species, *Rumex lunaria*, colonizes, sometimes by itself, the "*aa*" lava flows abundantly. The community described on lapilli in Del Arco & O. Rodríguez (2018) and Del Arco *et al.* (2006) of *Rumex lunaria* for the island of El Hierro might be similar to this association. The pioneering character of *Rumex lunaria* has also manifested in the recent lava flows of the National Park of Timanfaya on the island of Lanzarote. There it is acting as a sort of non native plant because there are no records of this plant occurring naturally on the eastern Canary Islands until it was imported from the island of El Hierro as a grazing plant for livestock and is now considered a serious and expanding problem (Wildpret *et al.*, 1995).

Table 3. *Soncho microcarpi-Rumicetum lunariae* ass. nova
(*Artemisio thusculae-Rumicion lunariae, Forsskaoleo-Rumicetalia lunariae, Pegano-Salsoletea)*

Altitude (m asl)	941	1140	792	800
Plot size (m^2)	60	100	50	50
Total cover (%)	90	30	30	30
Inclination (%)	5	30	45	45
Exposure	S	SE	S	S
Species N.	15	12	8	6
Relevé N.	1	2	3	4
Characteristics of association				
Sonchus microcarpus	2	1	1	1
Rumex lunaria	2	3	3	3
Characteristics of *Artemisio-Rumicion*				
Argyranthemum foeniculaceum	1	.	2	.
Lavandula canariensis subsp. *canariensis*	.	.	1	3
Characteristics of *Cisto-Pinion*				
Cistus symphytifolius	2	+	2	.
Descurainia lemsii	2	1	.	.
Pinus canariensis	+	1	.	.
Cistus monspeliensis subsp. *canariensis*	1	.	.	.
Teline canariensis	2	.	.	.
Characteristics of *Rhamno-Oleetea* cerasiformis				
Jasminum odoratissimum	3	.	.	.
Rubia fruticosa	2	.	.	.
Characteristics of *Aeonietea*				
Aeonium arboreum subsp. *holochrysum*	3	1	3	3
Pericallis lanata	2	.	.	.
Sonchus acaulis	.	1	.	.
Companion				
Echium virescens	2	1	1	.
Paragymnopteris maranthae subsp. *subcordata* var. *subcordata*	.	2	.	.
Allosorus fragilis	.	1	.	.
Polypodium macaronesicum	.	1	.	.
Umbilicus gaditanus	.	1	.	.
Micromeria hyssopifolia	3	.	.	3
Periploca laevigata	.	.	.	3
Davallia canariensis	.	.	2	.
Bencomia caudata	3	.	.	.

Localities: All plots are from Lava flows Arafo volcano (Tenerife, Spain). UTMs and date are: 1: 28R0358459/3134542, 15/2/20; 2: 28R0359258/3134873, 15/2/20, *holotypus ass.*; 3: 28R0359083/3134315, 15/2/20; 4: 28R0359046/3134902, 15/2/20.

***Aeonium arboreum* subsp. *holochrysum* community**

Pioneer community on recent lava flows made out of *Aeonium arboreum* (L.) Webb & Berthel. subsp. *holochrysum* (H.Y.Liu) Bañares, a succulent chamaephyte which develops on lava flow cracks through the Semiarid-Dry, Infra-Thermo-Mesomediterranean bioclimatic belts. During the flowering season (January-March) it becomes landscape defining as its yellow flowers contrast with the blackness of the basalt underneath. (Figures 7, 8).

Figure 7. Pioneer community of *Aeonium arboreum* subsp. *holochrysum* and *Stereocauletum vesuviani.*

Figure 8. Flower of *Aeonium arboreum* subsp. *holochrysum.*

***Davallia canariensis* pioneer community**

This pioneer community develops in the walls cracks of volcanic lava flows, which have a northeastern exposure and are thus enriched by the humidity brought by the trade winds coming from that direction (Figure 9). They also develop on "pinocha" (large deposits of pine needles), which is accumulated on the base of individuals of *Pinus canariensis* C. Sm. ex DC. in Buch of certain size. The community consists of, mostly, isolated individuals of *Davallia canariensis* between 500 to 1200 m asl through the Dry Thermo-Mesomediterranean belts.

Figure 9. Pioneer community of *Davallia canariensis*.

Echium virescens pioneer community

Another pioneer community that develops on lapillis and lapillis with volcanic bombs starting at around 1200 m asl (Figure 10). It is a community found in the accumulation zones near the slopes of the volcanic cone on the Dry Mesomediterranean belts. One of the characteristics of this lapillis is that they are very hygroscopic, which allows the edaphic humidity to stay relatively high. Therefore, this land has also been used as a cultivation area for Chestnut trees, *Castanea sativa* Mill., which is very much enjoyed in local gastronomy.

Figure 10. *Echium virescens* pioneer community on lapillis.

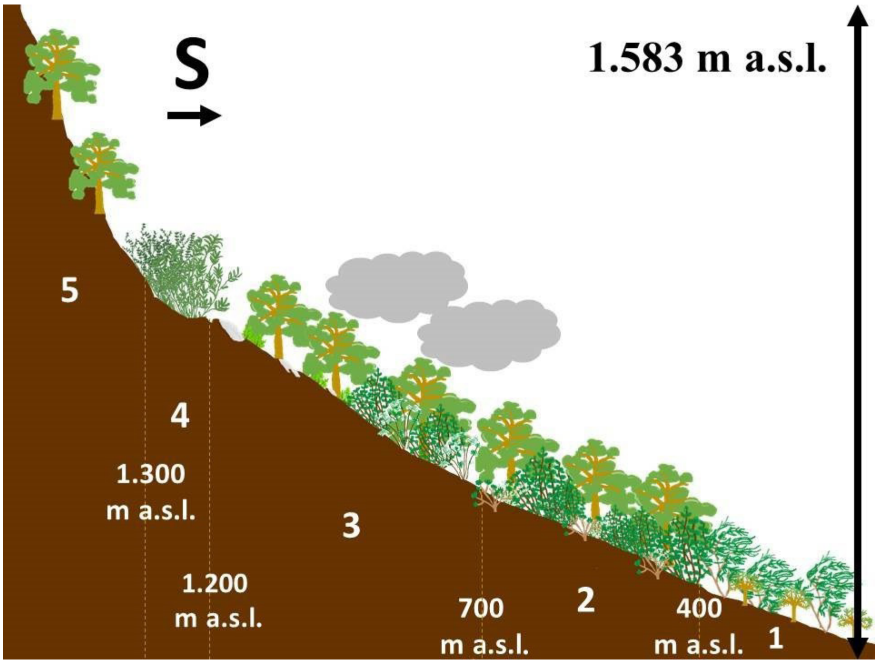

Figure 11. Current vegetation on the lava flow.

The vegetation transect of the current plant communities on the lava flow is distributed along the bioclimatic belts as follows (Figure 11):

1. Lower-semiarid Inframediterranean: Fragments of adjacent climatophilous vegetation *Periploco laevigatae-Euphorbietum canariensis*, fragments of adjacent vegetation *Ploclametum pendulae*, wild spurge shrubland *Euphorbietum lamarckii,* grasses community *Cenchro ciliaris-Hyparrhenietum sinaicae.* Up to 400 m asl
2. Upper-semiarid Inframediterranean: *Artemisio thusculae-Rumicetum lunariae*, pioneer community of *Aeonium arboreum* subsp. *holochrysum,* pioneer community of *Pinus canariensis.* Up to 700 m asl.
3. Lower-dry, upper-dry Thermomediterranean (with trade wind clouds): *Soncho microcarpi-Rumicetum lunariae,* fragments of adjacent vegetation *Cistetum symphytifolio-canariensis,* pioneer community of *Pinus canariensis,* pioneer community of *Aeonium arboreum* subsp. *holochrysum,* pioneer community of *Davallia canariensis, Cosentinio bivalentis-Paragymnopteretum subcordatae, Davallio canariensis-Polypodietum macaronesici, Stereocauletum vesuviani.* Up to 1200 m asl.
4,5. Lower-dry, lower-Mesomediterranean: Pioneer community of *Pinus canariensis,* retamoid mantle fragments of adjacent vegetation *Chamaecytisetum angustifolii, Cosentinio bivalentis-Paragymnopteretum subcordatae*, pioneer community of *Echium virescens.* Up to 1583 m asl.

The riverbed of the Barranco de Cosme at 1477 m asl was inventoried in the stratum corresponding to the alluvial deposits that surround the Arafo Volcano, the association of Teide broom shrubland, lapilli recent volcanic *Descurainio bourgeauanae-Spartocytisetum supranubii*.

A Syntaxonomic Scheme based on inventories is presented, done on the lava flows and its adjacent zones. It comprises nine phytosociological classes, ten orders, 15 alliances, 18 associations, and four pioneer communities:

Syntaxonomic scheme

AEONIETEA A. Santos 1976 [nom. mut. propos.] (*Greenovio-Aeonietea* Santos 1976, An. Inst. Bot. Cavanilles 33: 358. Art. 45, ICPN, Weber *et al.* 2000)

Soncho acaulis-Aeonietalia Rivas Goday & Esteve ex Sunding 1972 [nom. mut. propos.]

Aeonion aureae A. Santos ex Rivas-Martínez *et al.* 1993 [nom. mut. propos.] (*Greenovion aureae* A. Santos ex Rivas- Martínez *et al.* 1993, Itinera Geobotanica 7: 313. Art. 45, ICPN)

Aeonietum aizoi Rivas-Martínez *et al.* 1993 [nom. mut. propos.] (*Greenovietum aizoii* Rivas-Martínez *et al.* 1993, Itinera Geobotanica 7: 316. Art. 45-ICPN)

Soncho acaulis-Aeonion Sunding 1972 [nom. mut. propos.] (*Soncho-Sempervivion* Sunding 1972, Skr. Vidensk.-Akad Oslo, Mat-Naturvidensk Kl, N.S. 29: 94. Art. 45, ICPN)

Aeonium arboreum subsp. *holochrysum* pioneer community nova

ANOMODONTO VITICULOSI-POLYPODIETEA CAMBRICI Rivas-Martínez 1975

Anomodonto viticulosi-Polypodietalia cambrici O. Bolòs & Vives in O. Bolòs 1957

Polypodion cambrici Br.-Bl. *in* Br.-Bl., Roussine & Nègre 1952 [nom. mut. propos.]

Davallio canariensis-Polypodietum macaronesici Rivas-Martínez, Wildpret, Del Arco, O. Rodríguez, Pérez de Paz, García Gallo, Acebes, T.E. Díaz & Fernández-González ex Capelo *et al.* 2000

Davallia canariensis pioneer community nova

ASPLENIETEA TRICHOMANIS (Br.-Bl. in Meier & Br.-Bl. 1934) Oberdorfer 1977

Notholaeno marantae-Cheilanthetalia maderensis (Sáenz & Rivas-Martínez 1979) Rivas-Martínez & col. 2011

Cheilanthion pulchellae Sáenz & Rivas-Martínez 1979

Cosentinio bivalentis-Paragymnopteretum subcordatae ass. nova

CHAMAECYTISO-PINETEA CANARIENSIS Rivas Goday & Esteve ex Esteve 1969 [nom. mut. propos.]

Chamaecytiso-Pinetalia canariensis Rivas Goday & Esteve ex Esteve 1969 [nom. mut. propos.]

Cisto symphytifolii-Pinion canariensis Rivas Goday & Esteve ex Esteve 1969

Sideritido solutae-Pinetum canariensis Esteve 1973

subass. *pinetosum canariensis* [*typicum*]

subass. *cistetosum canariensis* (Del Arco, Pérez de Paz & Wildpret 1987) Rivas-Martínez *et al.* 1993 [*nom. mut. propos.*]

subass. *ericetosum canariensis* (Del Arco, Pérez de Paz & Wildpret 1987) Rivas-Martínez *et al.* 1993

Pinus canariensis on historic lava flows pioneer community nova

Telino canariensis-Adenocarpion foliolosi Rivas-Martínez *et al.* 1993

Chamaecytisetum angustifolii Del Arco, Pérez de Paz, O. Rodríguez, Salas & Wildpret 1992 nom. prov.

Telinetum canariensis Del Arco & Wildpret 1983

Echium virescens pioneer community nova

Spartocytisetalia supranubii Schönfelder & Voggenreiter 1994

Plantaginion webbii Martín Osorio, Wildpret & Rivas Martínez in Martín Osorio *et al.* 2007

Pterocephalenion lasiospermi Martín Osorio, Wildpret & Rivas Martínez in Martín *et al.* 2007

Arrhenathero calderae-Plantaginetum webbii Martín Osorio & Wildpret in Martín Osorio & B. Hernández 2003

Erysimo scoparii-Pterocephaletum lasiospermi Rivas-Martínez *et al.* 1993

Spartocytision supranubii Oberdorfer ex Esteve 1973 [nom. mut. propos.]

Spartocytisetum supranubii Oberdorfer ex Esteve 1973 [nom. mut. propos.] subass. typicum

subass. *descurainietosum lemsii* Martín Osorio & Wildpret in Martín Osorio *et al.* 2007

Descurainio bourgeauanae-Spartocytisetum supranubii (Esteve in 1973) Martín Osorio, Wildpret & B. Hernández in Martín Osorio *et al.* 2007

KLEINIO NERIIFOLIAE-EUPHORBIETEA CANARIENSIS (Rivas Goday & Esteve 1965) A. Santos 1976

Kleinio neriifoliae-Euphorbietalia canariensis (Rivas Goday & Esteve 1965) A. Santos 1976

Euphorbion regisjubo-lamarckii Rivas-Martínez, Wildpret, O. Rodríguez & Del Arco in Rivas-Martínez & col. 2011

Euphorbienion regisjubo-lamarckii Rivas-Martínez, Wildpret, O. Rodríguez & Del Arco in Rivas-Martínez & col. 2011

Euphorbietum lamarckii Del Arco & O. Rodríguez in Del Arco *et al.* 2006 nom. prov.

Plocamenion pendulae Rivas-Martínez, Wildpret, O. Rodríguez & Del Arco in Rivas-Martínez & col. 2011

Plocametum pendulae M.C. Marrero, O. Rodríguez & Wildpret 2003

Kleinio neriifoliae-Euphorbion canariensis (Rivas Goday & Esteve 1965) A. Santos 1976

Aeonio-Euphorbienion canariensis (Sunding 1972) A. Santos & Rivas-Martínez in Rivas-Martínez & col. 2011

Periploco laevigatae-Euphorbietum canariensis Rivas-Martínez *et al.* 1993

subass. *euphorbietosum canariensis* [typicum]

LYGEO SPARTII-STIPETEA TENACISSIMAE Rivas-Martínez 1978 [nom. conserv. propos.]

Hyparrhenietalia hirtae Rivas-Martínez 1978

Hyparrhenion sinaicae Br.-Bl., P. Silva & Rozeira 1956 *corr.* J.C. Costa, Capelo, Espírito-Santo & Lousã 2001

Cenchro ciliaris-Hyparrhenietum sinaicae Wildpret & O. Rodríguez *in* Rivas-Martínez *et al.* 1993 *corr.* Díez-Garretas & Asensi 1999

subass. *hyparrhenietosum sinaicae* [typicum]

PEGANO HARMALAE-SALSOLETEA VERMICULATAE Br.-Bl. & O. Bolòs 1958

Forsskaoleo angustifoliae-Rumicetalia lunariae Rivas-Martínez *et al.* 1993

Artemisio thusculae-Rumicion lunariae Rivas-Martínez *et al.* 1993

Artemisio thusculae-Rumicetum lunariae Rivas-Martínez *et al.* 1993

Soncho microcarpi-Rumicetum lunariae ass. nova

RHAMNO CRENULATAE-OLEETEA CERASIFORMIS A. Santos ex Rivas-Martínez 1987 [nom. inv. propos.]

Micromerio hyssopifoliae-Cistetalia canariensis Pérez de Paz, Del Arco & Wildpret 1990 *corr.* Rivas-Martínez, Martín & Wildpret in Rivas-Martínez & col. 2011

Micromerio hyssopifoliae-Cistion canariensis Pérez de Paz, Del Arco & Wildpret 1990 *corr.* Rivas-Martínez, Martín & Wildpret in Rivas-Martínez & col. 2011

Cistetum symphytifolio-canariensis Rivas-Martínez *et al.* 1993 *corr.* Rivas-Martínez in Rivas-Martínez & col. 2011

Trifolio-geranietea sanguinei T. Müller 1962

Origanetalia vulgaris Müller 1962

Ranunculo cortusifolii-Geranion canariensis Rivas-Martínez *et al.* 1993

Rumici maderensis-Pimpinelletum dendrotragii Rivas-Martínez *et al.* 1993

Pinus canariensis morphometric survey

The analysis of the frequency with different steam diameter groups (0-5 cm, 6-10 cm, etc.) (Figure 12) shows a decreasing tendency in tree frequency from lower to bigger diameter, being the highest diameter around 20 cm. There are only a few singular trees of more than 60 cm stem diameter, having the biggest 108 cm. Three hypotheses can explain this behavior; the first is that an increase in mortality in pine trees with increasing stem diameter, which we believe is the least likely scenario, due to the near-complete lack of visible dead trees in the study area, with just one recorded. This does not take into account seedling mortality, which is yet to be determined in this study. The second one is an acceleration of the colonization process in that each generation is more numerous than the previous one. Mature trees already present in the lava field are therefore responsible for an ever-increasing percentage of the new trees establishing in this terrain relative to the ones setting out of adjacent populations. This explanation seems to be likely due to the sometimes often clustered colonization of the lava field with bigger individuals usually surrounded by smaller pines of different sizes. The last hypothesis would be that most pines are severely impaired in their growth and are older than what their stem diameter might suggest. Older individuals would be explained through a more favorable location or altitude, which can contribute to the trees growing until they reach the soil beneath the basaltic flow and are able to access the nutrients and water supplies present in those lower levels. This last point could be playing a more prominent role in the trees found below 700 m asl (Figure 13, 14) as they have to tolerate lower precipitation and relative air humidity, meaning that they probably are being limited in their growth rate by this and other factors as further discussed below. Although a stem analysis showing that *P. canariensis* exhibits a typically fast-growing juvenile stage has to be taken into account, where growth of up to 2 cm per year in diameter and 1 m per year in height even in more xeric conditions was recorded (Climent *et al.*, 2004). It is very likely that all these hypotheses play a bigger or smaller part in conjunction with the others so we aim to expand upon this in the future to see how a pine forest naturally establishes.

For further visualization, the data was plotted against the altitude at which it was recorded. From this representation many aspects stand out. For example, the arrangement of the data in columns at specific heights indicates the different areas which were sampled and how, in each area, the trees were clumped at a similar altitude, despite covering a wide stem diameters range. It is also consistent with our observations that tree clumps in the lava flow harbor individuals of all age groups, as seen in Figure 13, from saplings to mature and occasionally older, much bigger individuals.

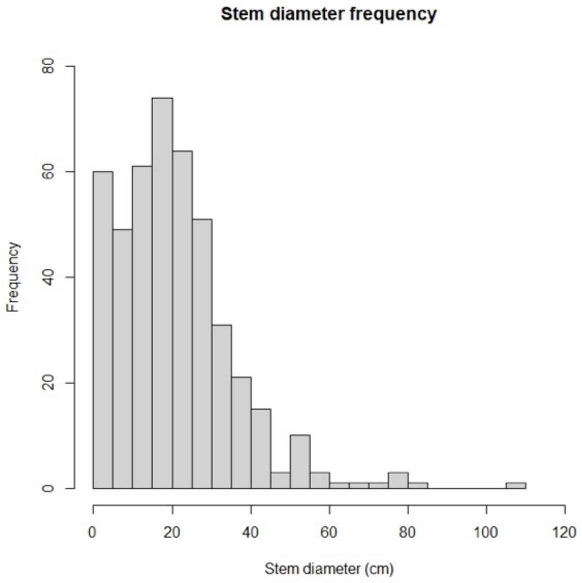

Figure 12. Steam diameter frequency in *Pinus canariensis*. The trees have automatically been divided in groups from 0 to 120 cm with 5 cm intervals.

Another factor, which stands out, is the visible gap between the 1200 and 1400 mark, which extends to approximately 1500 m asl. This is due to the presence of the *Castanea sativa* plantations mentioned above, which lay exactly in this altitudinal range and make use of a very different soil composition out of fine volcanic material in comparison to the hard and bare basalts of the lava flows further below. The trees found above the 1400 mark are the only ones that were found growing on this different kind of soil, and all belong to a small group of small trees present on the volcanic cone, one of them being near the top at 1567 m asl At this height and just a couple tens of meters away, there is a dense pine tree plantation which borders the volcanic cone, and from where we believe, the seeds for these trees originated.

Mueller-Dombois & Boehmer (2013) carried out similar observations in the Hawaiian archipelago, which are worth comparing to the observations made in the lava fields of Arafo. A couple of aspects are strikingly similar like an early lichen characterized colonization stage dominated by *Stereocaulon vesubianum* and succession through tree and fern stages, albeit with different taxons that act as vicariants. In both regions, the existence of vegetation islands that remained uncovered by the lava flows could be observed. It is probable that isolated trees on these islands exercise more pressure through their propagules for the colonization of their immediate surroundings, as has been proved by Mueller-Dombois & Boehmer (2013) for recent lavas in tropical bioclimates. The main differences rely on the bioclimatic conditions of both research sites and the speed at which different stages kick in.

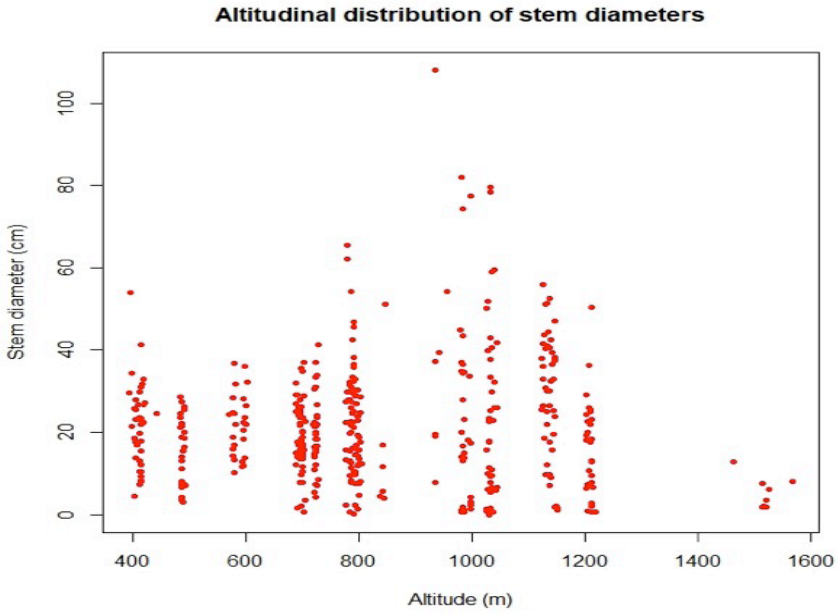

Figure 13. Raw representation of single data points (trees) in relationship between stem diameter distributed through altitude.

A consequence of this could be the fact that the trees present in the lava fields of Arafo are heterogeneous in size and age. In contrast, the tree colonization processes in Mueller-Dombois & Boehmer (2013) occurs synchronically, maybe as a consequence of the different pluviometric regime. We would like to implement many of the ideas proposed in the paper in future work, like a comprehensive analysis of the edaphization process, assessment of the historically recorded climatic data and the establishment of permanent and temporal plots to observe the exact development of this ecosystem and be able to make a proper comparison between the two volcanic archipelagos. As of today, our work only represents but a snapshot of the ecosystem dynamics taking place, but we aim to improve and expand our data sets in the years to come.

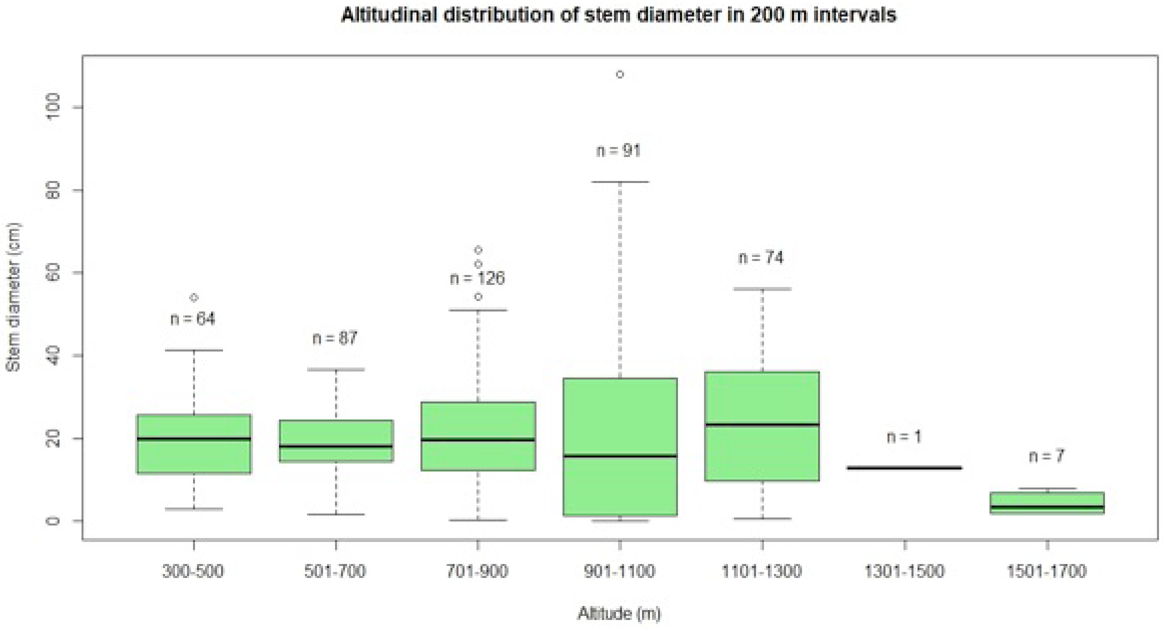

Figure 14. Boxplot representation of the altitudinal distribution of stem diameter in *Pinus canariensis*. Each interval covers 200m in altitudinal difference.

The most notable aspect, which can be seen in both Figure 13 and Figure 14, is the increase in the number of thicker, and therefore probably older, trees in the range between 700 and 1300 m asl This is highly interesting because it coincides with the distribution of the lichen *Stereocaulon vesuvianum* which is a powerful bioindicator of the increased humidity on this altitudinal range due to the effects of clouds which form in the valley and rest between these altitudes. A high correlation was found to exist between annual rainfall, fire frequency, serotiny, and bark thickness (Climent *et al.,* 2004).

The meteorological station of Añavingo (AgroCabildo, 2020) at 700 m asl, which has maximal monthly humidity registers of up to 96% in the month of June, also supports this idea. Further bioindicators for this increased atmospheric humidity are present in the form of increased diversity in hygrophilous communities of bryophytes and lichens (*Coelocaulon aculeatum, Cladonia* (*rangiformis* and *pyxidata* groups)*, Diploschistes bryophillus, Squamarina cartilaginea, Anaptychia* sp.) and floristic elements like *Erica canariensis, Morella faya* and *Bencomia caudata*, which although more abundant outside can also be found growing in the lava flows. The indication that in this range *Pinus canariensis* groups are especially healthy can be seen in the 901-1100 interval in Figure 14. Many of the biggest trees sampled were located in that range, and it can be seen from the boxplot that there are many trees with different stem diameters, indicating a high presence of younger individuals. This altitudinal distribution also fits very well with the described natural potential distribution of *Pinus canariensis* (Del Arco *et al.*, 2006). It leads us to think that the most successful colonization processes of the lava flow by *Pinus canariensis* is taking place at this altitudinal range. While it is capable of colonizing with success lower and higher altitudes, this is where it is at its highest potential. Furthermore, we believe that the lack of competition in the lava flow is allowing *Pinus canariensis* to exploit its tolerance range to adverse abiotic conditions as many of its competitors at lower and higher altitudes do not have the characteristics needed to survive in this kind of environment, but which are present in *Pinus canariensis.* For example, very deep roots to search for water and a very effective stomatal regulation system, adaptable leaf morphology depending on location and regulation of secondary metabolites concentration to resist the intense drought periods (Grill *et al.*, 2004; Jiménez *et al.*, 2005), which are probably even more severe due to the lack of a humidity accumulating soil in the lava flows. This point is further supported by observational evidence made at different altitudes on the vegetation surrounding the lava flow across the lava fields. It can see how the climatophilous adjacent vegetation provides the characteristic elements for each vegetation belt. Above the potential area of the pine forest, characteristic elements of "escobonal", *Chamecytisetum angustifolii,* and the "retamar", *Descurainio-Spartocytisetum supranubii* and on lower elevations fragmented elements of Laurel forest, "fayal-brezal" (substitutional shrubland with *Erica canariensis* and *Morella faya*) and even *Telinetum canariensis* appear, as well as the pioneer communities stages of the Artemisio-Rumicion (*Artemisio-Rumicetum lunariae* and *Soncho microcarpi-Rumicetum lunariae*). Below 700 m asl *Pinus canariensis* becomes increasingly difficult to find outside of the lava flow, albeit human intervention certainly has contributed to this fact.

Figure 15. Younger trees show a more yellowish tint than older ones due to lack of nutrients.

Nonetheless, one aspect remains unanswered, namely the age distribution of the pines sampled. An orientative correlation between stem diameter and age of the trees is clear for the altitudinal range between 700 and 1300 m asl (due to the presence and morphology of especially large individuals), it is not as clear what the situation is at lower and higher altitudes and also for a few extraordinary individuals which were recorded growing on top of massive volcanic bombs, nearly completely devoid of substrate. These trees are tiny in size but are probably much older than similarly sized individuals in other parts of the field study. The rest of the trees applies that due to the fact that pine trees on the lava flow are not as abundant above 1200 m asl the previous question focuses mainly on those below 700 m asl. All trees are certainly under hydric-stress and also have a visible lack in nutrients, which manifests through a yellow coloration of the needles as had been previously described in Oren & Schulze (1989) (Figure 15). Larger individuals on the lava flow and the ones outside of it do not show, or in a reduced way, this yellowish tint. It could be because such bigger individuals have managed to dig through the layer of basaltic materials and access the nutrient reserves which were buried by the volcanic eruption. Because of this fact we would like to propose and carry out in the future, an age sampling of several of the trees which have already been sampled in order to see if the lava flows have been colonised simultaneously at different altitudes or if in the more suitable range between 700 and 1300 m asl pine colonisation started sooner. Another way of looking at this question is if pine trees located outside the preferable altitudinal range of *Pinus canariensis,* where more water is available, are, in fact, younger or have had a slower growing rhythmus due to harsher abiotic conditions. This would hopefully lead us to a better understanding of how the colonisation dynamics work and allow us to compare it to other areas which have experienced recent volcanic events like the Chinyero, near the town of Santiago del Teide, which also has a cone at a very similar altitude of 1561 m asl but is much younger, erupting for the last time in 1909.

New populations of *Himantoglossum metlesicsianum* (W. P. Teschner) P. Delforge

Himantoglossum metlesicsianum, also known as "orchid of Tenerife" or "orchid of Chío" is a geophyte, perennial bulbous plant, with a basal leaf rosette and an erect and robust spike about 40 to 60 cm in height. It has relatively big, ornate flowers in a purple to pinkish color. Its seeds are very numerous and minute about 0.5 mm (author measurement). At first, it was considered endemism exclusive to the island of Tenerife. Still, the reports about population findings on the island of La Palma (Acevedo & Mesa, 2013) and very recently in the pine forest of Tamadaba, Gran Canaria (Marrero *et al.*, 2019, Muer *et al.,* 2016) have changed that perception. It is now considered as a Canarian endemism.

It is a very endangered species being listed in the Annex I of the Bern Convention and in the Spanish Catalogue of endangered species (Anon., 2011) and the Canarian Catalogue of endangered species (Anon. 2010) as "Endangered".

During the pine sampling in the study area, two new populations have been recorded for *Himantoglossum metlesicsianum.* Both of them are located in an altitudinal range of 1200 to 1400 m asl. The first one is in the upper region of Güímar (Altos de Güímar) at around 1200 m asl; it was there where the study of this population first began in 2019, observing up to 54 individuals. In the year 2020, monitoring is further carried out, noting a 43% increase in the number of individuals up to 97, of which 39,2% developed flower.

Afterward, a new population was located within the boundaries of the municipality of Arafo, mounting 22 individuals, three of them bearing an inflorescence. These individuals were located at 1400 m asl under an artificially repopulated pine forest (Figure 16). A single individual is isolated from the rest in a rockier terrain on the steep slopes of a neighboring ravine.

Figure 16. *Himantoglossum metlesicsianum* on pine needles layer (pinocha) in a *Pinus canariensis* forest.

The phenological cycle has a duration of about six months. The first leaves can be observed around the month of October, and afterward, the development of the inflorescence occurs during the month of November. The inflorescence holds around 30 to 50 flowers, depending on the size of the plant. Bigger orchids hold approximately 60 flowers, with a lip about 1,5 cm in length. The most significant sizes for the inflorescence was measured for Güímar at 96 cm height and the Arafo population at around 81 cm. This size was achieved before the end of the flowering period.

The central menace which lays upon the species is undoubtedly the poaching of wild individuals by exotic plant enthusiasts (Mesa, 2006). During the flowering period, especially in more accessible sites, the plant is dug out of the ground due to its "showy" inflorescence. We think it is highly probable that the decrease of recorded individuals in the Santiago del Teide population, in the core situated beneath town graveyard, can be attributed to those uncontrolled acts of poaching. Another risk factor that potentially looms over this species is the consequences of prolonged drought periods, which might lead to the death of individuals. Forest fires are an additional risk factor. The forest fire registered in 2007 seems to have had a notable impact on the species, as shown in a comparative population study between 2004 and 2012 (Krops *et al.,* 2012). Overall it seems that the population dynamic is currently recessive. These new populations are found on a 10 x 10 km grid (28R350000/3130000), in an altitudinal range between 1200 and 1400 m asl (Figure 17).

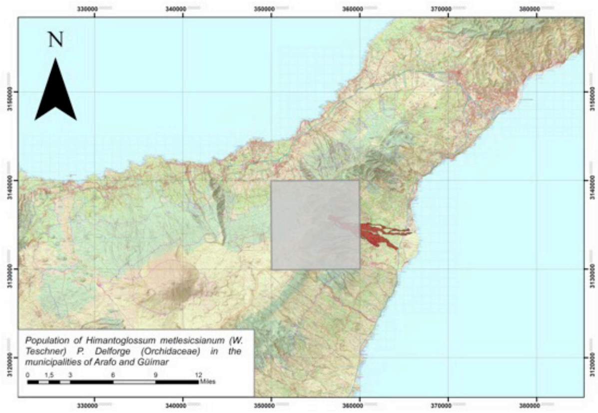

Figure 17. Distribution grid of *Himantoglossum metlesicsianum* new populations in Arafo and Güímar.

Conclusions

The vegetation which colonizes the recent lava flows of the Arafo volcano is formed by a vegetation complex where pioneer communities stand out. The landscape is mainly made up of the pioneer community of *Pinus canariensis,* which has a wide altitudinal range from 390 m asl to just over 1500 m asl. It is followed by the lichen communities of *Stereocauletum vesuviani* on basalts initially oriented to the humid trade winds which come from the NE and the pioneer community of *Aeonium arboreum* subsp. *holochrysum* growing in the fissures of the lava field. A new pioneer association is described: *Soncho microcarpi-Rumicetum lunariae*, which replaces the *Artemisio-Rumicion* above 700 m asl. At this height, an increase in relative air humidity takes place influenced by the cloud layer, which forms regularly in this area and which promotes the establishment of pioneer fern communities made out of macaronesian and canarian endemisms like *Cosentinio bivalentis-Paragymnopteretum subcordatae.* Above 1200 m asl the effect of the soil composed of the accumulation of lapilli and the descend in humidity leads to the switch in the pioneer communities to elements of the *Chamaecytisetum angustifolii* with the special protagonism of *Echium virescens*. On the base of the Arafo volcano, alluvial deposits can be found, which have been colonized by elements of summit broom shrubland *Descurainio bourgeauanae-Spartocytisetum supranubii.* It colonizes preferably soft materials, both salic and basaltic lapilli, from recent volcanic activity. The slopes of the volcano itself are nearly devoid of vegetation with just a few single floristic elements like *Pinus canariensis, Aeonium arboreum* subsp. *holochrysum* or *Plantago webbii*, which is the only taxon that can be found on the summit of the cone.

The correlation between altitude and stem diameter of *Pinus canariensis* is shown and, therefore, the one between stem diameter and potential altitudinal range of the pine forest.

Two new populations of *Himantoglossum metlesicsianum* are described for the island of Tenerife, the first on the slopes of the Güímar valley at 1200 m asl, 97 healthy individuals, and the second on the heights of Arafo with 22 individuals. Both populations are separated by the lava flow, which might have buried a more spaciously continuous community in the past.

Of the total taxa cited in the text, 60% are endemic, with ten taxa endemic to the island of Tenerife. This degree of floristic endemicity so high in the studied territory is a natural laboratory for studies related to plant colonization and global warming.

Clearly, the potential for future research in the study is very high. We plan to further develop the current research threads presented in this publication to be able to make more assertive declarations about the nature of this ecosystem as well as exploring ideas we currently have for further research and finding out new angles from which to conduct research on this impressive landscape and the unique vegetation growing on it.

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Appendix 1. Cited taxa. For every taxa the following information on distribution is shown: T, Tenerife; GC, Gran Canaria; P, La Palma; H, El Hierro; C & W Can., Central and Western Canary Islands; all species are endemics excepts those marked as NE, no endemic.

Adenocarpus foliolosus (Aiton) DC.	C & W Can.
Aeonium arboreum (L.) Webb & Berthel. subsp. *holochrysum* (H.Y. Liu) Bañares	W Can.
Aeonium spathulatum (Hornem.) Praeger	C & W Can.
Argyranthemum foeniculaceum (Willd.) Webb ex Sch. Bip.	T
Artemisia thuscula Cav.	C & W Can.
Bencomia caudata (Aiton) Webb & Berthel.	Macaronesian
Castanea sativa Mill.	NE
Allosorus fragilis Christenh.	Macaronesian
Asplenium aureum Cav.	C & W Can.
Cistus monspeliensis L. subsp. *canariensis* Rivas-Mart., Martín Osorio & Wildpret	C & W Can.
Cistus simphytifolius Lam. var. *villosus* Demoly	T
Cladonia pixidata (L.) Hoffm. group.	NE
Cladonia rangiferina (L.) F. H. Wigg. group.	NE
Coelocaulon aculeatum (Schreb.) Link	NE
Cosentinia vellea (Aiton) Tod. subsp. *bivalens* (Reichst.) Rivas-Mart. & Salvo	NE
Davallia canariensis (L.) Sm.	NE
Descurainia bourgeauana (E. Fourn.) O. E. Schulz	T, P
Descurainia lemsii Bramwell	T
Diploschistes bryophillus (Ehrht. ex Ach.) Zahlbr.	NE
Echium virescens DC.	T
Erica canariensis Rivas-Mart., Martín Osorio & Wildpret	Macaronesian
Himantoglossum metlesicsianum (W. P. Teschner) P. Delforge	T, P, GC
Jasminum odoratissimum L.	Macaronesian
Lavandula canariensis Mill. subsp. *canariensis*	T
Micromeria hyssopifolia Webb & Berthel.	T
Morella faya (Aiton) Wilbur	NE
Paragymnopteris marantae (L.) K.H.Shing subsp. *subcordata* Benl & Pöelt var. *subcordata*	T, H
Pericallis lanata (L`Hér.) B. Nord.	T
Periploca laevigata Aiton	NE
Pinus canariensis C. Sm. ex DC. *in* Buch	C & W Can.
Plantago webbii Barnéoud	T, P, GC
Polypodium macaronesicum A. E. Bobrov	NE
Pterocephalus lasiospermus Link ex Buch	T
Rubia fruticosa Aiton subsp. *fruticosa*	NE
Rumex lunaria L.	C & W Can.
Sideritis oroteneriffae Negrín & P. Pérez	T
Sonchus acaulis Dum. Cours.	T, GC
Sonchus microcarpus (Boulos) U. Reifenb. & A. Reifenb.	T
Spartocytisus supranubius (L. f.) Christ ex G. Kunkel	T, P
Squamarina cartilaginea (With.) P. James	NE
Stereocaulon vesuvianum Pers.	NE
Teline canariensis (L.) Webb & Berthel.	T, GC
Umbilicus gaditanus Boiss.	NE