SOME NOTES ON THE BROAD-LEAVED EVERGREEN FORESTS ON THE AZORES

F. KLÖTZLI[1] & G.-R. WALTHER[2]

[1]*Geobotanisches Institut ETH, Zürichbergstrasse 38 – 8044 Zürich, Switzerland*
[2]*Insitut für Geobotanik, Universität Hannover, Nienburger Strasse 17 – 30167 Hannover, Germany*

ABSTRACT – Under the Azorean climatic conditions, around 17°C at sea level, 13°C at 800 m, yearly fluctuations between hottest and coldest month of 7°C only, evergreen broad-leaved forests form the climax vegetation in all forest belts. However, precipitation is such that laurophyllous forest is replaced by temperate rainforest above 800 m, the only European true rain forest, dominated by *Erica* and *Juniperus* and partly by *Ilex* and *Laurus* up to the timberline. These conditions change along a gradient from east (Sta Maria) to west (Flores), the altitudinal limits of the vegetation belts are depressed, lowering timberlines to less than 700 m. Some of the subalpine and the alpine belt is dominated by wet heath types with *Calluna* (on Madeira also shrubby heath woodland). Flat areas are covered with large wooded bogs. Most forest belts are transformed to re-afforestations, to pastures and other agricultural areas. All these vegetation types have their equivalents on the continents; but similarity of (*Sphagnum* rich) heath and moist forest is rather low. Transitions to moist forest are present in the Southwest of the British Iles and southwestern Norway.

KEY WORDS – Macaronesia, temperate rain forest, heath, wooded bog, peroceanic timberline

INTRODUCTION

During the pleistocene most evergreen broad-leaved species vanished from conterminous Europe and found a refuge in Macaronesia[1)] (Mai, 1995) as well as in the Pontic Province at the Black Sea coast (e.g. Zazanashvili, 1999; Gagnidze, 1999) and in few sheltered places in the southern parts of the Balkan Peninsula, especially in the valleys and gorges opened to the Mediterranean Basin (cf. e.g. Pantic et al., 1997). The vegetation of most of these areas has been described rather extensively. Just recently, a monograph on the vegetation

1 Azores, Madeira and the Canary Islands. The northern part with the Azores belongs geographically to Europe, the southern to Africa. Madeira is in an ecotonal and transitional position.

of Georgia incl. the colchic vegetation has been published (Nakhutsrishvili, 1999). Amongst all stands most is known on composition, structure and site conditions of those on Teneriffa and Gomera (Canary Islands; cf. Oberdorfer, 1965; Voggenreiter, 1974, 1975; Kunkel, 1993; Rivas-Martinez et al., 1993a,b for continental areas). Much less is known from Madeira – except flora, climate and soil (Vahl, 1905; Cedercreutz, 1941 and older work; for vegetation see Sjögren, 1972, 1974; Oberdorfer, 1975; Hansen, 1979a). Finally, the Azores are (still) away from the normal beaten tracks of tourism and science. Not very much is known of its natural vegetation including details on its orobiomes and forest types (on flora and vegetation see Lüpnitz, 1975a,b,c; Hansen, 1979b; Sjögren, 1984, older references see Seubert and Hochstetter, 1843; Watson, 1870; Trelease, 1897; Guppy, 1917). An exceptional bryoflora is given by Sjögren (1977, 1990, as well as a small flora for the interested amateur: Sjögren, 1984). But so far, according to our knowledge, there is one reference only to be mentioned regarding its phytosociology and formations except surveys and some notes from Marler & Boatman (1952) and Tutin (1953). Lüpnitz (1975c) has elaborated a general overview on forest, heath and pastures on Pico (including history of research). That is the point of our motivation, but not the only one: Since 1988 (Gianoni *et al.*, 1988; Klötzli *et al.*, 1996; Carraro *et al.*, 1998; Walther, 2000) our institute has been working on the dispersal and spread of evergreen broad-leaved (laurophyllous or laurineous) species and other exotic thermophilous plants in the southern part of Switzerland (S Ticino). Later, in a general way, work continued in all lowland areas and, finally, a worldwide investigation was initiated, especially in ecotonal areas between laurophyllous and deciduous forests, including N Italy (Insubrian parts) NW Spain (Galicia, Basque Provinces on the foothills north and south of the Pyrences) southern Dinarids, Turkey (Trapezon), W Georgia etc. (Klötzli, 1988; Carraro *et al.*, 1998). A symposium was organised in March '97 to assess the status of knowledge on this topic (Klötzli & Walther, 1999).

Subsequently, Macaronesia was re-visited and special attention was given to Madeira and the Azores, especially to São Miguel, Pico and Faial, also gathering some experience from colleagues that had the chance to visit Flores and Corvo (A. Gentizon, Univ. of Lausanne, pers. comm.; Sjögren, 1977).

With the following paper a short sketch will be given on natural vegetation of the above mentioned islands but also on the position of these forests, woodlands and heath in the general frame of the biomes of the world (Walter & Breckle, 1983ff.).

GEOGRAPHICAL SITUATION

Well-known by the term "anticyclone of the Azores", the isles are quite frequently mentioned but physically hardly known for their natural splendour, their geographical situation and volcanic activities. These volcanic isles of late tertiary – pleistocenic origin (Pico 200'000 years old, Sta. Maria 14 Mill. years, all others 1-4 Mill. years) are all but the westernmost placed on a separate microplate above a central atlantic hot spot between the plates of Eurasia and

North America at a distance of 1500 km from Lisboa (isle of Faial, central group) and 2900 km from New Foundland. Not astonishingly Flores and Corvo are already lying on the american plate. Their surface area, geographical position, highest elevations and approximate date of their first settlements may be taken from table 1. On these volcanic isles parent rocks of chiefly alkali basalt or olivin prevail and soil types as cambisol, luvisol and andosol are dominating.

Detailed access to the climatic conditions is given by the climate diagrams of Kämmer (1982) and partly Walter & Lieth (1960ff.) (compare also the older values in Tutin, 1953). They are highly oceanic, mild temperate and humid. But in eastern and central coastal areas they are subject to a heavy drought period of at least one month (in the W) up to three months (in the E). They all are having a yearly mean of (≥) 17°C (at 800 m ca. 13°C) and monthly deviations between the means of the coldest and warmest month of about 7°C only, and from E to W precipitations between 697 and 1447 mm and around 1000 mm on the central islands, which may vary considerably on the coast (Pico, Madalena W side, 956 mm, Bandeiras NW, 1794 mm; Lüpnitz, 1975a). Their oceanity and nearly subtropical conditions are accentuated by the fact that frost is unknown near the coast. All being rugged mountainous islands they have steep climatic elevational gradients (see chapter "biome and climate"): there is no drought period (sensu Walter & Lieth, 1960ff.) above 300–500 m a.s.l. anymore and precipitations rise to 3000 mm or more (increase per 100 m difference in altitude according to Haggar 1988: 25%, thus at 400 m ca. 2 x 1000 mm = 2000 mm, 800 m up to 3000 mm; max. at about < 1500 m: 3500 mm).

With these climate data the isles are obviously in the biome of laurophyllous (laurineous, evergreen broad-leaved) forests, harbouring a great amount of subtropical and even tropical species (table 2a,b; details on this biome see Klötzli, 1988). However, above 500-800 m exotic vegetation is subject to even wetter climatic conditions. The upper reaches are part of our considerations in this paper, regarding the influence of climate on vegetation. Unlike to the conditions in drier parts of Macaronesia influenced by the trade winds where rising humid air is restricted by temperature inversion, the Azores are wet to the peak of Pico (Leuschner, 1996).

A word on the existence and conservation of these evergreen forests: Not one isle has preserved parts of its natural wooded areas at lower elevations (details in Lüpnitz, 1975a; also on the extinction of *Taxus* and the situation for some other endangered species). However, there are exceptional sites where at least nature-near woodlands with some exotic species may develop, on the so-called "misterios", lava flows reaching the coast at a number of localities. A special volcanic event occurred on Faial, when 1951/52 a new volcanic peninsula of several square kilometres developed and was consequently protected under the name of Capelinho, destined to develop without human influence.

Even higher elevations have been either transformed to pastures – with *Hydrangia macrophylla* hedges – or then to *Cryptomeria japonica*[2] plantations with *Hedychium gardneranum* tall forb stands in clearings or open forests.

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2 *Cryptomeria japonica*: a species of lowland to montane site conditions in the laurophyllous biome of C- and S-Japan

Comparatively minor patches of true natural montane forest have been set aside as "Reserva Florestal", e.g. on São Miguel, Terceira, S. Jorge, Flores but chiefly on Pico interspersed with wooded raised bogs or open fens.

Methods

On three of these islands and their few well-kept forests and woodlands including surrounding heathlands some relevés were placed and evaluated with the methods described in e.g. Braun-Blanquet (1964) and Dierschke (1997). The number of relevés is restricted due to difficult access and only few remnants of semi-natural areas. Therefore notes were made also on the more disturbed and more open forests including those with exotic species (table 3). A comparison with similar vegetation types in at least comparable climatic conditions in Europe in particular and elsewhere in the world in general was drafted using the formula suggested by Emberger (1930, 1955). For that purpose climate diagrams were taken from Kämmer (1982) and Walter & Lieth (1960ff.). With regard to literature and personal experience the climatic stations were grouped to present biomes. The limits between the different biomes must be seen as best approximation of simply virtual dividing lines. In reality the transient area is a true continuum between the biomes (fig. 1 & 2).

Results

VEGETATION AND PLANT COMMUNITIES RESPECTIVELY

The most natural stands of all the relevés, viz. (bog–)forest and heath may be seen on table 3. Several groups of species are distinguished, i.e. group A to G of which details are given below. They occur mostly in both vegetation types, forest and heath. Differential species for forest in group A and B, for heath G and E.

From the most natural and undisturbed forest patches on Pico a few units are described provisionally in context with open questions as to their biome. Successional trends in the tree layer of natural stands are not clear.

FORESTS AND WOODLANDS (ESPECIALLY PICO)

Typical for all types of forest or woodland above 700 to 800 m on Pico is a combination of *Erica azorica*, *Vaccinium cylindraceum*, *Juniperus brevifolia*, mostly with *Ilex perado* ssp. *azorica* and often *Laurus azorica*, in the tree layer. There is not much difference in the tree layer between forests on different sites. However, more convex sites are as a rule dominated by *Juniperus*. Often *Juniperus* carries a rare parasite, namely *Arceuthobium azoricum*, and *Elaphoglossum* as an epiphyte is rather frequent on *Laurus* and *Ilex*. More sheltered places are richer in certain more thermophilous species, e.g. *Hedera canariensis*, and colder areas near the timberline have an admixture of e.g. *Myrsine africana*, more *Erica* and less laurophyllous species.

Normally, grasses (e.g. *Agrostis castellana*) and ferns dominate the field layer, mostly *Athyrium filix–femina* and *Culcita macrocarpa* except in convex situations, partly also *Diplazium caudatum*, *Asplenium foliosum* may be seen, but also *Dryopteris aemula* (partly *D. azorica* as well) and the harder-leaved *Pteridium* and *Blechnum*. Amongst herbs mostly *Lysimachia nemorum* ssp. *azorica* is frequent, and *Luzula purpureo-splendens*, *Rubia peregrina*, *Veronica officinalis*, *Galium boreale* occur occasionally. *Hydrocotyle vulgaris* and, on convex forms (e.g. hills near Lagoa do Capitão) on Pico there are more species of the open heathland, e.g. *Leontodon taraxacoides*, *Phleum*, *Hypochoeris*, *Potentilla erecta*, *Lotus uliginosus* and *Holcus lanatus* (all more often in moist heathland). Other frequent or conspicuous species are e.g. *Carex peregrina*, *Deschampsia foliosa*, *Hypericum helodes*, *Melanoselinum decipiens* and *Euphorbia stygiana* (see tables 3 & 5).

On bogs (e.g. near Lagoa do Paúl on Pico) Sphagna dominate among the gnarled shrubby trees. But nearly all other species may also occur.

Mosses may dominate wherever possible, e.g. *Polytrichum commune*, *Thuidium tamariscinum* and several *Sphagnum* species, often *S. palustre*. Only on small hill tops or other convex sites there is hardly any *Sphagnum*, but also more *Hylocomium splendens* and different *Cladonia* species.

The richest places in moss diversity in these forests are certainly open slopes incl. road verges. They contain all the mosses of table 3, a number of Sphagna, and often *Hepaticae* dominate (*Marchantia*, *Pellia*, *Chiloscyphus*) and further most ferns and herbs of wet sites. More often than in forests *Tolpis azorica* ssp. *frutescens*, *Platanthera micrantha*, *Lepidotis cernua* (*Lycopodium*), *Equisetum telmateia* (= *maximum*) and large tufts of *Festuca jubata* may be seen (cf. Lüpnitz, 1975c; e.g. Eucladio-Adiantetum, Cardaminetum caldeirari; localities e.g. Caldeira Velha in the vicinity of Lagoa da Fogo, Serra de Tronqueira near Pico da Vara (1103 m), S. Miguel). Frequently, small swamps occur with species poor stands of *Potamogeton polygonifolius*, *Hypericum elodes* and *Juncus effusus* (information on: Eleocharitetum multicaulis, Isoëtetum azoricae, Hyperico-Potamogetonetum and other details on wetlands in Lüpnitz, 1975a,c).

HEATHLANDS

Heathlands as a rule are not all anthropogenic, in similar composition they occur above timberline or within the "subalpine" temperate rainforest. Mostly a mosaic of heath and forest can be seen within the ecotonal area around the elevations of the timberline, more sheltered places carrying dwarfed forest, and exposed surfaces or then sites with very shallow soil heathland, in moister depressions with *Sphagnum*-rich wet heath. Above 1800m (on Pico) there is not much closed vegetation anymore (up to ca. 1800 m, especially with *Thymus caespititius*, *Daboecia azorica*, *Tolpis azorica*, *Calluna vulgaris*). Windswept ridges above Lagoa das Furnas and near Lagoa do Fogo below Punto de Barrosa at around 800 m, on S. Miguel, are most likely nearly treeless.
Similarly, as may be seen in forests, heath is also dominated by *Agrostis castellana* and mostly by *Calluna*. Specific open range herbs are e.g. *Anagallis tenella*, *Holcus rigidus*, *Viola palustris*. Other frequent species are *Luzula purpureo-splendens*, *Holcus lanatus*, *Lotus uliginosus*, *Lysimachia nemorum azorica*, *Potentilla erecta*, *Hydrocotyle vulgaris*, *Plantago lanceolata*, *Leontodon taraxacoides*. Also drier places contain *Lotus* and *Hydrocotyle*, especially on Pico, or then *Anagallis tenella* and *Blechnum*, partly *Pteridium*. Frequent mosses in heathland are *Hypnum cupressiformes*, *Scleropodium purum*, *Rhytidiadelphus squarrosus* (often mixed with *Cladonia* species, partly *Aulacomnium palustre*, and the ever present *Polytrichum commune*, *Thuidium tamariscinum*, *Hylocomium splendens* and mostly *Sphagnum palustre*. Depending on water regime and management, dwarf shrubs may loose in vitality, and grasses may dominate patchwise or on large surfaces. Transitions to bogs are frequent (with e.g. *Carex serotina*, *C. echinata*, *Galium palustre*, *Eleocharis palustris* and many mosses; see e.g. Lüpnitz, 1975c).

TIMBERLINE
(definition see e.g. Körner, 1998; Wardle, 1971; principally elevational limit of trees not lower than 2 m)

The development of a timberline depends on the oceanity, or precipitation respectively, in the hills of the islands, or then, specifically on Pico, on its uppermost elevation as well ("Massenerhebungseffekt").
On Pico timberline is around 1000-1200 m, higher up the slope "forest" is only shrub–like or split up into islands. On one of the westernmost peroceanic islands, on Flores, the uppermost stunted trees – mostly *Juniperus* – grow between 600–800 m, heath growing up to the summit at more than 800 m.
On some islands, e.g. São Miguel, higher elevations also above the potential timberline have been re–afforested, especially with *Cryptomeria japonica*: It has a tendency to produce brown needles at temperatures dropping below –5°C (Larcher, 1978). As a rule young trees die when exposed to conditions above timberline or near that value, thus, marking a physiognomic timberline dotted with small or dead shrub–like *Cryptomeria* which is endorsed by the appearance of last remnants of natural woodlands with older trees on the same isle at almost the same elevations (Pico do Carvão, at around 560–813 m and adjacent peaks, S. Miguel W similar above Lagoa do Fogo, around 800 m on rather shallow windswept sites). This specific altitude can also be assessed by extrapolating the climatic data of the nearest climatic station and by comparing it with results from other isles (see discussion).

BIOME AND CLIMATE

From the general evaluation of the climatic data of the Azores (see table 4 and fig. 1 & 2 and Kämmer, 1982; Walter & Lieth, 1960ff.) and of similar vegetation from other parts of the world the results in figures 1 and 2 were drawn.

(Oro–)Biomes on the climatic gradient (table 4)

Comparing the climatic gradients on the basis of climate diagrams (mostly from Kämmer, 1982) from Sta Maria (East) to Flores (West) or then from coastal to highland stations (e.g. Punta Delgada 22 m, 697 mm, 17.3°C, $T_{min\ abs.}$ 4.8°C <–> Achado da Furnas 550 m, 1730 mm, 13.2°C) makes it easy to give the following statements:

- From east to west the coastal dry season is reduced, precipitations are increasing, and oceanity is more and more accentuated.

- The same tendency is visible on the elevational gradient, especially on São Miguel and Pico.
- On both ways typical laurophyllous forest is present, either several hectometers above the coast or in the W already at sea level (details on composition and elevational belts see table 2a,b, 4 & 5).
- Typical species of laurophyllous forests are present at elevations around (0) 50-200 m and higher in the western parts and above 300–500 m up to 1200 m in the central and eastern parts (compare situation on Morro dos Homens and Caldirão, Sjögren 1984).
- The temperate montane to subalpine rainforest as an orobiome does not exist in the east. They may be seen above 700–800 m on the central islands (especially Pico) and were probably present in bushy form around 200 m above the coastal areas on Flores and Corvo. (On top of Flores and Corvo, compare table 2 & 5, they are mostly in the form of open remnants of bushy *Juniperus* woodland in mosaic with wet heathland; see also Sjögren 1977 for Corvo).
- In the east,summer drought provokes the occurrence of a drier type of laurophyllous woodland with the typical appearence of *Picconia*, hence not as dry as on E-Madeira (with sclerophyllous species, cf. table 4). Next to *Picconia* probably *Myrica faya* and *Erica arborea* were dominant, now usually more and more replaced by the exotic *Pittosporum undulatum* from SE Australia ("incenso") (on the history and distribution of *Pittosporum* on the Azores see e.g. Haggar, 1988; Marler & Boatman, 1952 and especially Lüpnitz, 1975a). In sheltered areas *Festuca jubata* is forming rock-meadows, and also under the canopy of rock woodlands with e.g. *Picconia*, *Laurus*, *Persea indica*, *Ilex perado*, *Juniperus*, *Erica azorica*, *Vaccinium cylindraceum*, *Viburnum tinus* ssp. *subcordatum*, *Senecio malvifolius* etc. (e.g. near Ribeira Grande, Ponta de Cintrão, P. Formosa, P. do Ajudo, Conteira da Velha and in Sete Cidades above 250 m, with *Pittosporum* and *Myrica* not reaching the top of Pto da Qumeira, 856 m). Similarly on Faial "misterios" are covered by *Myrica*, *Erica*, *Pittosporum*, *Laurus*, *Persea*. In gardens and ruderal places *Monstera deliciosa* grows up to lushious thickets, and stately trees of *Metrosideros* and *Araucaria cookii* (e.g.) are plentiful.
- In swampy lakes some subtropical genera of Cyperaceae and Poaceae are present (e.g. *Brachiaria*, *Kyllinga*) together with *Eleocharis multicaulis*, *Hypericum helodes*, *Cynodon*, *Agrostis castellana*, *Osmunda regalis*, sometimes with *Littorella uniflora*, *Callitriche* etc. Also stands with *Isoëtes azorica* may occur (e.g. at Empedada and Lagos Verde in the region of Sete Cidades, S. Miguel).
- Comparing the potential timberline of Flores and São Miguel the altitudinal difference or depression is around 200 to 400 m.
- Analysing the elevational distribution of most species thriving in laurophyllous forests there are clearly no specific rainforest species (table 2a, 3 & 4). However, a number of bog and other wetland species move into the forest (*Sphagnum* and *Polytrichum* mats, *Hydrocotyle*, *Anagallis*, table 3, groups E and G), while some typical genera of the laurophyllous forest are not extending their territory into the rainforest. Rainforest is normally species poor with the following genera in the tree and shrub layer: *Juniperus*, *Ilex*, *Laurus*, *Vaccinium*, *Erica* and partly *Myrsine*, *Daphne laureola*.

GENERAL ASPECTS

Comparing the three groups of Macaronesian isles, the Azores, Madeira and the Canary Islands (e.g. Teneriffa, Gomera, table 4) the difference may best be seen near the coast, depending on aspect and slope. On Teneriffa semi–desert scrub and/or sclerophyllous woodland are prevailing at lower elevations, true laurophyllous forest is found in the mist belt only (Voggenreiter, 1974; Oberdorfer, 1965; Rivas-Martinez et al., 1993a,b).

On Madeira a mediterrancan (now ± extinct) scrub with patches of *Hyparrhenia hirta* grassland (or vice versa) occurred in the eastern lower part up to 300–500 m, shrinking to a narrower belt west of St. Lucia. Typical genera are of mediterranean to dry tropical origin (*Olea*, *Maytenus*, *Sideroxylon*, table 2b). Typical laurophyllous forest grows above 600 m (S) or 200–300 m (N) and is replaced by heath–(scrub) forest at around 1000 m up to the timberline at about 1600 m. There is no true rain forest belt (details for Madeira in Sjögren, 1972).

Only the Azores have the full extent of all types, except the driest ones, however not on one single island. The elevational gradient on São Miguel starts with a rather drought resistant laurophyllous forest (e.g. slopes of the caldera of Setc Cidades) on the one hand, and has some nearly untouched surfaces of typical laurophyllous forest on the slopes of Pico da Vara (Tronqueiro). On the other hand Pico has well growing patches of *Picconia–Myrica*–scrub on rocky lava coasts ("misterios") (e.g. near Bandeiros & Madalena with *Dracaena draco* in home gardens!) which are somewhat drought resistant (details in Lüpnitz, 1975c).

Temperate rainforest starts at about 700–800 m on the highland plateau (with large *Sphagnum* mats, same as on Corvo acc. to Sjögren, 1984), replaced partly by secondary heath scrub or above around 1000 m by primary heath scrub with laurophyllous species (incl. *Myrsine africana*) up to a vague timberline at 1200–1300 m. From there on wet heath scrub appears gradually getting lower and more open until at around 1800 m heath(–like) vegetation with *Thymus caespititius* and Ericaceae, *Calluna*, *Daboecia azorica* reaches a scrub line (see table 2a, 4 & 5; Lüpnitz, 1975b).

Considering the distance between the eastern most isle Sta Maria and the capital Lisboa it is quite astonishing how similar these laurophyllous stands are when comparing the respective genera with the floristic structures of the equivalent late tertiary forests in Europe (Mai, 1995).

Physiognomic structures are (or were) probably similar in the true laurophyllous belt on all the isles including the Canary Islands (e.g. Teneriffa and Gomera) and Madeira considering their variability under analogous conditions (Klötzli, 1988).

However the uppermost "subalpine" stands, chiefly on Pico, are on very wet soil with *Sphagnum* mats. Some of the same but wind-swept laurophyllous species are gnarled and dwarfed; humidity indicators are invariably dominating in the herb layer (see also Lüpnitz 1975b). With these characteristics this type of forest has

definitely a special position in Europe and even in North America. They are true temperate rainforests and their nearest equivalent types, although physiognomically different, are wet coniferous forests in SW–Norway and some parts of the pacific coniferous forests, or then on the deciduous partly laurophyllous side near the coasts of the western British Isles (compare fig. 2). The oak forests in Cornwall, SW England, NW Wales grow also under very mild winter conditions (≥ 4°C January isotherm, same as in Galicia), and they normally contain evergreen shrubs and herbs (often exotic) and are rich in ferns. Also Haggar (1988) stresses the fact, that the Azoran stands between 700-1100 m or ≥1100 m up to the treeline respectively had a lot in common with certain tropical montane and subalpine rainforests and humid forests in East Africa and the northern Andes and e.g. also in the Blue Mountains of Jamaica described by Grubb & Tanner (1976); and Lüpnitz (1975c) calls them "mist forests".

Together with the ±equivalent stands on Madeira and the western Canary Islands Oberdorfer (1965) considers them as part of the Pruno-Lauretea, the true European Laurel Forests although on the Azores they hardly grow up to 10 m.

Also phytosociologically these forests have no near equivalent in conterminous Europe, also considering their herb layer. However, all the heathland types, although harbouring a great number of humidity indicators are not much different from any other moister *Calluna* heath in western Europe, at least physiognomically.

PLANT COMMUNITIES

Forest and woodland

On the European continent there are no forest associations of a similar composition. But on other isles in Macaronesia (e.g. northern Teneriffa and west and central Madeira, table 4) the similarity amongst moister laurophyllous forests is – at least on the level of the genera in the tree layer – quite remarkable. Each group of islands, partly each isle has vicariating species, (compare e.g. Oberdorfer, 1965; Voggenreiter, 1974, 1975 etc.). The same statement is valid for moister laurophyllous forests on Madeira (Sjögren, 1972 and own investigations). All herb layers are rich in ferns, often in grasses, and rich in wetland mosses. (General description in Klötzli, 1988; on forest vegetation of the Azores especially Pico see first of all Lüpnitz, 1975c, then also Marler & Boatman, 1952; Tutin, 1953; Haggar, 1988)

Heath

Comparing the composition of *Calluna*–rich plant communities (surveys in Oberdorfer, 1965; Pott, 1995; Schaminée et al., 1996) with those on the Azores the chief differences are

- the highly constant humidity indicators as e.g. *Hydrocotyle vulgaris*, *Lysimachia* * *azorica* (etc.) and also *Viola palustris* (group E) (similarly as in Juncion squarrosi)

- some missing species: frequent or characteristic species invariably missing on the isles, e.g. *Genista*, small *Vaccinium* species, also *Sieglingia decumbens*, and there are no Nardetalia–species (except *Nardus*) only *Potentilla erecta* and *Calluna* of the Nardo-Callunetea or Calluno-Ulicetea respectively are present. Apart from the possible shrub–like appearance of *Calluna* (up to 100 cm) the average appearance has its nearest equivalents in warmer hyperoceanic parts of southern Europe, also in Insubria. From Corvo, Sjögren (1979) submits similar but above 650 m less species-rich types. Below that elevation they are richer and more pasture-like (due to anthropogenous influence). Especially above 650 m there are deep bog-like *Sphagnum* mats. Also Lüpnitz (1975a,c) describes similar plant communities, e.g. Festucetum jubatae and Tolpidetum azoricae. On the transformation of *Erica* scrub to *Calluna* heath and "creeping *Calluna*" on Pico details are given by Tutin (1953), Marler & Boatman (1952), and Lüpnitz (1975c) also submits some similar species lists for "damp places" but also for grazed pastures on heath sites with principally the same combination of species. Details on enclosed wetlands see e.g. Lüpnitz (1975c), Marler and Boatman (1952), Pietsch (1975), Tutin (1953) (tables 3 & 5).

BIOMES

Considering the schemes drawn in fig. 1 the limits between the rainforest biomes – temperate, subtropical and tropical – are placed according to data from literature and personal experience (Walter & Lieth, 1960ff.; Walter & Breckle, 1983ff.; Klötzli, 1988; Kämmer, 1982). Also the limits between laurophyllous and sclerophyllous forest, heath and rainforest are based on the same data. Even if there is an arbitrary aspect on those dividing lines, there is a true continuum demanding a decision between types.

Accepting the scheme in fig. 1 the elevational gradients and belts may be reconstructed. Fortunately, there are also several climatic stations on the Azores, even at some higher elevations (Kämmer, 1982). Comparing the Emberger quotients of these stations on the Azores and the rest of Macaronesia with stations in the (oro) biome of rainforests, laurophyllous and heath forests, the following results may be drawn (example from Pico, around 400 m lower on Corvo with similar floristic composition):

- The lowest, mostly destroyed belt fringing the coastal areas is in the biome of the laurophyllous forest, however, on the drier side with aspects towards the sclerophyllous woodland.
- The intermediate belt between about 300–600 m is true "classical" laurophyllous forest just as may be seen in similar situations in types of Madeira and the Canary Islands.
- The uppermost floristically often quite similar forest belt is situated in the "cloud–" or "mist–zone" which is mostly above (500–)800 m on Pico (above ca. 250–400 m on Corvo, Sjögren 1979). It may be considered as a true temperate rainforest, physiognomically often of the heath woodland type (difference in altitudinal belts between C– and W–Azores around 200(–400) m (last good remnants of *Juniferus brevifolia* stands on Corvo at Morro da Fontes, 200 m, in

small ravines of the Caldeira). Above and partly below timberline heath, intermingled with *Sphagnum* bogs, dominates and also shows transitions to bushy heath woodland.

Analysing the position of certain stations in SW-Norway, SW-Britain, Ireland it is quite clear that chorological barriers prevent the migration of more indigenous laurophyllous species in hyperoceanic Europe. Such deciduous (Oak-)forests may be transformed to laurophyllous forests and are actually stands of unstable composition if barriers are opened. The same conditions may be found in similar areas regarding climate and soil.

ON THE GLOBAL POSITION OF THE HUMID BIOMES OF THE AZORES (FIG. 1 & 2)

It is obvious that some considerations on the similarity of the humid woody vegetation of the Azores are necessary. In a global context they should be compared with vegetation under similar climatic conditions. Under such conditions similar structural types are spread all over the world, partly directly comparable to the Azores, partly showing an independent shrub zone above timberline containing spheric bushes as e.g. in New Zealand (southern isle) partly Tasmania (Southwest & Mt. Field National Park), in the chinese Hengduan mountains (e.g. Wolong), etc. On the Azores or on Madeira there is no such independent belt, *Erica* species building rather similar but not spheric bushes. Under harsh conditions, e.g. in bog basins, the structures are similar for *Juniperus*, *Ilex* etc. This latter type is to be seen under similar conditions in S Fireland or near the timberline in the Andes (temperate zone) or then in bogs (not considering subtropical and tropical situations).

Following our impressions from Tasmania ("rain scrub"), Fireland etc. true temperate montane to subalpine rainforest has generally

- short gnarled shrub-like stems,
- rather small to medium, moderately hard to soft leaves, often with coniferous trees and especially in sloped basins and small ravines with tree ferns,
- a herb layer with dominating soft-leaved chamae– and hemicryptophytes ("macrophorb-meadows"),
- a luxuriating moss layer, often with Sphagna,
- a dure epiphytic vegetation with mostly cryptogamic species (mosses, liverworts, lichen, ferns, moss-ferns, including Hymenophyllaceae).

The general impression is that of an impenetrable shrubby thicket-like forest, often in an open mosaic with high forb meadows, heath and wetlands depending on parent rock and landform.

Floristically a certain similarity in these different areas is also given by the appearance of exotic, often subtropical plants in gardens, frequently with a high tendency to escape from the gardens and invade the surrounding forests. A higher flexibility to adapt to the local conditions is typical for such species e.g. shown in Macaronesia by stands of *Hydrangea*, *Hedychium* and the like. Also exotic tree ferns and coniferous trees show a similar tendency.

All the above-mentioned attributes are typical for the uppermost forests of the wetter azorean islands. Thus, there is no doubt that they may be considered as montane to subalpine temperate rain forests with often the same species as in the adjacent laurophyllous forests.

To sum up:

- Europes "forgotten" isles, the Azores, have a neglected European orobiome: the temperate rainforest, represented in local high montane and subalpine belts of Pico and less well developed on some other isles in the western Azores and parts of Madeira.
- Considering Madeira as a part of Europe then it is the only European locality with tall heath scrubforest and heath. They are present on Central Madeira and as pure bushy heath belts on the most oceanic summital locations above timberline on the Azores.
- Those heath types are all on isles with evergreen broad-leaved (laurophyllous) forest in the lower (submontane and colline) altitudinal belts on (hyper-)oceanic locations of the Azores and Madeira.
- Fig. 1 & 2 depicts the extraordinary position of some locations in the deciduous and coniferous forest biome. Structurally they are not in a "mature" position. Without chorological or historical barriers they would probably be composed of laurophyllous species.
- And last but not least the Azores give a good picture of the former tertiary european forest, or then, how the structures of transitional forest might change under the influence of global warming, as e.g. in the transforming insubrian forests (Carraro, et al. 1998; Klötzli & Walther, 1999).

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TABLE 1 - THE ISLES OF THE AZORES

	Name of the isle	Western longitude	Northern latitude	Max. elevation [m a.s.l.]	Area [km²]	Colonised since	Remarks
E	Santa Maria	25°07'	36°58'	587	97	1439	discovered since ca. 1427
	São Miguel	25°30'	37°50'	1103	760	1443	
	Terceira	27°10'	38°40'	1021	402	~1450	Ital. sea-maps since 1375 [1]
	Graciosa	28°05'	39°05'	398	62	~1450	
C	San Jorge	28°03'	38°40'	1053	246	~1440	
	Faial	28°42	38°35'	1043	173	1466	ca. 1500 km from Lisbon, ca. 2900 km from New Foundland
	Pico	28°20'	38°30'	2351	442	1459	
W	Flores	31°13'	39°25'	914	143	1462	discovered ca. 1452 [2]
	Corvo	31°04'	39°40'	718	17	1548	
	Madeira	= 17	33	1862	741	1400	discovered after 1300, from Lisboa 1000 km, Cap Juby (MC) 600 km [3]

[1] ca. > 1000 species of vascular plants on all 9 isles, 53 endemics
(230 indigenous = 30 % of which 3/4 also in Central Europe; 9 % endemic species, 12 % macaronesian endemics)

[2] Corvo ca. 250–300 species, 50% of all indigenous azorean species on Corvo.

[3] 1200 species, 15% endemics (180 species)

TABLE 2A - TYPICAL SPECIES IN THE ELEVATIONAL BELTS OF THE AZORES
(SJÖGREN, 1984,1974; LÜPNITZ, 1975b; SEE ALSO SHORT LISTS IN LEUSCHNER, 1996)

Elevational belts			
8	9	10	11
S *Viburnum tinus* ssp. *subcordatum* T *Persea indica* S *Picconia azorica* T *Pittosporum undulatum* (from SE-Australia) H(S) *Hedychium gardnerianum* T *Ilex perado* ssp. *azorica* H *Rubia peregrina* H *Bellis azorica* H *Lactuca watsoniana*	(S)H *Senecio malvifolius* S *Hydrangaea macrophylla* F *Osmunda regalis* S *Hypericum foliosum* H *Ranunculus cortusifolius* S *Frangula azorica* S *Prunus lusitanica* ssp. *azorica* H *Odontites grandiflora* H *Carex peregrina* H *Platanthera micrantha* H *Deschampsia foliosa* F *Phyllitis scolopendrium* F *Diplazium caudatum* F *Blechnum spicant* F *Woodwardia radicans* F *Culcita macrocarpa* F *Elaphoglossum hirtum* F *Trichomanes speciosum* T *Juniperus brevifolia* / P *Arceuthobium azoricum* H *Chaerophyllum azoricum* H *Melanoselinum decipiens* H *Sanicula azorica* L *Hedera helix* ssp. *canariensis* H *Cardamine caldeirarum* H *Calluna vulgaris* S *Erica scoparia* ssp. *azorica* S *Vaccinium cylindraceum* (S)H *Euphorbia stygiana* H *Centaurium scilloides* (S)H *Thymus caespititius* T *Laurus azorica* S *Myrsine africana* H *Luzula purpureo-splendens* H *Festuca jubata* H *Holcus rigidus* H *Leontodon* fil. *L. taraxacoides* H *Tolpis azorica*	S *Daphne laureola* H *Anagallis tenella* H *Lysimachia nemorum* ssp. *azorica* S *Daboecia azorica*	

TABLE 2b - TYPICAL SPECIES IN THE ELEVATIONAL BELTS OF MADEIRA
(SJÖGREN, 1972,1974; OBERDORFER, 1975; FOR CANARY ISLANDS SEE RIVAS MARTINEZ ET AL., 1993 a, b)

Elevational belts			
4	5	6	7
S *Chamaemeles coriacea* S,T *Dracaena draco* H *Hypericum hirta* T *Maytenus umbellatum* H *Mesembryanthemum nodiflorum* S *Olea europea* ssp. *maderensis* T/S *Sideroxylon mermulana* H *Geranium maderense* H *Goodyera macrophylla* H *Mercurialis maderensis* (*sanguinea*) H *Scilla maderensis* S *Teucrium abutiloides* T *Visnea mocanera* S *Hypericum inodorum* (= *grandifolium*) T *Juniperus cedrus* H *Melanoseirinum decipiens* T *Ocotea foetens* S *Sambucus lanceolata* L *Semele androgyna* L *Tamus edulis* S *Teline maderensis* H *Polystichum falcinellum* T *Myrica faya* T *Ilex perado perado* T *Laurus azorica* var. *longifolia* (– 1500 m) S *Rubus grandifolia*	T *Appolonias barbujana* S *Frangula azorica* T *Clethra arborea* L *Convolvulus massonianus* (= *C. canariensis*) S *Phyllis nobla* T *Picconia excelsa* H *Gennaria diphyllum* H *Geranium palmatum* S (*Dracocephalum*) *Cedronella canariensis* H *Helianthemum aciculatum* S *Isoplexis sceptrum* T *Prunus lusitanica* ssp. *hixa* S *Rhamnus glandulosa* H *Luzula sieberi* H *Alta* spp. T *Persea indica* (– 1700 m)	S *Echium candicans* H *Orchis scopulorum* H *Agrostis castellana* T,S *Erica arborea* (– 1800 m) S *Erica scoparia* (– 1920 m) H *Hypericum saltagoi* H *Plantago malato-belizii* H *Ranunculus cortusifolius* H *Thymus caespititius* (– 1900 m) S *Vaccinium padifolium* (– 1700 m)	H *Diplazium maderense* H *Erica cinerea* ssp. *maderensis* (ca. – 1600 m) H *Viola paradoxa*

Special remarks to 7 see DE MENEZES (1926): *
Examples: *Cerastium tetrandrum* – 1750 m, *Cytisus scoparius* – 1860 m, *Anthyllis lemaniana* – 1750 m, *Anthoxanthum odoratum* – 1750 m, *Agrostis castellana* – 1720 m, *Aira caryophyllea* – 1720 m, *Deschampsia foliosa* – 1700 m, *Festuca jubata* – 1750 m, *Vulpia bromoides* – 1950 m

TABLE 3 - EVERGREEN BROAD–LEAVED FOREST AND HEATH ON THE AZORES

Island (M = Madeira, SM = S. Miguel, F= Faial)		M	Pico				Pico				SM	F
Locality		RF	/ /	∩	/	/	P	/ /	P	/	LF	C
Altitude [hm a.s.l.]		8-12	7	8	8	7,5	12,5	7	9	8	8	10
Type		(type ① on table 4)	Forest (type ⑧ on table 4)					Heath				
N°		1	2	3	4	5	6	7	8	9	10	11
Cover %	Tree layer	-80	-20									
	Shrub layer	-10	30	50	90	75	50					
	Herb layer	-20	90	70	70	-20	-75	50	75	50	50	50
	Mosses	-5	20	30	50	75	30	65	80	-90	10	10
Height	Tree layer	5-15	-5	/	/	/	–	<	<	∪	<	–
	Shrub layer	-3	-2	-4	-3	-1,5	0,8					
	Herb layer	-100	-100	-40	-100	-30	-25	-20	-15	-10	-40	-30
A	*Erica * azorica*	√	(+)	2	2	1	3			/ 1		
(F)	*Vaccinium cylindraceum*	√	2	2	3	2	2					
	[1])*Juniperus brevifolia*	√	2	3	2	4	1					
	Ilex perado azorica	√	2		+	1	2					
	Laurus azorica	√	4		+	1						
	Myrsine africana					1	+					
	*Hedera canariensis * azorica*	√	1		1							
B	*Dryopteris aemula*	√	2		2		1					
(F)	*Athyrium filix-femina*	√	3	+	2							
	Culcita macrocarpa	√	2		2	2						
	Dryopteris filix-mas	√	1									
C	*Pteridium aquilinum*	√	1	1	1	1			partly ( )			
(E,	*Blechnum spicant*	√	1	1	1	1	1			1	1	
H)	*Selaginella kraussiana*	√	2	partly ( )								
	Rubus ulmifolius u.a.	√	+	2					partly ( )			
D	*Agrostis castellana*	√	1	3	•	2	3	3	3	3	2	•
(F,	*Lysimachia nemorum ssp. azorica*	√	1	1		1	+	+	1		+	•
H)	*Leontodon taraxacoides* (– 1450)			1				1		1	1	•
	Luzula purpureo-splendens	√	1			1	1			1	+	•
	Potentilla erecta	√		2	•				2	2	1	•
	Hydrocotyle azorica			1		1		1	1	1		
	Calluna vulgaris			2			+			2	3	
	Lotus uliginosus	√		1	•				2		+	•
	Holcus lanatus			1						1	+	•
	Veronica officinalis (– 1950)	√		1	•					1		•
	Galium boreale		1		•					1		•
	Prunella vulgaris			1	•					1		•
	Plantago lanceolata			1					2	1		•
	Rubia peregrina			1		1						•
	Hypochoeris radicata			1			+				+	
E	*Anagallis tenella*							1		+		•
(H)	*Holcus rigidus*					+	1			1	+	•
	Viola palustris							1		+		
F	*Sphagnum palustre* Mosses			+	•	2		1	+	+		
(F,	*Polytrichum commune*		3	1	•	4	4		2	1		
H)	*Thuidium tamariscinum*		2	1	•			2	2		1	
	Hylocomium splendens			2			2	3		2	1	
G	*Scleropodium purum* Mosses							2	3	2		
(H)	*Rhytidiadelphus squarrosus*							2	1	1		
	Hypnum cupressiforme							1		1		
	Aulacomnium palustre									3	+	Partly with *Daboecia azorica*
	Cladonia rangiferina u.a. Lichens							1				

Altitudinal notes: limiting sites sensu Lüpnitz, 1975a

Additional species in forest (F), heath (H) and both, forest and heath(B):

F *Trichomanes speciosum, Elaphoglossum hirtum, Woodwardia radicans* (a.o. ferns) *Sanicula azorica, Ranunculus cortusifolius, Melanoselinum decipiens, Dryopteris azorica, Diphasium madeirense, Rubus hochstetterorum, Euphrasia grandiflora* (cf. Lüpnitz, 1975a,b)

H *Acrocladium cuspidatum, Tolpis azorica, Poa, Festuca, Nardus, Galium palustre, Frangula azorica, Daboecia azorica, Thymus caespititia, Daphne laureola*

B *Carex peregrina, Juncus effusus, Nardus, Frangula azorica Anthoxanthum odoratum.*

Compare:
Daphno(laureolae)-Ericetum azoricae sensu Tutin, 1953; Marler & Boatman, 1952; Lüpnitz, 1975a,b (relevé 6) and Culcito-Juniperion brevifoliae sensu Lüpnitz, 1975a,b;
on physiognomy, structure and status see Haggar, 1988, transect from Misterio da Prainha 600 m to „Juniper-Elfinwood" 1250 m; detailed comparisons, lower part with *Myrica faya*, upper part without *Laurus* but including *Daphne laureola* (relevés 2–5)

Similar species lists also for *Calluna* heath; additional species in the Ericetum: *Rhamnus latifolia, Viburnum tinus* ssp. *subcordatum* (above 900 m: also *Daphne laureola*), in the herb layer e.g. *Lycopodium* (*Huperzia* + *Diphasium*) species.
Further highly constant species in Marler & Boatman, 1952: e.g. *Carex flava* agg. (between 1100 – 1300 m)
They also give detailed data on the upper soil horizon: on the average pH 4,9 – 5,4, base saturation 58 – 78 % [43], loss on ignition 43 – 54 % [65], base constant mg equiv./100 g dry soil: 42 – 108, with dom. *Calluna* around 100 [do.]
[for *Juniperus/Erica* stands]

Above and near timberline, according to Lüpnitz, 1975a,b:
- Daboecion azoricae (Nardo-Callunetea) with Potentillo–Agrostietum castellanae, pasture, secondary – 1400 m, basins with trees,
- Daboecietum azoricae (1300 –) 1700 – 2200 m (above that elevation dissected vegetation) (*Calluna, Daboecia, Thymus caespititia, Lysimachia* * *azorica, Silene vulgaris, Agrostis castellana, Blechnum spicant, Luzula purpureo-splendens* only)

also in lower heath, but mostly in Daboecietum:
H *Huperzia selago*, H *Lycopodiella cernua*, H *Polygala vulgaris* (– 1650), H *Carex pilulifera azorica*, H *Carex flava serotina* (– 1650) (relevés 7–11)

TABLE 4 - ALTITUDINAL DISTRIBUTION OF THE (ORO-) BIOMES IN MACARONESIA

Locality / Biome	AZORES				MADEIRA		CANARY ISLANDS
	São Miguel	Pico [1]	Faial	Flores	E S Slope	W/C N Slope [2]	Teneriffa [3] E (N) Slope
Sclerophyllous woodland					④ 0 – 400(600)	[(4)]	①
Laurophyllous woodland dry type	⑧ 0 – 400(500)	⑧ 0 – 400	⑧ 0 – 400		⑤ 400 – 800	⑤ 300(600) – 800	②
Laurophyllous woodland	⑨ 400(500) – 1100	⑨ 400 – 800 (– 600)	⑨ 400 – 600	⑨ ≈ 0 – 200	⑥ 900 – 1200(1400)	⑥ 600 – 1000(1200)	③ Fog
Temperate rainforest	(⑩) ?	⑩ (600 – 800) – 1200 (–1500)	(⑩) 800 – 1100	⑩ 200 – 800		⑥	
Heath woodland		(⑪) gradual transition			(Fog) 1200 – 1600	⑦ (1000)1200 – 1600	Cañadas with Retama
Heath	partly > 800	1200 – 1500 (– 1600) with *Juniperus* – 2000 (without *Juniperus*)	> 1100	> 800		mostly *Agrostis*-grassland or heath with *Erica cinerea* ssp. *maderensis* & *Erica arborea*	

[1]cf. Lüpnitz, 1975a, b, c; [Tutin, 1953], Haggar, 1988, Marler and Boatman, 1952
Laurion macaronesiae: 0–600(–700) [Perseo-Myricetum]
Culcito-Juniperion brevifoliae: (500)600–1500(1600) [Ericetum azoricae]
Daboecion azoricum: (1300–)1500–2200
(Comparison of older divisions in Tutin 1993)
⑥Daphno-Ericetum (upper elevations: Daboecion azoricae)

[2]cf. Sjögren, 1972, 1974; Oberdorfer, 1975: to ⑦ *Erica/Vaccinium* scrub
to ⑤+⑥ Clethro-Laurion azoricum
Juniperus cedrus might have been a further treeline species (Sjögren, 1972)
to ⑦: Erico/Vaccinium scrub

[3]cf. Rivas-Martinez et al., 1993a,b to ②+③:

Pruno-Lauretea azoricae - ctalia		to ①: infra-medit., xerophytic
Ixantho-Laurion azoricae		to ②: infra-/thermo-medit.
Ilici canariensis-Ericetum platycodis, 810–930 m	} N till S	to ③: thermo-/meso-medit., subhumid to humid, mesophyt.
Lauro-Perseetum indicae: 800–1120 m		

Diplazio-Ocoteetum foetentis 720–930 m NW to NE, only
to ①,② Visneo mocanerae-Arbutetum can.:500–1150 m, NE to NW
in ③ mostly secondary Fayo-Ericetum arboreae with *Pinus can.* – According to Leuschner 1996 *Juniperus cedrus* dwarf shrub above *Pinus* forests have probably been destroyed.

above ③: Sideritido solutae – Pinetum canariensis;	meso–medit., subhumid, mesophyt.
	below Retama; supra–medit., dry

⑧ table 3 colums 2–5
⑨ table 3 column 1, 6, 7
⑩ table 3 column 8–11, description of communities see table 3 and comments

Species lists for units 1–11:
Azores, table 2a
Madeira, table 2b
Canary Islands, see Rivas-Martinez et al., 1993a, b

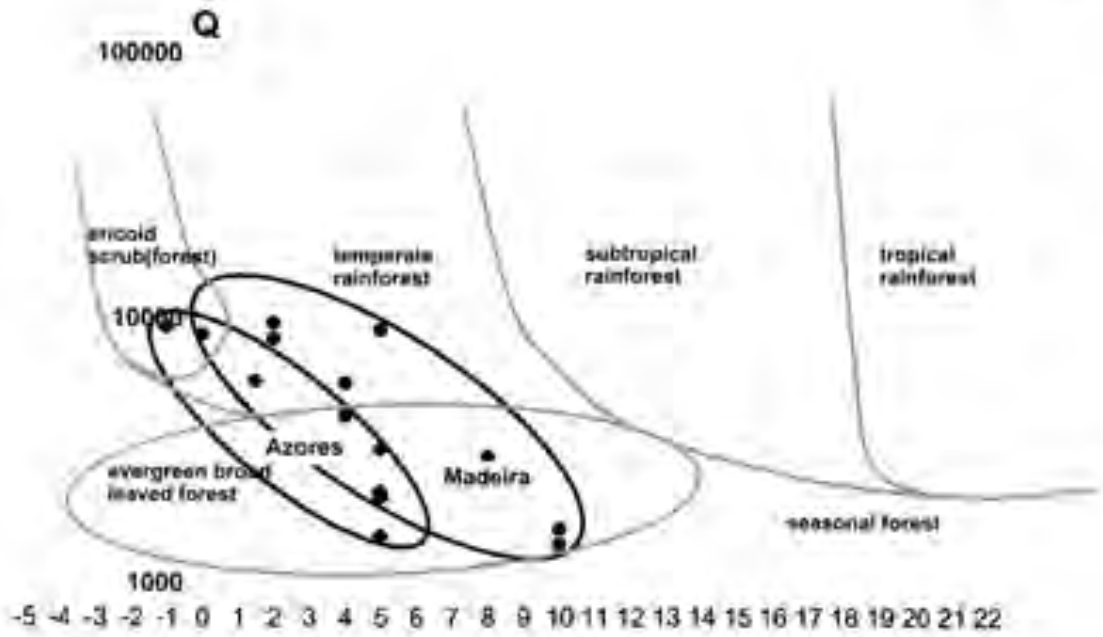

Fig. 1. - The position of Macaronesian stations in the world biomes

Geographic region	Meteorological station	T_{min}	Q
Azores			
	Santa Cruz/Flores	5	3200
	Horta/Faial	5	2300
	Angra do Heroismo/Terra	5	2100
	Punta Delgada/Sao Miguel	5	1500
	Achado d. Furnas/Sao Miguel	1.5	5800
	Pico	-1	9300
Madeira			
	Lugar de Baixo	10	1400
	Funchal	10	1600
	Sanatorio de Monte	8	3000
	Camacha	4	5700
	Sto de Serra	5	9000
	Santana	4	4300
	Queimadas	2	6400
	Encumeada	2	9600
	Arieiro	0	8700

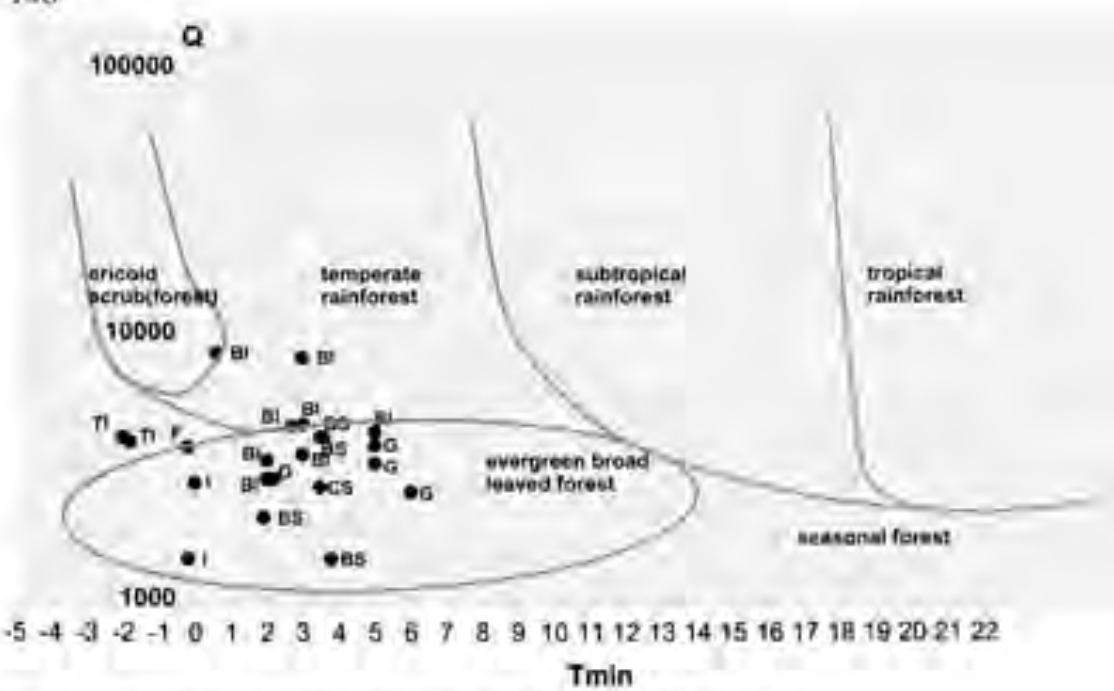

Fig. 2. - The position of western Eurasian stations in the world biomes

Geographic region	Meteorological station	T_{min}	Q
Black Sea (BS)			
	Batumi	3.5	4000
	Rize	3.6	4000
	Trapzon	3.8	1400
	Zonguldzic	1.9	2000
Caspian Sea (CS)			
	Pashlya	3.5	2600
British Isles (BI)			
	Valentia (SW-Ireland)	5	4200
	Aber (Wales)	3	4500
	Mallaranny (Ireland)	3	5000
	Cork (Ireland)	2.7	4400
	Penzance (Cornwall)	3	3450
	Newquay (Cornwall)	2	2800
	Barnstaple (Cornwall)	2	3300
	Ft William (Scotland)	0.6	8350
N-Spain/Galicia (G)			
	Bilbao	5	2500
	Santiago	5	3750
	San Sebastian	5	3200
	Dax	2.2	2800
France (NW-Pyrenees) (F)			
	Bagneres de Bigorre	-0.2	3700
NE-Italy (I)			
	Treviso	-0.2	1400
	Gorica	0	2700
S-Switzerland/Ticino (TI)			
	Locarno	-2	4000
	Lugano	-1.8	3850

TABLE 5

		Lauretum azoricae	Lauro-Perseetum indicae	Hedychio-Pittosporetum undulatae	Myrico- Pittosporetum undulatae	Myrico- Pittosporetum undulatae	Ericetum azoricae (lowland-form)	Ericetum azoricae (success. stages)	Cerastio-Juniperetum brevifoliae
Elevation in hm a. s. l.		(3–)4–8	1,6–3,0	0,9–3,4	1–4	1–4	0,4–1,5	4–6	6,2–8,2
		1	2	3	4	5	6	7	8
K	*Erica azorica*	IV	2	III	III	IV	V	V	?
V_2	*Myrica faya*	II	1	IV	V	V	IV	III	
K	*Myrsine africana*	V	2	II	III	III		III	II
K	*Hypericum foliosum*	V		III	II	IV	I	IV	I
K	*Laurus azorica* (C1)	V	3	IV	I	IV	?	?	III
(K)	*Rubus ulmifolius* (D1)	IV	1	III	III	I	?	V	?
	Blechnum spicant	V	1	II	III	II		IV	V
	Pteridium aquilinum	III	2	IV	II	III	III	IV	I
	Selaginella kraussiana	II	2	IV	I	IV		II	III
O_2/K	*Osmunda regalis*	II	1			II		I	II
	Carex peregrina	II	1	II	I	I			II
V_3	*Athyrium filix-femina*	I	1	III		II			II
	Calluna vulgaris	IV			II	II		IV	III
O_2/K	*Rubia peregrina* v. *azorica*	V		II	I	I		I	IV
	Vaccinium cylindraceum	IV			I	II			V
V_3	*Ilex perado*	III	1	1		I			IV
	Festuca jubata	II	2		I	II		III	V
O_2/K	*Luzula purpureo-splendens*	II	1			I		IV	V
	Sibthorpia europaea	II	+	1		I		I	IV
V_3	*Culcita macrocarpa*	II	1	1		I			III
O_2/K	*Dryopteris aemula*	II				I			V
	Agrostis castellana	II				I			II
	Deschampsia foliosa	II	1						III

(Cont.) TABLE 5

O_1/K	*Hedera helix canariensis* (D1)	IV	2	V	II	V			I		I		
	Smilax excelsa (D1)	III											
O_1/K	*Brachypodium silvaticum*	V	2	III	III	II							
O_1/K	*Woodwardia radicans* (D_2)	II	3	III		III			I				
O_1/K	*Asplenium menianitis*	I		II	I	II							
O_1/K	*Ranunculus cortusifolius*	II	I										
	Pteris serrulata	III				II							
	Viburnum tinus subcordatum	II		I		I							
V_2	*Umbilicus rupestris*	I	I	II	II	IV							
V_2	*Geranium robertianum*	I	I	II	II	IV							
O_1/K	*Polypodium australe* (D2)	I	3	II		II					I		
O_1/K	*Persea indica* (C2)		3	I	I								
O_1/K	*Picconia azorica* (D2)		3	III	II	I					II		
V_2	*Pittosporum undulatum* (C4)		2	V	IV	V	II	I					
	Asplenium trichomanes		2	I		I							
V_2	*Chaerophyllum azoricum*			III	II	II							
	Carex punctata			II		II							
V_2	*Tradescantia multiflora*			III									
	Myrtus communis (D4)				IV								
V_2	*Corema album* (D4)			I	III								
	Lysimachia nemorum azorica	I		III		II			IV	V			
	Hypericum undulatum			II	II	II			III				
V_2	*Hedychium gardneranum*	I	I	V	II	IV			IV				
	Festuca petraea						III						
	Plantago coronopus						III						
	Daucus carota				III		V						
	Mentha pulegium	I			I				IV	I			
	Leontodon saxatilis				I	I	I		III				
	Satureja nepeta								II				
	Hypericum humifusum								II				
	Hydrangea macrophylla					I			II				
	Plantago lanceolata								II				
	Epilobium obscurum								II				
	Gnaphalium luteo-album								II				
V_3	*Juniperus brevifolia*	I									V		
C_4	*Cerastium vagans*										V		
D_8	*Galium palustre*										IV		
D_9	*Hymenophyllum tunbrigense*										V		
D_8	*Dryopteris filix-mas*										V		
	Eleocharis multicaulis	?									III		
	Lotus uliginosus										V		
V_3	*Picris filii*										II		
O/K	*Habenaria micrantha*										II		
V_3	*Arceuthobium oxycedri*										II		
D_8	*Juncus effusus*	I			I	I			III	V			
	Holcus lanatus					I			V	IV			
	Holcus rigidus								II	IV			
	Potentilla erecta								IV	IV			

Legend:

			relevés	av. nr. of sp.						
1	Lauretum azoricae	400–800 m	20 R.	7 Sp.	P	F	SM	Fs	Pruno-Lauretalia	(O_1)
2	Lauro-Persetum indicae	200–400 m (–1100 m)	15 R.	3 Sp.	P	F			– Laurion macaronesicum	(V_1)
3	Hedychio-Pittospor. undul.	90–250 m (–340 m)	17 R.	9 Sp.	P	F		Fs	Ericetalia azoricae	(O_2)
4	Myrico-Pittosporetum undul.	100–400 m							– Myrico-Pittosporetum undulati	
	– SAss of Myrtus + Corema		10 R.	9 Sp.	P	F			"	
5	– SAss Type	110–370 m	19 R	8 Sp.	P	F		Fs	"	
6	Ericetum azoricae (lowland-form)	40–150 m	8 R.	5 Sp.	P	F			– Ericion azoricae	(V_2)
7	Ericetum azoricae success.-stages	400–600 m		7 Sp.		F		Fs	"	
8	Cerastio-Juniperetum brevifoliae	(620–)690– 820 m	23 R.	9 Sp.	P	F		Fs	– Culcito-Juniperion brevifoliae	(V_3)

Total 57 R. (+ 2 R. not evaluated)

Remarks: to columns 1–8

1) Best differential species: *Smilax excelsa*, *Pteris serrulata*, differential against 2): *Calluna/Rubia*-group, *Rubus ulmifolius*, *Blechnum spicant*; well aerated humic soil.
2) On blocks and gravel screes. Best differential species against 1): *Persea indica*-group, *Woodwardia radicans*.
3)&4) Since the early 19th century *Pittosporum* (from SW Australia) intruding neophyte into *Erica/Myrica* scrub (same site conditions).
3) Edaphically rather dry in young geolog. substrate on lava streams with crude blocks.
4) older withered soils, humic soil, closed stands
5) shallow humus layer H 6–7m
6)&7) *Erica azorica*: 0–20 hm. Faial 0,5–5 hm Scrub dense in lower elevations many foreign species, unconsolidated stands, develops towards 5) ± Syn. Daphno (-laureolae)–Ericetum arboreae
8) Rich in endemics! Very thick *Sphagnum* moss layers, wet (also in Caldeira of Faial).

C = character species of asssociation in column 1–8 following Lüpnitz, 1975a, modified.
D = differential species do. for alliances (V), order & class (O/K) (see legend).
According to details from Lüpnitz, 1975a
Absence/presence of species in columns 1–8 is questioned comparing own experience with the tables of Lüpnitz (e.g. *Erica azorica* in column 8).
Differential species for plant communities 1–8 according to the authors