[IMAGE]

Typical maquis on the Cap Corse of the island of Corsica (Zonobiome IV) with white-flowered *Cistus salvifolius, C. monspeliensis* and the sclerophyllous evergreen oaks *Quercus coccifera* and *Qu. ilex* in the background (photo: Rafiqpoor)

[IMAGE]

Fruiting dragon tree (*Dracaena draco* var. *ajgal*) in southern Morocco (Zonoecotone III/IV). It was described in 1997 as a new taxon from the Anti-Atlas (east of Agadir) (photo: Breckle).

**II Special part**

**Part G -ZB IV: Zonobiome of sclerophyllic woodlands Mediterranean winter rain areas**

1. General, climate and soils
2. About the origin of the ZB IV and its relations to the ZB V
3. The Mediterranean region
4. Importance of sclerophyllia in competition
5. Arid Mediterranean subzonobiome, North Africa, Anatolia, Iran
6. California and neighboring regions
7. Central Chilean winter rainfall area with the zonoecotones
8. The Cape Province in South Africa
9. SW and S Australia
10. Mediterranean orobiome
11. Climate and vegetation of the Canary Islands
12. Afghanistan at the eastern edge of the winter rain area
13. Man in the Mediterranean
14. Literature

[IMAGE]

Mediterranean rock garrigue (zonobiome IV) on steep limestone slopes with high biodiversity of herbs, geophytes (several orchids, *Muscari*) and annuals in southern Albania (photo: Breckle)

1 General, climate, soils

It is convenient to divide **zonobiome IV** into five floristic biome groups according to the floristic kingdoms that condition strong floristic differences, each of which forms typical, often similar-looking vegetation units (◘ Fig. G-1). Of these, the Mediterranean is the largest, as winter rains extend from the Atlantic Ocean into Afghanistan. However, severe winter frosts already occur in Anatolia and further east, so that these areas must be placed in ZB VII.

The Mediterranean climatic regions of the ZB IV are mostly followed by arid zonoecotones (ZE), in which the winter rain regime still prevails, but the drought or the winter frosts have a stronger effect. However, this type of climate is also generally described as Mediterranean. In southern Australia, the southwest, but also the south, has Mediterranean features; there are two separate sub-areas (► Fig. G-1).

The climate diagrams for the individual biome groups are very similar, except that the summer drought is sometimes more pronounced, sometimes less. However, the range of different manifestations of this climate type is also very wide in the western Mediterranean region (◘ Fig. G-2).

The sclerophyllic vegetation of ZB IV, typical of winter rainfall areas with only sporadic frosts, does not tolerate prolonged cold. The most favourable growing season is spring, when the soil is moist and temperatures rise, and autumn after the first rains. The winter period is already too cool for good growth at temperatures around 10 °C or below.

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| **Box G-1** The five Mediterranean regions of the world |
| The five winter rainfall areas: **1.** the Mediterranean (with evergreen forest, maquis, garigue, asphodel, etc.) **2.** the Californian (with sclerophyllic forest, chaparral, partly encinal, etc.) **3.** the Chilean (with matorral, espinal, etc.) **4.** the Capensian (with fynbos, renosterbos, etc.) **5.** the Australian (with jarrah forest, sclerophyllic bush = mallee, etc.). |

◘ **Fig. G-1** Areas with a Mediterranean climate, arranged at comparable latitudes. They are preferentially located on the western side of the continents. **Green**: Mediterranean climate type with Mediterranean zonobiome IV; **Orange**: arid areas with predominantly winter rainfall, various ZE of ZB IV, especially ZE III/IV; ZE III/VII (modified after Walter & Breckle 1991).

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| **Box G-2** Similarities and differences of Mediterranean woody floras |
| The Mediterranean vegetation is dominated by sclerophyllic woods, which are similar in appearance but mostly belong to completely different genera in the different areas. |

◘ **Fig. G-2** Climate diagrams of Messina in Sicily, Azrou in the montane belt of the Middle Atlas (Morocco) and Cabo de Gata (SE Spain) = the driest place in Europe (desert, ZEIII/IV).

The individual Mediterranean areas are geographically far apart from each other. Superficially, the vegetation units and the biotopes sometimes look strikingly similar. This similarity is particularly great between the Mediterranean area, California and Chile (◘ Fig. G-3), as well as between the Cape region and Australia. This certain dichotomy is not least related to geological history. Although the climate as a formative primary factor is similar in all five areas, the geological history of the areas is very different. Australia and the Cape region are parts of the ancient Gondwana mass, they have been depleted for millions of years, and the soils are very poor in nutrients (◘ Fig. G-4). Much younger and strongly influenced by Tertiary mountain formation are the other three areas. The nutrient status of their soils is up to a factor of 10 better in terms of nitrogen and over 100 times better in terms of phosphate.

◘ **Fig. G-3** The five Mediterranean regions. The thickness of the connecting lines schematically indicates the similarity of the five regions in terms of the phylogeny of flora, phenology, morphology and vegetation types, as well as climate and land-use patterns (modified after Castri 1981).

In discussing the climatic subzonobiomes of each biome group, the zonoecotones (ZE) will also be discussed subsequently. The transition can take place from ZB IV to ZB V, VI or VII.

The present climate of the ZB IV was not always so. Both the wide distribution of fossil soils and the development rhythm of the main representatives and other facts (fossils) indicate that in the Tertiary the climate was still tropical with summer rains. Only shortly before the Pleistocene did the shift of the rainfall maximum to the winter months take place. The plants had to adapt: A sharp selection took place, and only those species with small xeromorphic leaves that grew on dry sites in the previous climatic epoch survived. The present reduction of activity in summer is imposed by drought. It is absent when plants have sufficient water available. The ephemerals and ephemeroids, which serve as vegetation buffers, are restricted in their development to the favourable spring or the again wet autumn.

◘ **Fig. G-4** The phosphate and nitrogen contents in soils (total contents in %) of the five Mediterranean regions (modified after Rundel 1982, Castri 1981).

Consideration of these historical facts facilitates understanding of the ecological behavior of vegetation (Specht 1973, Axelrod 1973, Castri et al. 1981, Arroyo et al. 1995). Close relationships exist between many taxa of ZB IV and ZB V or ZB II (for example, species of the genus *Olea, Eucalyptus,* and others). Thus, *Quercus baloot* (closely related to *Q. ilex* s.l.) grows in Afghanistan with additional summer rainfall. The Encinal vegetation of the mountains in Arizona with summer rain corresponds to the chaparral in California with winter rain only.

2 Origin of zonobiome IV and their relations to zonobiome V

In their monograph Castri & Mooney (1973), in addition to various aspects of ZB IV, historical questions of the origin of this ZB IV are discussed, which is closely related to those of ZB V. Both go back to a common root, the tropical vegetation of the Tertiary reaching the higher latitudes.

Axelrod (1973) has summarized the further development of vegetation up to the present for California and comparatively applied it to the Mediterranean area.

Fossil finds show that at the beginning of the Tertiary in the Eocene, tropical evergreen but also deciduous species grew in the Northern Hemisphere in the area of today's temperate climate, indicating a tropical climate with a pronounced summer rainy season at that time. Studies of fossil marine mollusks allow the conclusion that in California the minimum sea surface temperature was about 25 °C around 50 million years ago. During the Oligocene and Miocene, a steady cooling of the sea occurred, and by the end of the Tertiary in the Pliocene, the minimum was only 15°C. Correspondingly, the climate on the mainland also became cooler and cooler and the flora poorer in species with high heat requirements. At the same time, however, the rainfall distribution in California changed. The summer maximum became less pronounced and towards the end of the Miocene it disappeared; in the Pliocene a shallow minimum was already noticeable in summer. During the Pleistocene with the ice ages, cold ocean currents developed on the western sides of the continents and at the same time a climate with pronounced summer drought and rain only in the winter months, i.e. the type of ZB IV.

During the Tertiary the ever-rising mountains also bulged fully in western North America, and in Europe the alpine ranges. The consequence of this was that in the Tertiary tropical zone of today's higher latitudes arid climates and arid local sites in unfavorable exposure developed, so that among the evergreen species a selection took place into species with the typical leathery leaf of the humid tropics (often called laurel-leaved – lauriphylls; leaf mesophyll thickened usually by thick cellulose cell walls) and into more drought-resistant sclerophyllous species (hard-leaved species; leaf mesophyll cellwalls usually thickened by lignification). Then, during the Pleistocene, as the summer-dry climate (termed Mediterranean) developed on the western side of the continents, the sclerophyllous species gained dominance in this climatic region and the woody species flora became impoverished, while on the eastern side of the continents, favoured by warm ocean currents, the humid climate with summer rains at somewhat lower annual temperatures was maintained as zonobiome V. On the humid eastern coasts of the continents of N and S America, as well as SE Africa, SE Asia, and E Australia, the transition from tropical humid to subtropical humid and warm-temperate species-rich flora with evergreen leather-leaves is still quite gradual.

The sclerophyllous vegetation of ZB IV did not evolve by adaptation to summer drought, but the tertiary species were already preadapted to dry sites. Only a limited number of new species evolved, in California for example in the genus *Ceanothus* with 40 species, *Arctostaphylos* with 45 species, others, as mentioned, spread strongly, for example *Adenostoma. Arbutus* has a more leathery leaf (◘ Fig. G-5).

Of the 113 woody genera (with 169 species) of the hardwood range in Chile, only 13 genera are the same as the 109 genera (with 272 species) in California. Australia, with 66 genera (with 140 species), has even only 2 genera in common with California and 3 with Chile. However, the total number of species is much higher. Especially the partly very small areas of ZB IV represent a certain exception to the rule that species richness increases from the poles to the equator (◘ Table G-1).

The corresponding but much smaller area in the S-African Cape region is thought to contain about 8,000 species, SW Australia the same 8,000 species, while the much more extensive and richly divided Mediterranean area is estimated to contain about 24,000 species of vascular plants.

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| **Box G-3** Relationship of ZB IV with neighbouring ZBs |
| The formation of zonobiome IV is closely related to zonobiome V, it occurred only during the late Tertiary. |

◘ **Fig. G-5** The strawberry tree (*Arbutus*) is a typical Mediterranean element. This tree occurs with two species in the Mediterranean area: *Arbutus unedo* (**a** and **b**) in the western Mediterranean region, *Arbutus andrachne* (**c-e**) with red trunk in the eastern Mediterranean region (photos **a-b**: Rafiqpoor; **c:** http://bit.ly/2mYGaZd; **d-e**: Breckle). A third species (*Arbutus canariensis*) is only known from ZB V (Macaronesia).

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| **◘ Table G-1** Number of genera and species in zonobiome IV of California and Chile, winter rainfall area (after Arroyo et al. 1995). | | |
| **Parameter** | **Chile** | **California** |
| Area in km2 | 294 600 | 278 000 |
| Number of genera | 681 | 806 |
| Number of species | 3385 | 4240 |

This evolutionary history also makes it understandable that between ZB IV and ZB V the same genera but represented by vicariant species are often present, for example sclerophyllous *Quercus* speciesin California and the leather-leaved evergreen *Quercus virginiana* in southeastern North America (ZB V). In Australia, the leather-leaved *Eucalyptus* speciesof ZB IV in SW and S Australia differ little from those in the summer rainfall area of ZB V of the east coast. There, as in the west, a rich Proteaceae vegetation is also found on dry calcareous soils, only the species are different. Also, the occurrence of the fossil "terra rossa" soils in the Mediterranean area becomes understandable. In these one finds relics of the tropical soil fauna, which at greater depths does not feel the summer drought. The rest of the fauna of ZB IV confirms the remarks made with regard to the vegetation (contributions in Castri & Mooney 1973).

As Axelrod emphasises, the fossil record in North Africa also points to a similar history of Mediterranean vegetation. However, the conditions in Europe are more complicated. Since the postglacial period, the climate of Western Europe has been determined by the warm Gulf Stream.

The cold Canary Current (► Fig. F-2) only makes itself felt south of this archipelago as far as Senegal (fog coast). The ZB IV extends from the west along the coasts of the Mediterranean Sea, due to the extensive coastlines, far to the east.

The last ice ages had a particularly negative effect in Europe and practically destroyed the flora. Remnants did not migrate again from the few refugia until the postglacial period. The flora remained poor, so that continuous fossil records from the Tertiary to the present, as in California, are lacking. But the prevailing view is that the history of ZB IV was essentially similar everywhere, and that a climate corresponding to ZB IV with zonal sclerophyllic vegetation did not yet exist in Tertiary times, although the hardleaf species did on dry local habitats.

3 The Mediterranean area

The climatic conditions in this zone are shown in the diagrams (► Fig. G-2). In winter the cyclones bring rain, while in summer the Azores high-pressure causes hot and dry summers. Since the Mediterranean area is one of the oldest cultural regions, the zonal vegetation had to give way to cultivated crops on most sites.

Nevertheless, there can be no doubt that the zonal vegetation was an evergreen sclerophyllous forest with *Quercus ilex* (► Fig. G-8).

Based on small remnants, the following information can be given about the original forests:

Holm oak forest (Quercetum ilicis):

**Tree layer:** 15 to 18 m high, closed, largely formed by *Quercus ilex* alone.

**Shrub layer:** 3 to 5 (up to 12) m high,

* *Buxus sempervirens,*
* *Viburnum tinus,*
* *Phillyrea media,*
* *Phillyrea angustifolia,*
* *Pistacia lentiscus,*
* *P. terebinthus,*
* *Rhamnus alaternus,*
* *Rosa sempervirens* and others

**As lianas:**

* *Smilax,*
* *Lonicera*
* *Clematis*.

**Herb layer:** about 50 cm tall, sparse but rich in species

* *Ruscus aculeatus,*
* *Rubia peregrina,*
* *Asparagus acutifolius,*
* *Asplenium adiantum-nigrum,*
* *Carex distachya* and others.

**Moss layer:** Very sparse.

Under these low forests, in calcareous areas, one usually finds a terra rossa soil profile with a litter layer, a blackish humus horizon and below it a 1 to 2 m thick, clayey, plastic, red terra rossa horizon. In cultivated soils the upper horizons are missing (erosion), so that the colour is already visible at the soil surface. They are mostly fossil soils of a more tropical climatic period. Today brown loams are developing (Zinke 1973).

The aspect sequence begins in March with the flowering of many shrubs. The main flowering time, also for *Quercus ilex,* is May; in June *Rosa, Clematis* and *Lonicera* arestill flowering. The coincidence of the highest temperatures with the greatest drought causes a relative dormancy. Only with the autumn rains recommences new growth and sometimes a renewed flowering of the sclerophyllous woods. The holm oak (*Quercus ilex*) is widespread in the western Mediterranean area as far as the Peloponnese and Euboea (Greece), and the cork oak (*Quercus suber*) is also found (not on calcareous soils) in the far west (◘ Fig. G-6). Its growth is promoted by cultivation, especially by repeatedly clearing these forests of competing species and regular debarking of older tree trunks (Breckle 1966).

In the eastern Mediterranean, the Kermes oak (*Quercus coccifera*) replaces the previously mentioned tree species. In Palestine it occurs as an arboreal race (*Qu. calliprinos*) (◘ Fig. G-7).

◘ **Fig. G-6** Cork oak forest (*Quercus suber*) in southern Spain. The oaks are freshly debarked, the cork sheets are collected and then transported away for processing. Cork can be obtained from older cork oaks about every 10 years (photo: Barthlott).

In the hot lower level of Spain and North Africa, the wild olive tree (*Olea oleaster*) and the carob tree (*Ceratonia siliqua*) (◘ Fig. G-8a) grow in the tree layer with *Pistacia lentiscus* (► Fig. G-8b); in addition, there are various *Cistus* species(◘ Fig. G-8c) as well as the European palm (*Chamaerops humilis*) (► Fig. G-8d). Of particular interest on Crete are Tertiary relict sites of a wild form of the date palm (*Phoenix theophrasti*) already mentioned by Theophrastus. A large stand grows in front of a small lagoon near Vai (at Cape Sideron, NE corner of Crete) above groundwater and in a few other locations and also on the SW coast of Turkey.

*Quercus ilex* shows a montane distribution in N Africa from Morocco to Tunisia (◘ Fig. G-9) above an intercalated coniferous forest belt with *Tetraclinis* (*Callitris*) and *Pinus halepensis* (Aleppo pine). The SE corner of Spain, with 130 to 200 mm rainfall, has almost desert-like conditions (► Fig. G-2, Gata).

Today, real *Quercus ilex* forests canonly be seen in a few places in the mountains of N Africa.

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| **Box G-4** Human impact on plant cover |
| The slopes were deforested and grazed, so that severe soil erosion set in and today only various stages of degradation remain. |

◘ **Fig. G-7** Tall maquis and scrubland with *Quercus calliprinos* in Galilee (Keziv Park) with species-rich herb layer (**a**, photo: Breckle). **b**: The typical maquis formation on Cap Corse in Corsica. It consists mainly of *Quercus ilex, Erica arborea, Arbutus unedo, Pistacia lentiscus, Cistus monspeliensis, Cistus albidus, Cistus incanus* etc. with a species-rich herb layer (photo: Rafiqpoor).

◘ **Fig. G-8** Floral elements of lower altitudinal Mediterranean vegetation: *Ceratonia siliqua* (**a**), *Pistacia terebinthus* (**b**, photo: Breckle), *Cistus incanus* and *Cistus albidus* as understory (**c**), *Chamaerops humilis* (**d**) (photos: Rafiqpoor).

Otherwise, they are felled as coppice every 20 years and regenerate by means of shoots from old stumps. The result is a man-high shrubbery with sparse areas in between, which is called **Maquis or Macchia.** Macchia can also be found on slopes where the shallow soil does not allow a tall forest to grow. The sclerophylls, which are usually only known as shrubs, can form real trees in favourable locations when they reach a higher age; mighty trees of *Quercus ilex* can be seen in old gardens or parks. If the felling takes place every 6 to 8 years and the areas are regularly burned and grazed, then higher woody species are absent and we get open communities called **Garigue** (◘ Fig. G-10) (or Garrigue, in Greece 'Phrygana' in Spain 'Tomillares', in Palestine 'Batha').

In the garigue, single species often predominate, such as low bushes of *Quercus coccifera, Juniperus oxycedrus* (in the east also *Sarcopoterium spinosum* bushes) or *Cistus, Rosmarinus, Lavandula, Thymus,* etc. The most favourable conditions for grazing are provided by the *Brachypodium ramosum-Phlomis lychnites* communityin southern France on limestone. In spring, many therophytes (ephemerals) occur on bare patches. Geophytes (ephemeroids) such as *Iris,* Orchids *(Serapias, Ophrys)* and *Asphodelus* speciesarealso not absent. Finally, on sites very degraded by fire and grazing, an almost pure **Affodill** vegetation with many bare soil(◘ Fig. G-11) remains. The garigue and open affodill sites are a sea of flowers in spring, while they scorch out severely in late summer. If the cultivation of crops or grazing are abandoned, successions become noticeable, tending towards the direction of zonal vegetation, as shown in the scheme (◘ Fig. G-12) for S France.

On sandstone or acid gravel soils, succession proceeds similarly, except that the individual stages have a different floristic composition; characteristic species are, for example, the strawberry tree *(Arbutus)* and the tree heath *(Erica arborea).*

In the eastern Mediterranean, the arboreal *Quercus calliprinos* (closely related to the western Mediterranean, mostly shrubby *Qu. coccifera*) takes over the role of *Qu. ilex* and represents the zonal forest type (◘ Fig. G-13 and ► Fig. G-7). The stages of progression and regression are similar to those in the western Mediterranean region, although other species usually dominate in the genera represented in each case. The manifold influence of man often leads to a barely usable thorny, low-growing garigue (Batha) with sparse, thorny dwarf shrubs (especially with the also fire-tolerant *Sarcopoterium*) or even to completely open rock heaths (► Fig. G-12), where the soil is largely washed away, leaving bare rock in many places. Progression (regeneration) seems almost impossible here without appropriate measures.In the continental Mediterranean area of S-Anatolia, the pine *Pinus brutia* (close to *P. halepensis*) plays a greater role (◘ Fig. G-14). It often forms the tree layer, while the sclerophyllic species occur as macchie in the shrub layer. Since pine does not regenerate in the macchie due to lack of light, these stands can only rejuvenate after forest fires, which explains the evenness of the tree layer being all much the same age. The umbrella pine *(Pinus pinea)*, which is frequently planted in the Mediterranean region, probably had its natural habitats on poor sandy areas on the coast.

◘ **Fig. G-9** *Quercus ilex* foreston limestone above Azrou in the Middle Atlas (Morocco) (photos: Rafiqpoor).

◘ **Fig. G-10** Garigue is an open community mostly of thorny cushion plants, in which also here and there some small trees of *Juniperus communis* or *Pistacia lentiscus* etc. from the macchie may occur. The picture shows the rock garigue on Corsica, in the background on the slopes the macchie stands as a somewhat higher formation (photo: Rafiqpoor).

◘ **Fig. G-11** Affodil site (*Asphodelus aestivus*) as a degradation form of the Mediterranean cultivated landscape in Cap Corse on Corsica (photo: Rafiqpoor).

◘ **Fig. G-12** Scheme of the regeneration stages of degraded pastures or cultivated soils on calcareous soils in the Languedoc (southern France) to holm oak forest (*Quercus ilex*) or, in the case of persistent grazing (and fire), to *Rosmarinus cistus* garigue. The dependence of the changes on the type and intensity of use is indicated (modified after Walter & Breckle 1991).

◘ **Fig. G-13** Regression and progression (regeneration) stages in the *Quercus calliprinos* zoneat Jebel Ansariye in Syria on limestone rock (modified after Nahal 1991). **G** = ongoing grazing; **GD** = interrupted grazing; **F** = deforestation; **U** = vegetation turnover.

◘ **Fig. G-14** *Pinus brutia* forestsat the Anatolian Plateau mountain fringe on the western slope of the Taurus Mountains in Turkey (photos: Rafiqpoor).

4 Importance of sclerophylly in competition

If one is interested in the ecophysiological conditions in the Mediterranean area, the question immediately arises to what extent the plants are affected by the long summer drought. One must first distinguish between the sclerophylls and the malacophylls, which are strongly represented by *Cistus, Rosmarinus, Lavandula, Thymus,* and others. Furthermore, one must take into account that the favourable euclimatopes are nowadays occupied by crops, for example vineyards, and that the Mediterranean species are relegated to the shallow sites, i.e. grow under relatively unfavourable conditions.

If the rock is deeply fissured, the abundant winter rains penetrate deeply and are stored in the soil. In the rock crevices, the roots of the woody species can be traced 5 to 10 m deep, down to layers that still contain sufficient exploitable water even in summer (Breckle 1966).

Cell sap studies throughout the growing season revealed in sclerophylls that the water balance is not significantly disturbed during the drought period. However, this can only be achieved by restricting gas exchange through partial stomatal closure when water supply is impeded. Transpiration measurements showed that at dry sites water release in summer is about three to six times lower than at moist sites. At extremely dry sites with only stunted growing specimens the cell sap concentration increases strongly (-3.0 - -5.0 MPa). It must be remembered, however, that on the good soils, where the vineyards yield is heavy in the autumn, the water conditions are much more favourable. Thus, summer dormancy caused by drought was hardly an option in the original sclerophyllic forests.

In contrast to the hydrostable sclerophylls, the malacophylls are hydrolabile. *Cistus, Thymus* and *Viburnum tinus* show increases in cell sap concentration up to 4.0 MPa in summer. At the same time, a strong reduction of the transpiring area occurs in them, as a large part of the leaves is shed. Often only the buds remain. These species do not root so deeply. The laurel *(Laurus nobilis),* which does not belong to the sclerophylls, has its natural habitat in the Mediterranean region always in the shade, in valleys or on northern slopes. Today it forms forest stands only in the fog belt of the Canaries or in a macchie in the winter rain area without pronounced summer drought (N Anatolia), *Prunus laurocerasus* behaves in the same way.

The ecological importance of sclerophylly is probably to be seen in the fact that the sclerophyllic species are active in gas exchange when water supply is good (number of stomata 400 to 500 per mm2), but in the case of water shortage they are able to strongly throttle water losses by closing the stomata. This gives them the ability to survive months of drought while maintaining plasma hydration and without loss of leaf area until the next rainy season, when they can immediately resume substance production in autumn.

But the conditions change immediately if the summers in the humid winter rainfall areas are not decidedly dry, or if in a typically Mediterranean climate the site is permanently damp, for example on north-facing slopes or in floodplain forests. On the former, the sclerophylls are first displaced by laurel-like evergreen species and then by deciduous trees. *Quercus ilex* isreplaced by the deciduous oak (*Qu. pubescens*) with greater growth.

In the floodplain forests of the Mediterranean area, deciduous tree species grow, such as *Populus* and *Alnus* species, *Ulmus campestris, Platanus orientalis* and in SW Anatolia the Tertiary relict species *Liquidambar orientalis.* However, as soon as the rivers dry up in summer, we do not find deciduous woody species, but the evergreen sclerophyllous oleander *(Nerium oleander).*

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More precise data for 1 (Box G-6) are not available, but it can be assumed that the proportion of leaf mass to total phytomass is more favourable in deciduous species than in sclerophylls. Regarding 2, the ratio is two times greater in the thin deciduous leaves than in the evergreen ones, and for 3, the measurements show that the intensity of photosynthesis in deciduous and evergreen leaves, calculated per unit leaf area, does not show great differences. As for 4, the evergreen leaf is obviously more favourable. Two points are thus in favour of the deciduous species and one point for the evergreen species.

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| **Box G-5** Competitiveness of sclerophyllous species |
| Sclerophylls outcompete both non-sclerophyll, more lauriphyllous evergreen species sensitive to drought, and deciduous trees only in winter rainfall areas. |

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More precise calculations showed for the humid, mild climate of Lake Garda, where both *Quercus ilex* and *Qu. pubescens* grow, a substance yield in grams per gram of branch weight of 22.9 for *Qu. pubescens* compared with only 17.9 for *Qu. ilex*, confirming the observation of the greater competitive power of deciduous species under these climatic and site conditions. In the same climate, but on steep cliff faces from which much of the rainwater runs off so that the site is dry in summer, we find evergreen *Qu. ilex* shrubs. At such growing sites *Qu. pubescens* is not competitive (Freitag 1975). In addition, on steep rocky slopes *Qu. ilex* is protected from cold air stagnation in winter. This is because its northern limit is mainly due to winter cold, affecting seedlings and saplings.

Of course, sclerophylly also has an effect on soil formation, because the decomposition of leaves with high lignin content and high crude fibre content is slower than that of malacophyllous leaves. The decomposition rates of leaves depend on their mechanical strength on the one hand, and on their mineral content on the other. Ashy leaves rich in minerals are decomposed faster by the decomposers in the soil.

**◘ Fig. G-15:** Litter input and litter accumulation in different zonobiomes. ZB IV is highlighted, here individual species are indicated (A.f. = *Adenostoma fasciculatum*; A.g. = *Arctostaphylos glauca*; G.v. = *Garrya veatchii*; Q.c. = *Quercus coccifera*; Q.i. = *Qu. ilex*; Q.w. = *Qu. wislizenii*; S.m. = *Salvia mellifera*). The range of some other zonobiomes is circumscribed. k is the rate of decomposition, assuming uniform negative exponential decomposition (modified after Read & Mitchell 1983).

In comparison with other zonobiomes, the Mediterranean region with the hardwoods is about average, so to speak, with regard to litter production and the accumulation of litter (due to reduced decomposition rates by decomposers) (◘ Fig. G-15). The needle litter of conifers in ZB VIII is mineralized even more slowly, of course also due to the unfavourable climate with very long winters, as is that of the tundra (ZB IX), so that raw humus accumulation occurs there. In the Mediterranean area, litter input and accumulation are more or less balanced, whereas in ZB I the permanent litter input is very high, but the accumulation is insignificant; there, everything that accumulates is continuously degraded (k = 1, ► Fig. G-15).

5 Arid Mediterranean subzonobiome, N Africa, Anatolia, Iran

Small arid areas are found in the Ebro Basin in NE Spain (Walter 1973), where winter cold already plays a role, and even more pronounced in SE Spain (Freitag 1971a), the only corner of Europe that can almost be counted as having conditions like ZB III (► Fig. G-2).

As an example of a larger area, however, Central Anatolia should be mentioned, which still belongs entirely to the winter rainfall region and represents a central basin landscape enclosed by high peripheral mountains at over 900 m asl. The mountains hold off a large part of the winter precipitation. In May, the already heated but still humid rising air leads to thunderstorm formations and a rainfall maximum (Nisançi 1973) (◘ Fig. G-16).

Total precipitation is less than 350 mm, summer drought is very marked, but the months of December to March are cold (minima to -25 °C), although interrupted by thaws (ZE IV/VII). No forest can grow under these conditions. The *Pinus* forests ofthe encircling mountains (montane - Mediterranean belt) pass over a scrub zone with *Juniperus, Quercus pubescens, Cistus laurifolius, Pirus elaeagrifolia, Colutea, Crataegus* and *Amygdalus* (dwarf almond) species into a steppe. It is therefore a ZE IV/VII. The steppe has now become mostly arable land (winter wheat cultivation as "dry farming = Lalmi"), or it is heavily grazed. This results in a degradation to an *Artemisia fragrans-Poa bulbosa* semi-desertwith very many early therophytes and geophytes.

At higher altitudes, many species of *Astragalus (Tragacantha)* and *Acantholimon* (Plumbaginaceae) occur as spherical thorny cushions, which are especially characteristic of the cold Armenian-Iranian highlands.

Originally, a herb-rich grass steppe *(Stipa-Bromus tomentellus-Festuca vallesiaca* community) prevailed in Central Anatolia, already reminiscent of the Eastern European steppe, except that the species are Mediterranean elements. The soil has a typical chernozem profile, but with an A-horizon not very rich in humus. The vegetation period in this steppe is shortened to four months by the winter cold and summer drought. Very important is the rain maximum in May.

◘ **Fig. G-16** Climate diagram of Ankara, arid Mediterranean. Homoclimates are Erevan (High Armenia) and Tashkent (Central Asia, slightly lower and warmer).

The most favorable season is the spring. Already from February to March the first geophytes (*Crocus, Ornithogalum, Gagea* and others) bloom. They are followed, especially in case of overgrazing, by the numerous small therophytes, which root only in the upper 20 cm and therefore disappear already by June. The actual perennial steppe species reach their development maximum in May and dry up only in July. As the soil contains enough water in spring, the cell sap concentration of these species is low (1.0 to 1.5 MPa) and increases just before withering. A number of species, which include also the spherical thorn cushions, flower only during the main drought. These species are characterized by a deep taproot, allowing them to draw water from deep soil horizons that are still moist in summer. In the case of camelthorn *(Alhagi),* a root depth of 7.65 m has already been measured in a 30-month-old plant. The cell sap concentration is also below 1.5 MPa.

The periphery of the Mediterranean steppes are among the areas settled by man particularly early and are the cradle of human culture and civilisation. This is true not only for the Hittites in Anatolia, but also for the area of the "Fertile Crescent", that is, for the mountain slopes that surround Mesopotamia from the west, north and east. Here (around Jericho, Beidha, Jarmo) have been found the oldest traces of the cultivation of grain, for which the steppe is especially favorable. At the same time, livestock farming was possible in this area. The neighbouring forest served hunting purposes and provided wood. In these primeval settlement areas, man has destroyed the natural vegetation thoroughly and almost completely over the past millennia and in some cases transformed formerly fertile areas into deserts. Today, these processes are referred to as desertification. The onset of soil erosion has created many "bad lands" in which all plant growth is absent.

We will come back to the very different zonoecotones in the north of the Mediterranean area, which extends very far in west-east direction.

6 California and neighboring regions

This area is restricted in western N America by the mountain ranges (Cascades, Sierra Nevada) to a narrow strip on the Pacific coast. The winter rainfall area extends up the west coast from British Columbia to lower (Baja) California, but in the north the rainfall is so high and the summer drought so short that these are species-rich hygrophilous to mesophilous coniferous forests, which should already be considered zonoecotone IV/V (Barbour & Major 1977). Only central and southern California are a sclerophyllous region,while Lower California is already too arid (◘ Fig. G-17 and ◘ Fig. G-18).

California ZB IV corresponds to the proper Mediterranean Californian floral province, which is very species-rich (► Table G-1). Since the present-day western American flora still largely resembles the Pliocene flora, i.e., it did not undergo Pleistocene depletion, all plant communities are very species-rich; genera such as *Quercus, Arbutus,* and others are represented by a large number of species, plus a great amount of genera that are entirely absent in Europe, for example, the important genus *Ceanothus* (Rhamnaceae) with 40 species; of *Arctostaphylos,* 45 shrubby species are present. A leading species is the Rosaceae *Adenostoma fasciculatum* ('Chamise') with needle-like leaves. The distribution of this shrub fairly reflects the extent of the sclerophyllic zone.

Ecologically, a site of an *Adenostoma* chaparralnear San Diego in the mountains (458 to 1,678 m NN) south of the Mojave Desert, protected for 40 years, was studied in more detail by Mooney & Parsons ( in Castri & Mooney 1973). Climate data for the station at 815 m asl are as follows: Mean annual temperature 14.3 °C, abs. maximum 42.5 °C, abs. minimum -7.8 °C, frost may occur from October to May; mean annual rainfall 670 mm mainly in December to March; evaporation 1,625 mm a year, mainly in the four hot summer months. The soil can dry out to a depth of 1.2 m in low rain years, below which it is always moist.

**◘ Fig. G-17** Climate diagrams of stations on the Pacific coast of N America (from N to S) in the coniferous forest, hardwood vegetation, and desert transition area.

◘ **Fig. G-18** Climate diagram of Sagehen Creek at the pass summit (1931 m asl) of the Sierra Nevada before Reno. The small rain maximum in August is due to summer thunderstorms. Absolute temperature maximum 34.4 °C, -minimum -33.9 °C (from Walter 1990).

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| **Box G-7** The arrangement of the plant cover is climate-dependent |
| The north-south gradient means that evergreen sclerophyllous oak forests occur only in the northern part of the California hardwood range, sometimes even mixed with deciduous species, while in the southern part a scrub formation known as chaparral predominates. It corresponds to the more Mediterranean macchie. |

Fires after lightning are common, with flame temperatures reaching 1,100 °C, 650 °C at the soil surface, and 180 to 290 °C at a depth of 5 cm. *Adenostoma* sprouts more than 50% even during drought, often in 10 days after fire, forming 25 cm shoots in 30 days. All plants of *Quercus agrifolia* and *Rhus laurina* sprout. *Adenostoma* reaches greatest cover 22 to 40 years after a fire, and growth almost ceases after 60 years. Stand regeneration occurs after a new fire. About 50% of shrub species rejuvenate by sprouting, the others by seed. About 20 years after a fire, the stand is closed again. In the first few years after fire, severe soil erosion occurs on steep slopes. Aboveground phytomass reaches 50 t●ha-1, and belowground is probably twice that. Net aboveground production in a year is about 1 t●ha-1 ●a-1in young stands and decreases with age. The shrubs are normally photosynthetically active all year round.

In the spring develops a very rich ephemeral vegetation. Some of these species germinate only after fire. *Adenostoma* dominates on southern slopes, whereas *Quercus dumosa* grows in the denser stands on northern slopes.

The coastal strip of California immediately bordering the sea north of 36 degrees latitude is not part of the sclerophyllous zone because the fog caused by the cold ocean current (California current) makes the summer season cool and moist, allowing the hygrophilous northern tree species to grow.

The chaparral, unlike the macchie, is a natural zonal vegetation that corresponds to the relatively low winter precipitation of 500 mm. It is true that fires are also very frequent here; but these fires were a natural factor before human intervention. Accurate statistics from the "National Forest Administration” have shown that fires caused by lightning are exceptionally common in the chaparral area, so that a constant fire watch is necessary during thunderstorms. It has been found that fires that recur about every twelve years do not change the chaparral because the shrubs keep striking out. If the fires stay out for a very long time, then species such as *Prunus ilicifolia* and *Rhamnus crocea* invade. If one fire is followed by another in two years, the seedlings of the shrub species that do not sprout after fire are killed, thus pushing back these woody plants.

The root systems of sclerophyllic species reach far down into the soil, because its uppermost soil layers usually dry out completely in summer. The maximum depths of the roots far into the crevices are 4 to 8.5 m (more detailed information with root system profiles can be found in Kummerow 1981). A certain water absorption is therefore possible in summer. This can be seen from the fact that after a fire in midsummer, the shrubs sprout very soon; after the loss of the transpiring surface, even a small amount of water absorption is sufficient to make the buds grow. The autumn rains do not have a direct effect. It takes over a month for the water to reach a depth of 1m. Meanwhile, the temperature drops so much that the shoots stop growing. The peak of development is April, when the temperature rises with a good water supply. The old evergreen leaves assimilate into the spring. They do not fall off until June, when the young ones become fully functional. Almost all species of the chaparral have a mycorrhiza. The *Ceanothus* species*,* however, form nodules that assimilate nitrogen.

A very detailed vegetation monograph with much ecological information was published by Barbour & Major (1977).

Evergreen oak sclerophyllic forests are also found in N America as a montane belt in the mountains of S and C Arizona above the cactus desert at 1,200 to 1,900 m elevation. It is the **Encinal belt**, which is divided into a lower and an upper belt on the basis of the various *Quercus* species*.* The latter is replaced by the *Pinus ponderosa* belt*.* The chaparral species *(Arbutus, Arctostaphylos, Ceanothus)* occur as shrub layer below the tree layer. Although there are two rainy seasons in Arizona, the vegetation is very reminiscent of that in California, but the sclerophyllic forests in the mountains are much better developed and still native. The occasional summer thunderstorms supplement the scant winter precipitation. Nevertheless, the summer drought is very pronounced. East of the Sierra Nevada, in the state of Nevada, winter precipitation decreases to about 150 - 250 mm.

◘ **Fig. G-19** Climate diagrams from the sagebrush area (*Artemisia tridentata* semi-desert): Reno, Winnemuca, and Salt Lake City (already transitioning to grasslands).

◘ **Fig. G-20** The dependence of precipitation amounts (top) on relief (bottom), shown on a W-E profile through western North America at about 38°N (modified from Walter 1960).

The cold season lasts 6 - 7 months at 1300 m altitude. This is shown by the climate diagram of Sagehen Creek (► Fig. G-18) at the top of the pass with still relatively high precipitation and a forest as well as bog vegetation. Reno (◘ Fig. G-19) is already in the lee. Only an *Artemisia tridentata* semi-desertcalled "Sagebrush" persists there (ZB VIIa). The extent to which precipitation levels depend on relief in this area can be seen in ◘ Fig. G-20. The *Artemisia* semi-desertoccupies vast areas in Nevada and Utah and adjacent states. It replaces the southern *Coleogyne* and *Larrea* semi-desertsin the cold climate. *Artemisia* prefers the heavy soils of the basin landscapes and is replaced on the elevations by the "Pinyon". These are low scattered *Pinus monophylla* or *P. edulis-Juniperus* tree communities, which include some cold-resistant chaparral species. In the mountains at about 2000 m elevation the true coniferous forests begin with *Pinus flexilis* and *P. albicaulis*, while further east *Pinus ponderosa* occurs, replaced higher by *Pseudotsuga* and *Abies concolor*, whereas *Picea engelmannii* and *Abies lasiocarpa* form the tree line at above 3000 m. The dry southern slopes often remain devoid of treees, so that *Artemisia* reaches up to the alpine belt; however, the succession of elevational belts can change spatially very strongly. Aspen *(Populus tremuloides)* (► Fig. K-12) also plays a major role with extensive clonal suckers (shoots from the roots) on water-rich soils.

7 Central Chilean winter rain region with the zonoecotones

The state of Chile forms a strip about 200 km wide, extending 4300 km at the western foot of the High Andes from 18 to 57°S, showing all transitions, from rainless subtropical desert in the north to a sclerophyllic wood area to very humid temperate and subarctic forests in the south. Winter rains predominate in central Chile (◘ Fig. G-21). The cold Humboldt Current, which isflowing aloing the entire coast, moderates the summer drought so that temperatures are lower compared with California; the annual temperature of Pasadena at 34°N, for example, is 16.8°C, whereas that of Santiago at 33°S is only 13.9°C. A comparison of the climate of the two areas was made by Castri (1973).

Since Chile belongs to the Neotropics, the floristic conditions are completely different from those in the Mediterranean region and in California. Only the cultural landscape is very similar. The same species are grown and cultivated in the gardens.

The hardwood region occupies the central part of Chile and connects to the arid areas in the north. It is also present only in remnants.

We may mention *Lithraea caustica* (Anacardiaceae), which causes skin rash and fever on contact, the soap bark tree *Quillaja saponaria* (Rosaceae), *Peumus boldus* (Monimiaceae) or the Lauraceae *Cryptocarya* and *Beilschmiedia,* whichprefer damp ravines. In addition, there are a number of shrubby species. In a narrowly defined area northeast of Valparaiso grows the endemic palm *Jubaea chilensis.* On dry rocky sites, columnar cacti *(Neoraimondia arequipensis)* (◘ Fig. G-22) and the large *Puya* species(Bromeliaceae) are found, along with the thorny Rhamnaceae *Colletia* and *Trevoa.*

Externally, the sclerophyllic species of California, Chile and Australia look similar, but there are considerable differences, for example, in the fruit shapes, as ◘ Table G-2 shows. According to this table, there are particularly many species with fruit appendages, with spines or hooks in Australia and almost half of the species have small dry fruits, whereas in Chile and California many species also have large and fleshy fruits. The colour of the fleshy fruits also differs significantly, which allows conclusions to be drawn about the fruit-dispersing animals.

The actual Matorral area is very small in terms of surface area, because the Andes drop very steeply on the Chilean side. The almost 7,000 m high Aconcagua is only about 100 km away from the sea coast.

In the mountains, debris communities predominate, and the elevational belts are difficult to discern. The hardwood vegetation only goes up to about 1500 m (◘ Fig. G-23). Shrub communities transition to the alpine belt, with the coniferous species *Austrocedrus (Libocedrus) chilensis* occurring in places. Widespread are alpine debris shrubs, such as *Tropaeolum* species, *Schizanthus* (a Solanaceae with zygomorphic flowers), as well as Amaryllidaceae *(Alstroemeria, Hippeastrum)* and *Calceolaria* species.

For the upper alpine belt flat cushion plants (*Azorella* and other Apiaceae) are characteristic. The species at these elevation of the orobiome, but also south of the sclerophyllous, are already Antarctic elements, which include the arboreal *Nothofagus* species*.* South of Concepcion, the forest with *Nothofagus obliqua* (zonoecotone IV/V), which sheds its foliage in the cool winter months, begins with decreasing summer drought (◘ Fig. G-24), and still farther south, with precipitation above 2,000 to 3,000 mm, transitions into ZB V of the evergreen Valdivian temperate rain forest (Quintanilla 1974) (◘ Fig. G-25). It is hardly inferior to the tropical one in luxuriance, and the standing wood mass may be even greater. The woody species are partly neotropical elements, and bamboos *(Chusquea)* also play a major role; some are already Antarctic elements such as the evergreen *Nothofagus dombeyi.* Very old conifers are also represented, especially in montane locations. Besides *Austrocedrus* and *Podocarpus* species*, Saxegothea, Fitgroya, Araucaria araucana (*= *A. imbricata)* and *Pilgerodendron uviferum* shouldbe mentioned. In the very moist and cool, but frost-free climate, this evergreen forest merges into the Magellanic forest, which extends almost to the southern tip of the continent (◘ Fig. G-26); in the process it becomes increasingly sparse in species and lower, finally only 6 to 8 m high. All the offshore islands to the west are covered by cushion bogs (*Sphagnum* occurs but plays no role). This vegetation is floristically close to that on the Antarctic islands. Similar Antarctic elements can be found on New Zealand as well as on the mountains of Tasmania - a sign that these areas used to be in direct contact with each other via the Antarctic continent. The bogs can be described as Antarctic tundra (ZB IX).

◘ **Fig. G-21** Climatic diagram map of Chile with vegetation zones (modified from Schmithüsen 1956): **1** Northern High Andes, **2** Desert area, **3** Dwarf shrub and xerophytic shrub area, **4** Sclerophyllous wood region, **5** Deciduous forest, **6** Temperate evergreen rainforests, **7** Tundra-like cold zone vegetation, **8** Sub-Antarctic deciduous forest, **9** Patagonian steppe, **10** Southern Andes.

◘ **Fig. G-22** Landscape view of the cactus rock desert with *Neoraimondia arequipensis* at the foot of the Andes on the Chile-Peruvian border (photo: Barthlott).

**◘ Fig. G-23** West-east transect through central Chile indicating the main vegetation formations up to the Andes (modified after Rundel 1982).

◘ **Fig. G-24** The *Nothofagus* forests(here an example from S Chile), belong to the Antarctic elements and occur in all continents of the S hemisphere as evidence of their former connection (Gondwana continent). Leaves of *Nothofagus dombeyi* from Argentina (photo: https://t1p.de/gg7j) (photo small: https://t1p.de/n714).

◘ **Fig. G-26** The ever-humid cool Magellanic forests are common at the windswept southern tip of the South American continent in Chile (photo: [https://t1p.de/im68](https://t1p.de/im68" \t "_blank)).

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| **Box G-8** Vegetation of central Chile |
| The typical vegetation of C Chile is a 10-15 m high woody shrub, the matorral, with xerophytic hardwood species. |

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| **Table G-2** Fruit shapes of the Mediterranean flora in C Chile, California and Australia and percentage distribution of fruit colours of fleshy fruits (after Hoffmann & Armesto 1995). | | | |
| **Condition of the fruit** | **Chile** | **California** | **Australia** |
| Small, fleshy fruits | 34,2% | 29,1% | 12,1% |
| Small, dry fruits | 19,8 % | 43,7 % | 45,0 % |
| Large fruits (> 15 mm) | 14,4 % | 6,3 % | 0 |
| Anemochore (for example winged fruits) | 29,7 % | 19,4 % | 23,6 % |
| Other (with aril, hooks, spines, etc.) | 1,8 % | 1,5 % | 19,3 % |
| **Colouring of fleshy fruits:** | | | |
| Black/Purple | 48 % | 27 % | - |
| Red | 16% | 43% | - |
| Green | 12% | 2% | - |
| Other | 24% | 28% | - |

8 The Cape Province in South Africa

The South African winter rainfall area is confined to the extreme south-western tip of Africa, but nevertheless encompasses an entire floral kingdom - the **Capensis**. The species richness in this small area is quite extraordinary. In the Jonkershoek Conservation Area alone, some 2,000 species have been recorded on 2,000 ha, as well as on the 50 km stretch from Table Mountain to the Cape of Good Hope. The genus *Erica* comprises 963 species (◘ Fig. G-27), *Restio* (Restionaceae) 108 species, *Muraltia* (Polygalaceae) 115 species, *Cliffortia* (Rosaceae) 117 species, *Protea* about 100 species. The Proteaceae (◘ Fig. G-28) play a particularly important role among the sclerophyllic plants. This family is otherwise only strongly represented in Australia, but by another subfamily; a few genera also occur in S America.

The species richness is certainly partly due to the deep valleys and steep mountains with a strong dissection (Knapp 1973), but also due to the isolation to the north, which has existed for a long time due to the climatic aridity of the Karroo semi-desert.

The endemic genus *Aspalathus* (Fabaceae) comprises 43 species. Among other things, it also provides the rooibos tea (*Aspalathus linearis,* ◘ Fig. G-29). Its centre of distribution is concentrated in the Cape area. Among our houseplants many originate from the Cape (*Pelargonium, Zantedeschia* = *Calla, Amaryllis, Clivia* and others). The climate diagram of Cape Town corresponds to that of Tanger; only the annual precipitation is 260 mm lower; the summer, however, is somewhat less dry (◘ Fig. G-30).

The Fynbos, like the Matorral, also has only a very small area (◘ Fig. G-31). The only tree species *Leucadendron argenteum* (silver tree: ◘ Fig. G-32) has a very small range on the moist slopes of Table Mountain below 500 m asl. Woodland-like stands occur in moist ravines; however, these are the last outcrops of moist temperate forests on the SE coast of Africa (ZB V). Some of the leaves of *Protea* are very large (► Fig. G-28); they have little mechanical tissue but a thick cuticle and are therefore hard. The water balance of proteaceous shrubs, as in all hardy shrubs, is balanced, that is, the cell sap concentration shows little variation during the year. The soil is always likely to contain exploitable water in the rooted deeper layers, even in summer. The soils in the Cape region are acidic and very low in mineral nutrients, which particularly suits the Proteaceae and Ericaceae (with obligate mycorrhiza).

The most important ecological factor is the fire. After a fire, countless geophytes (*Gladiolus, Watsonia*, etc.), in which the Cape flora is very rich (about 350 species), appear in the first year, followed by herbaceous species, together with dwarf shrubs (◘ Fig. G-33).

After about seven years the proteaceous shrubs have grown up again, either as stick shoots or as seedlings. They can reach a great age, but then become woody and flower weakly, thus seeming adapted to periodic burning. Again, fire from lightning is likely to be a natural factor.

Today, burning is caused deliberately or due to human negligence. It is interesting that the bulbous plants only come to flower after a fire, but otherwise grow vegetatively. Fertilization by the ashes does not play a role, rather the suddenly for some time reduced root competition of the burnt shrubs seems to be the triggering cause. With increasing elevation in the mountains, the rainfall increases namely on the SE slopes where the moist warm air from the Indian Ocean is forced to rise. Table Mountain station, which is 750 m above Cape Town, records three times the amount of precipitation (► Fig. G-30). The Cape province is a mountainous region with isolated basins between the mountain ranges. On top of these very often lies the "Tablecloth", i.e. a cloud cover produced by warm moist winds from the Indian Ocean, which creeps up the SE slope to dissipate again on the NW slope (◘ Fig. G-34).

It forms a weeping mist on the plateaus of the mesas, so that they are moist and tend to become scrubby *(Restio, Erica)* or even boggy (moss mats with *Drosera* and *Utricularia* species, ◘ Fig. G-35). Succulents (*Rochea coccinea* and others) grow in dry niches between boulders. Inland, winter precipitation decreases (► Fig. G-30), especially in the rain shadow of the individual mountain ranges. In the rain shadow, the dry formation form of the cape vegetation, the Renosterbos, occurs first, with *Elytropappus rhinocerotis* (Asteraceae) (◘ Fig. G-36) as the dominant, rod-shaped shrub species. This is the transitional area, the ZE IV/III. This is then replaced by the semi-desert vegetation types of Karroo.

◘ **Fig. G-27** The genus *Erica* in the Cape region,as a small but independent floral kingdom, achieves the greatest species differentiation worldwide with 936 species. We bring some examples collected only on Table Mountain. (Above **a**: *Erica* spec.; **b**: *E. versicolor*; **c**: *E. galdulosa*; **d**: *Erica sessiliflora*; **e**: *Erica* spec.; **f**: *E. formosa*; **g**: *E. subdivaricata*; **h**: *Erica* spec*.*; **j**: *E. cerinthoides*) (photos: Rafiqpoor).

**◘ Fig. G-28** The genus *Protea* also reached its greatest differentiation and speciation in the Fynbos Formation in the Cape region. Here are some examples from the Cape of Good Hope Fynbos Formation: (**a**: *Leucospermum cordifolium***; b**: *Protea cynaroides***; c**: *Mimetes fimbriifolius***; d**: *Leucospermum cordifolium***; e**: *Leucospermum cordifolium***; f**: *Protea aurea* subsp. *aurea***; g**: *P. eximia* (photos **b**: Breckle; rest: Rafiqpoor).

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| **Box G-9** Fynbos in South Africa |
| The sclerophyllous vegetation of S Africa is called **Fynbos***.* It is a macchia-like proteaceous scrub 1 to 4 m high. |

◘ **Fig. G-29** The famous Rooibos tea of South Africa is obtained from *Aspalathus linearis* in the Cape Province. This species is an element of the Renosterbos in the northern Cape. However, the shrub is also cultivated on a large scale (photos: Rafiqpoor).

◘ **Fig. G-30** Climate diagrams from South Africa: typical sclerophyllic area, humid montane climate (rich in fog), transitional area and typical Karroo.

◘ **Fig. G-31** The Fynbos formation occupies large areas in the winter rainfall region of the southern Cape. *Restiona* and *Protea* are widespread in the Fynbos (photo: Rafiqpoor).

◘ **Fig. G-32** The silver tree (*Leucadendron argenteum*) is a typical element of the Cape Fynbos (photos: Rafiqpoor).

◘ **Fig. G-33** The Cape region is rich in geophytes. We bring here some examples from the Renosterbos area as examples. **a**: *Dietes grandiflora***; b**: *Moraea sisyrinchium***; c**: *Moraea flaccida* **d**: *Ferraria crispa***; e**: *Gladiolus alatus***;** (photos: Rafiqpoor).

◘ **Fig. G-34** The "Tablecloth" on Table Mountain near Cape Town. It develops not only on Table Mountain but also on other higher ridges on the south coast of Africa. The northern flank is sunny and the southern flank is shrouded in dense clouds that spill over to the north (photo: Breckle).

◘ **Fig. G-35** Boggy areas covered with Restionaceae develop on the wet parts of the Table Mountains in South Africa. In these boggy sites, the soil surface is in many places covered with moss mats in which carnivorous *Drosera* species(e.g. in the picture *Drosere trinervia* as an endemic on Table Mountain in Cape Town) grow (photos: Rafiqpoor).

The sclerophyllous vegetation of the Fynbos has spread widely since the settlement of the Cape, i.e. after 1400 AD. In former times, the evergreen temperate forest with palaeotropical elements extended along the entire SE coast of Africa to beyond the S tip of Africa (Cape Agulhas) (ZB V).

9 SW and S Australia

Perth in SW Australia occupies almost the same latitude as Cape Town. The climate is also very similar (◘ Fig. G-37). But not only the SW corner of this continent has winter rains, but also the area around Adelaide in S Australia.

As a result of the special floristic conditions, the sclerophyllic vegetation is distinguished by a different character than in the other winter rainfall areas of the world. The tree form (*Eucalyptus* species) is dominant, the Proteaceae form the shrub layer among these or predominate on the sandy heaths. The eucalypts do not have hard, but leathery leaves. Many shrubby or low *Eucalyptus* speciesgrow in the Mallee, forming a lignotuber (◘ Fig. G-38). Lignotuber formation is a genetically fixed trait, although it may be highly modified by environmental factors. Lignotubers are interpreted as an adaptation to survive adverse events (fire, drought, cold). They occur in all Mediterranean areas. Many species in Australia in particular have lignotuberous formations.

◘ **Fig. G-36** The Renosterbos Formation with *Elytropappus rhinocerotis* (Asteraceae) is still widespread in the winter rainfall area in northern Cape province (photo: Rafiqpoor).

The ecological significance of lignotuber formations is not always clear. In California, the lignotuber-forming *Arctostaphylos glandulosa* grows alongside the lignotuber-free *Arctostaphylos glauca* inthe same habitat. In addition, *Adenostoma fasciculatum, A. sparsifolium, Ceanothus, Quercus dumosa, Rhus laurina,* and others possess a lignotuber in California. *Eucalyptus camaldulenesis* does not have a lignotuber in S Australia, those growing more northerly are ecotypes with lignotubers. Numerous species of the W Australian Eucalypts, but also *Banksia,* etc., form lignotubers. in Chile, for example, *Colliguaja odorifera, Quillaja saponaria, Eithraea caustica, Cryptocarya alba*; in the Mediterranean region lignotuber formation is regularly known only from *Quercus suber.* In all cases, the possibility of rapid sprouting after fires certainly plays an important role.

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| **Box G-10** ZB IV in Australia |
| In Australia, ZB IV occurs in SW and S Australia . The sclerophyllic vegetation is formed by *Eucalyptus* forests(Jarrah) and shrubs (Mallee). |

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| **Box G-11** Importance of lignotuber |
| A lignotuber is an underground woody tuber (between 5 cm and up to more than 2 m in diameter) with numerous, protected dormant buds, from which the plant can sprout again rapidly. |

◘ **Fig. G-37** Climate diagrams from SW Australia. Stations in the Karri forest, the Jarrah forest and the Shrub Heath (► Fig. H-10, Adelaide).

◘ **Fig. G-38** In all Mediterranean regions of the world, a large number of plant species form lignotubers. This is true for many plant families also in Australia, especially for Myrtaceae, Araliaceae, etc. We bring here two examples from Australia: **a**: *Eucalyptus botryoides* (photo: P. Woodard, https://t1p.de/ezkh); **b**: *Cussonia paniculata* (photo: Gent, [https://t1p.de/ucwx](https://t1p.de/ucwx" \t "_blank)).

A special feature of SW Australia are the grass trees (*Xanthorrhoea, Kingia*,◘ Fig. G-39), the Cycadeae *Macrozamia* and the *Casuarina* species. The Ericaceae are replaced by Epacridaceae. The soils are as poor and acid as in the Cape region. They are quartz-rich with iron concretions representing laterite crusts of an earlier period of tropical climate. The parent rocks are among the oldest geological formations on earth due to their long Gondwana history. An indication of soil poverty is the fact that the herb layer of the forest around Perth contains 47 carnivorous species of *Drosera* (sundew), especially climbing ones, which thrive on nutrient-poor sites. The bracken fern is also widespread when there is sufficient moisture.

South of Perth, rainfall increases (to over 1,500 mm), but decreases to the N and inland. With each change in climate, other *Eucalyptus* speciescome to dominate. The wetter the climate, the taller the trees grow and the greater the leaf area per hectare. The vertical position of the leaves allows a lot of light to penetrate the trunk area, so that the shrub layer is usually well developed if it is not reduced by frequent fires.

For the climate comparable to the Mediterranean, with 625 to 1,250 mm of rain and a summer drought, the **'Jarrah' forest** is characteristic, in which *Eucalyptus marginata* absolutely predominates. This species can become 200 years old and reaches a height of 15 to 20 m (maximum 40 m). In the more humid southern part, the **'Karri' forest is** found with *Eucalyptus diversicolor,* which reaches 60 to 75 m (maximum 85 m) in height (ZE IV/V). With a canopy closure of 65%, a shrub layer and a dense herb layer, often with fronds of bracken up to 1.5 m high, are developed (◘ Fig. G-40).

The drier **'Wandoo' zone** with *Eucalyptus redunca* receives only 500 to 625 mm of rain. The woodlands are sparser. It is slightly more inland, but is now almost entirely converted to sheep pasture. In the absence of suitable native grasses, *Lolium rigidum* is sown with the Mediterranean clover *Trifolium subterraneum,* which is annual but buries its fruits in the soil, as a nitrogen source; prior superphosphate fertilization is essential given the poverty of the soils. Fertilization and seeding are done from the airplane given the large extent of the land. The species-rich Mallee with numerous shrubs, also many Proteaceae and an enormous species richness of small shrubs, herbs and geophytes is almost today only preserved in protected areas (◘ Fig. G-41).

◘ **Fig. G-39** Grass trees (*Xanthorrhoea*) are a special feature of Australia (photo: Breckle).

**Fig. G-40** *Eucalyptus diversicolor* forestin SW Australia. Undergrowth *Acacia pulchella* and bracken fern (*Pteridium esculentum,* picture foreground left). Fire tracks are visible on the tree trunks (photo: S. Porembski).

◘ **Fig. G-41** Species-rich Mallee with several *Eucalyptus* speciesand shrubby Proteaceae (*Banksia*), herbs and geophytes west of Raventhorpe, SW Australia (photo: Breckle).

In the zone with 300 to 500 mm of rainfall, many loosely standing *Eucalyptus* speciesoccur (ZE IV/III), but this area is now the winter wheat zone with farms of several 100 ha in size, managed by two to three men when the farms are fully motorised. Growing wheat in the wetter zones is unprofitable due to the incidence of rust fungus damage.

If the mean annual precipitation falls below 300 mm, the eucalypts disappear and the very extensively grazed shrub semi-desert begins (◘ Fig. G-42). S Australia lacks the wet winter rainfall areas. Conditions are otherwise similar to SW Australia, but more complicated because various mixed stands of several *Eucalyptus* specieseach are found. The area is also mountainous, which in turn causes a strong differentiation of the vegetation.

◘ **Fig. G-42** The dry savannah in the vicinity of Devils Marbles, Australia, was formerly *Eucalyptus* open forest land. Today, this region has been converted to pasture (photo: Breckle).

In addition to the forests described, proteaceous heaths ½ to 1 m high are common over wide areas. They grow on sands so poor that even the undemanding *Eucalyptus* speciesare not competitive on them. They are peinobiomes. They are also uncultivated and rarely grazed. The strange thing, however, is that the species richness on these poor sands is particularly high; on 100 m2 we could count 90 species, including 63 small woody species, mostly Proteaceae or Myrtaceae; *Drosera* speciesand an *Utricularia* with tubers were not missing.

Results from an ecophysiological study are available for such a heath with 450 mm rainfall and seven months of drought in summer in S Australia.

Soil temperatures at 15 and 30 cm depth ranged from 4.1 to 36.0 and 5.8 to 29 °C, respectively. Root systems of 91 species were excavated. The dominant sclerophylls are the shrubby *Eucalyptus bacteri,* 9 Proteaceae, 2 *Casuarina* species*, Xanthorrhoea,* Leguminosae and others.

The main growing season is the dry summer, as the soil remains moist at greater depths. The smaller perennial species (42%) root only in the upper 30 to 60 cm; they develop in spring. *Drosera* and orchids are ephemeral species because they root only 5 to 7 cm deep. Water is found to be very unevenly distributed in the sandy soil with a wilting point of 0.7 to 1%; this is because the large species channel rainwater to the stem. The composition of the heath is determined by the fires. After a fire the grass-tree *Xanthorrhoea* sprouts first; it flowers only after a fire. The Proteaceae *Banksia* rejuvenates by seedlings after fire. Its share of the aboveground phytomass increases to 50% by the 15th year. The main mass of dry matter in 25-year-old specimens is accounted for by the large inflorescences, which open only after a fire.

*Banksia* thus belongs to the **pyrophytes** that arevery common in Australia, i.e. species that can only rejuvenate after fires because the woody fruits do not open otherwise (► Fig. A-33). This fact suggests that fires caused by lightning were also a natural factor in Australia. Today, forest and heath are very often burned because the woody plants seem to have no monetary value and they interfere with grazing. "One blade of grass is worth more than two trees" says the farmer - but for how long?!... crazy!

The pyrophytes include a great amount of Proteaceae and Myrtaceae, the conifers *Actinostrobus,* etc. *Eucalyptus* spp. also seed themselves particularly abundantly after a fire. In a heath that has not been burnt for a long time, all the nutrients are bound in the fruits of *Banksia,* in the old leaves of *Xanthorrhoea*, and in the accumulating litter. A 50-year-old stand therefore degenerates. It is only by fire that mineralization of the nutrients occurs, and new succession is initiated.

The ecophysiological conditions of *Eucalyptus marginata* correspond fairly closely to those of sclerophyllic vegetaion. The roots go partly through the hard laterite crust up to more than 2 m deep. There is no summer dormancy, transpiration is restricted only at noon from 10 h to 15 h by partial crevice closure, so that the water balance can be maintained. The cell sap concentration was 1.6 MPa in winter and probably only slightly higher in summer.

Not only the **flora** and therefore the vegetation of Australia differs strongly from that of other continents, but also the **fauna.**

Only in Australia do the primitive mammals - the cloacal animals (Monotremata) - occur, to which the platypus *(Ornithorhynchus anatinus)* belongs, which still lays one to three eggs that are incubated by the mother. In contrast, the echidna *(Tachyglossus* = *Echidna)* hatches only one egg in the brood pouch. Altogether Australia is thus the home of 5 remaining species of egg-laying monotremes. It passes on to the marsupials *(Marsupialia).* With few exceptions, these are also restricted to Australia. Among them are herbivorous and carnivorous representatives. The best known group are the kangaroos *(Macropodidae)* with the large kangaroo *(Macropus),* which as a grazing game certainly influences the vegetation.

In total the fauna of Australia includes a large number of different animal species that are only found on this continent. 83% of mammals, 89% of reptiles, 90% of freshwater fish and insects and 93% of amphibians are endemic species. This high proportion, as with the flora, is due to Australia's long geographical isolation and the geological stability of the continent.

The Australian continent is also home to the five remaining species of egg-laying monotremes. The high number of poisonous spiders, scorpions, octopuses, jellyfish, mussels and stingrays is also striking. It is also unusual that Australia is home to more venomous than non-venomous snakes.

In the Pleistocene, Australia was home to a rich fauna of large animals, including the giant *Diprotodon*, the Tasmanian rhinoceros *Zygomaturus*, the Marsupial Lion, the Marsupial Tapir *Palorchestes*, large short-snouted kangaroos (*Procoptodon, Simosthenurus*), the giant rat kangaroo *Propleopus* and the giant bird *Megalyania*.

Most of these large animal species are thought to have died out around 50,000 years ago, which correlates strongly with the first appearance of humans on the continent (Roberts et al. 2001) It is, however, still an open dispute to what extent the Aborigines are involved in the extinction of the Australian megafauna.

10 Mediterranean orobiome

In the mountains of the Mediterranean region we have to distinguish the humid elevational sequence and the arid elevational sequence (Walter 1975):

1. The arrangement of the humid elevational belts of mountains occurs at the northern edge of the western, maritime Mediterranean zone, where with increasing elevation not only the temperature decreases, but at the same time the drought disappears. In both cases, several vegetation units corresponding to the zonobiome (hypsozonal or orozonal vegetation) form the arrangement of the elevational belts.

Here the evergreen sclerophyllous belt is followed by a deciduous sub-Mediterranean deciduous forest belt with deciduous oaks (*Quercus pubescens*) or sweet chestnut *(Castanea)* and above it, at the height of the summer cloud cover as a fog forest, a beech *(Fagus)* and fir *(Abies)* belt*.* The beech forms the tree line in the Apennines as well as in Catalonia (Montseny Mountains); it still occurs on Etna and in N Greece. In the Maritime Alps, above the beech belt, we have a subalpine spruce *(Picea)* belt, in the Pyrenees one with *Pinus sylvestris* and *P. uncinata.*

1. The arrangement of the arid elevational belts occurs in the continental climatic region with a summer drought that is noticeable up to the alpine belt. Here a deciduous forest belt is absent; the Mediterranean sclerophylls belt is immediately followed by a series of different coniferous forest belts, for example, on the southern slope of the Taurus in Anatolia an upper Mediterranean with *Pinus brutia,* a weakly developed montane with *Pinus nigra* ssp*. pallasiana,* a high montane with *Cedrus libanotica* and *Abies cilicica* (wetter) or *Juniperus* species(drier), and a subalpine with *Juniperus excelsa* and *J. foetidissima.* But in the rainy northeast corner of the Mediterranean with the Amanus Mountains (= Kohe Nur in the Turkish-Syrian border area) a cloud belt with *Fagus orientalis* is present. *Cedrus libanotica* also occurs on Cyprus and as a small remnant in Lebanon at 1,400 to 1,800 m asl. In Cyprus and Crete, as well as in Cyrenaica, cypress *(Cupressus sempervirens)* always occurs in its natural form with horizontal branches in the upper Mediterranean belt. The frequently planted columnar variety is a mutation. Cedars *(Cedrus atlantica)* also form the high-montane belt (>2,300 m asl) in the Atlas Mountains from the eastern High Atlas to the Tunisian border; (◘ Fig. G-43) but the elevational belts change greatly depending on the course of the range and the slope exposure. The likewise complicated arrangement of the elevational belts of the Spanish mountains are shown on ◘ Fig. G-44.

**Fig. G-43** *Cedrus atlantica* forests atthe Zeida-Midelt Pass, form an open forest belt in the upper montane belt (2,200 m NN) of the Atlas Mountains in Morocco. Underneath, *Quercus ilex* standsoccur as montane forests (photo: Rafiqpoor).

◘ **Fig. G-44** Elevational belts of the crystalline high mountains of the Iberian Peninsula on a NW-SE profile (modified after Ern 1966). **1** Deciduous oak forest *(Quercus robur, Qu. petraea),* **2** Pyrenaean oak forest *(Qu. pyrenaica),* **3** Holm oak forest (*Qu*. *ilex),* **4** Beech forest (*Fagus sylvatica),* **5** Birch forest (*Betula verrucosa),* **6** Pine forest *(Pinus sylvestris),* **7** Mixed deciduous forest *(Quercus, Tilia, Acer),* **8** High altitude forest of Serra Nevada (*Sorbus, Prunus,* etc.), **9** High alpine grassland and herbaceous meadow, **10** Dwarf shrub heath *(Calluna, Vaccinium, Juniperus),* **11** Broom heath *(Cytisus, Genista, Erica),* **12** Thorn cushion belt, 13 *Festuca indigesta* dry grassland.

The difference between the arid and the humid sequence of the elevational belts can be seen even above the tree line in the alpine belt. Whereas in the humid sequence conditions like in the Alps can be found, in the arid sequence a hemispherical cushion belt (◘ Fig. G-45) occurs, sometimes with many convergent species of different families, which can be easily distinguished only in the flowering state; this is followed by a dry grassland belt, and only in places kept moist by thawing snow in summer can be found hygrophilous, mostly endemic species of arctic-alpine affinities.

The interlocking of the Mediterranean vegetation is particularly complicated in the mountains of SE Europe, where transitions to ZB VI and in part expressions of ZB VII become effective and frosts occur more frequently. The submediterranean deciduous forests there are almost always degraded to a deciduous scrub, the **Shibljak**, by logging, slash-and-burn and forest grazing. Towards the east, more and more deciduous shrub species appear in the macchia-like formations, representatives of the East European Shibljak from the ZE IV/VI of Bulgaria and Yugoslavia, for example *Ostrya carpinifolia, Cotinus coggygria, Fraxinus ornus, Pyrus spinosa* and others. Such a mixed vegetation formation with evergreen species of the maquis and deciduous species of the Shibljak is called **Pseudo-macchie**.

An overview of the elevational zones of the Mediterranean region is given by Ozenda (1975). Particularly interesting conditions are found in the orobiomes of Macaronesia, especially the Canary Islands, which are exposed to the NE trade winds.

11 Climate and vegetation of the Canary Islands

Macaronesia includes the archipelagos of the Azores, Madeira, the Canary Islands and Cape Verde.The first three are characterised by a climate with winter rain and summer drought and thus belong to Zonobiome IV, partly with hints of Zonobiome V, while the climate on Cape Verde is so dry and uniformly warm that this group of islands south of the Tropic of Cancer must already be counted as Zonoecotone II/III. Of these island groups, the Canaries and especially the islands of Tenerife and Gran Canaria are the most interesting. They are also the most studied botanically. Since Alexander Von Humboldt interrupted his journey to Venezuela on Tenerife in 1799 and distinguished five altitudinal zones on the basis of a brief survey, numerous botanists have subsequently studied the flora of this island.

The corresponding bibliography lists 1030 titles (Sunding 1973). Works on the sociology of plants include those by Oberdorfer (1965) and Sunding (1972), and ecological studies (Voggenreiter 1974, Kunkel 1976, 1987, Kull 1982, Peinado & Rivas-Martinez 1987, Lösch 1988, Höllermann 1991, Pott et al. 2003).

The origin of the volcanic islands goes back to the Cretaceous period. Gran Canaria rises to almost 2,000 m above sea level, Tenerife even to just over 3,700 m. They are very steep orobiomes, which differ from those of the others of ZB IV in that they rise directly from the ocean and are located around the 28th latitude (north), thus exposed to the trade winds. As a result, their northern slopes, which are exposed to the wind, have different climatic conditions than the southern slopes, which are in the lee.

◘ **Fig. G-45** Thorn cushion belt with *Erinacea pungens* (Fabaceae) in the mountainous region of Teruel (Spain) at the Linares Pass (2000 m NN) (photo **a**: Breckle) and in the subalpine elevational belt of the Atlas Mountains at the Tubkal Massif in Morocco (photo **b**: Rafiqpoor).

On the northern slope, the trade wind clouds accumulate, causing upslope rains with additional fog precipitation, so that a summer drought is absent. From the fog cover, *Pinus canariensis* treescomb out the fog droplets (◘ Fig. G-46). The warm, humid climate of the middle slopes is more like that of ZB V with evergreen laurel forests (◘ Fig. G-47). In contrast, the southern slope, especially at lower elevations, is particularly dry and more frequently exposed to the hot Saharan winds. As a result, site conditions corresponding to ZB III-V are found on these islands, and at higher altitudes even those under increasing frost exposure. On Tenerife, the Pico de Teide above 3,000 m asl is covered with alpine debris deserts, which are actually typical for the tropical mountains.

◘ **Fig. G-46** On the northern slope of the Canary Islands orobiome, *Pinus canariensis* treescomb out moisture from the saturated fog cover (photo: http://is.gd/MDOFZ1).

◘ **Fig. G-47** Laurel forest of *Laurus azorica* on the fog-exposed northern slope of the Anaga Mountains in Tenerife, Canary Islands. The dry leeward side of the mountains is generally free of forest (photo: Rafiqpoor).

The volcanic islands were colonized with plants from neighboring Africa at various times, especially in the Tertiary, when evergreen Tertiary forests grew there; these tree species have been preserved on the moist and warm northern slopes of the islands to the present day as in a living museum, while they became extinct on the neighboring mainland.

This results in floristic relationships with now distant elements at the humid southern tip of Africa *(Ocotea foetens),* with India (*Apollonias*), with other tropics *(Persea, Visnea -* a Theaceae, *Dracaena draco)* or with the humid Mediterranean area, such as *Laurus azorica, Laurocerasus (Prunus) lusitanica, Phoenix canariensis*. On the other hand, elements of the arid regions have also immigrated, finding suitable niches at low altitudes and rocky sites (*Launaea, Zygophyllum,* succulent *Euphorbia -* and *Kleinia* species). Many species are endemics, for example the numerous succulent Crassulaceae, which used to be placed with *Sempervivum* s.l., but are now considered endemic genera (*Aeonium* with 33 species, *Aichryson* with 10, *Greenovia* with 4, *Monanthes* with 15 species).

In the case of quite a few species, it is evident that more primitive, namely woody, representatives of genera that are herbaceous on the Euro-African mainland occur on the islands in Macaronesia. Examples are: *Plantago arborescens, P. webbii*; *Centaurea webbiana*; *Carlina salicifolia; Sonchus congestus*; *Echium giganteum*; *Isoplexis canariensis.* The reason for this is probably the low competitive pressure and similar environmental conditions over long periods of time. The different islands show closely related species, so-called vicariant species.

Lösch (1988) has shown in extensive studies how succulent Crassulaceae have adapted to small-scale sites and how the evolutionary history with the typical adaptive radiation of certain genera can be deduced from this. The adapted cold and heat resistance and the interplay of temperature and water availability have differentially expressed the existing ability of CAM photosynthesis, but each suitable to the microclimatic site conditions. Based on traits compiled according to morphological criteria and ecophysiological findings, Lösch (1988) summarized the kinship circles and stages of radiation of species in a phylogenetic tree-like manner, in a scheme that is still widely accepted today. On islands isolated from the mainland, competition from immigrating species is low or non-existent, so ancient forms tend to be preserved. The geological history of such island groups thus plays an important role in developmental processes (Kull 1982).

The age of the dragon tree individuals (*Draceana draco*) was discussed for a long time. These monocotyledonous trees have no annual rings, only by indirect methods Mägdefrau (1975) could show that none of them is more than a thousand years old, rather all trees are younger than 300 years, only the oldest tree in Icod de los Viños is about 365 years old.

*Dracaena draco* is frequently planted, it occurs only in a few wild sites (◘ Fig. G-48). The genus has a very disjunct distribution, there are relict species with isolated occurrences in the Anti-Atlas, in Socotra (► Fig. E-54b), on islands of the Indian Ocean, in West and South Africa, in Central America, in Cuba, in Hawaii, etc.

In addition, real Mediterranean elements were probably added in the Pleistocene at the earliest.

Since the islands were settled by Spain 500 years ago, the immigrants brought other Mediterranean species as well as the goats. The settlements with the cultivated areas spread more and more. As a result, the original vegetation became severely endangered. This is especially true for the unique moist evergreen laurel forest. This forest is felled for its valuable woods, its litter layer and humus soil are removed to improve the cultivated soils, which makes it impossible for the forest to regenerate on the felled areas. More undemanding species *(Erica arborea, Myrica faya)* are spreading, or the forest is being replanted with *Pinus* and even *Eucalyptus.* On Gran Canaria, the laurel forest remnants can only be found on 2% of the original area (◘ Fig. G-49), and on Tenerife the forests are also shrinking more and more.

◘ **Fig. G-48** This stately dragon tree *Draceana draco* (**a**, photo: K. Rafiqpoor) has stood here on the island of Tenerife since Alexander von Humboldt's voyage to South America. *Draceana draco* occurs in a 1996 newly discovered variety *"Draceana draco* var. *ajgal"* (**b**, photo: Breckle) at Jebel Imai/Djebel Imzi, north of Etnine in the Anti-Atlas about 80 km east of Tiznit at an elevation of 600-700 m. asl before in Morocco (see also Foto on page xxx). .

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| **Box G-12** Human impact on islands |
| "One is shocked when one visits them [the Canaries] again after 40 years and finds only concreted-over fairgrounds with motor roads. Nature conservation usually only becomes effective when there is hardly anything left to protect. Today's youth can no longer get to know the quiet and yet so sublime untouched nature" (after Walter). |

Just like everywhere else in the world, the most impressive landscapes of these beautiful islands have the last decades been threatened by mass tourism, which is only aimed at profit.

Kämmer (1974) and Höllermann (1991) have dealt with the climatic conditions on Tenerife in great detail, especially with regard to the significance of the fog precipitation combed out by the trees in the cloud belt (► Fig. G-47) (Kämmer) and the question of land use and forest fire (Höllermann). On the basis of his measurements, which were extended over several years, Kämmer comes to the conclusion that the steeply increased gradient rainfall in the laurel forest belt is of greater importance than the relatively small additional fog precipitation. The information given by Sunding (1972) that a rain gauge set up in an open place in the laurel forest showed an annual precipitation of 956 mm, while another one, which collected the dripping water under trees, showed 3038 mm, may probably not be generalized. Kämmer estimates fog precipitation at only about 300 mm per year. For epiphytes, as we know from the tropics, it is not so much the amount of precipitation that matters, but the frequency of wetting and, in the case of epiphytic mosses, the low evaporation. The short duration of sunshine and consequently high humidity in the cloud belt, namely in summer, is also an important factor for the laurel forest.

The climate diagrams on ◘ Fig. G-50 provide information about the general climate character on Tenerife. The climate of Santa Cruz on the seashore corresponds to a semi-desert climate. On the south coast, the amount of rainfall per year is likely to exceed 100 mm only slightly, so that one can speak of a desert climate. The climate of La Laguna still under the cloud level, on the other hand, is typically Mediterranean and frost-free (exception 1869). Izana at 2,367 m asl at the upper cloud level again receives somewhat lower precipitation, which decreases further at even higher altitudes. The upper timberline is a dry line, as it is in Mexico. Izana does not yet have a cold season, but frosts can occur from October to April (see Kämmer 1982 for more details).

The climate diagrams of Gran Canaria (Sunding 1972) show the same climatic character, the most arid station on the southeast coast receives only 91 mm of rain a year, Las Palmas 174 mm, the stations above 1,500 m asl more than 900 mm of rain. The clouds here often envelop the lower peak.

The vegetation structure of Tenerife can be seen from the vegetation map and the profile (A to B) on ◘ Fig. G-51 and ◘ Fig. G-52. On the S shore, in the shade of the trade winds, there is a narrow desert-like area with Saharo-Arabian elements, such as *Launaea (Zollikoferia) arborescens, Zygophyllum fontanesii* (on Gran Canaria also *Suaeda vermiculata*), etc.; above this, on the steep slopes, there is the semi-desert with succulents, which is especially pronounced on the southern slope. The montane forest belt consists of the laurel forest remnants in the cloud level, and above them *Pinus canariensis* forests(◘ Fig. G-53, ► Fig. G-46), which form the whole forest belt on the dry southern slopes. This three-needled pine species is related to *Pinus longifolia* in the Himalayas.

The summit of Mount Teide (3,718 m NN) usually rises completely above the cloud cover (► Fig. G-53). Above the timberline, it is covered with shrubby broom species (*Adenocarpus, Cytisus* spp.); above this, the alpine belt begins. In its lower part, closed stands of white-flowered broom *(Spartocytisus supranubium)* still grow, while the plant cover becomes more and more loosened with increasing elevational and the endemics *Sisymbrium bourgaeanum,* the purple-flowered *Cheiranthus scoparius* aswell as the several-meter-high viper's bugloss (*Echium bourgaeanum)* with reddish inflorescences appear (◘ Fig. G-54).

Above 2,600 m asl, the alpine debris belt begins, which is constantly in motion due to **solifluction** (frost-induced slope sliding) on frost-change days. Here only single debris creepers like *Nepeta teydea, Viola cheiranthifolia* and *Silene nocteolens* persist. Above 3,300 m asl only cryptogams occur: some cyanobacteria *(Scytonema),* mosses *(Weissia verticillata* and *Frullania nervosa)* and lichens (*Cladonia* spp. and others).

The plant communities on Gran Canaria have been studied in detail by Sunding (1972). The elevationalzonation is the same as on Tenerife. However, it only reaches up to 2,000 m asl, i.e. hardly above the timberline. Human encroachment has resulted in some irreversible changes in the sites, for example, severe soil erosion on deforested areas, which consequently do not reforest (► Fig. G-49B). The map of potential vegetation (► Fig. G-49A) does not show the very narrow desert-like zone along the seashore predominantly on the south and east coasts. Above this, occupying over half of the total area, follows the succulent semi-desert belt on the north side below 400 m asl, and on the drier south side below 800 m asl. The rest is occupied by the forest belt, namely by the *Pinus canariensis* coniferous forest; only in the lower part of this belt, but only in northeast exposure, the evergreen laurel forest in a broader sense (the drier form with *Myrica faya* and *Erica arborea* included) might have prevailed in former times. The natural range of the broom belt above the timberline was, in Sunding's opinion, confined to the small summit area.

If one compares this map with today's vegetation (► Fig. G-49B), leaving aside the settlements with cultivated areas on the lower flat slopes, one can see the enormous change: the desert-like vegetation on the flat seashores will soon be completely displaced by hotels or holiday homes with bathing beaches. The succulent semi-desert has expanded enormously at the expense of the forest belt and now covers 78% of the total area. In the upper part of the forest belt, mainly broom heaths replace the former forest, and the remaining forest area has shrunk very much, with almost only pine forests left today. Of the formerly extensive evergreen laurel forest, only in some ravines on the northern side such small remnants remain that they could only be entered as dots on the reduced map.

Natural vegetation is therefore only found today on the steep rocky slopes of the succulent semi-desert belt, which are often difficult to access. From an ecological point of view, this is a highly heterogeneous unit almost with a micro-mosaic structure ranging from dry rocky surfaces and shallow soils, to crevice-rich rocks and scree slopes on which deep-rooted species are relatively well supplied with water, to groundwater-bearing valleys and gorges or dripping wet rock faces. Therefore, a wide variety of ecological types find suitable niches here and often occur side by side, but under quite different conditions. At one extreme are the stem-succulent euphorbias, which can tolerate long periods of drought, and at the other the delicate Venus fern *(Adiantum capillusveneris)*, which isconstantly found on wet rock faces in the shade. Beneath it are found moss cushions encrusted with lime, which remains after evaporation of the water. The small amounts of NaCl in the water can also accumulate, so that even a halophilic species, *Samolus valerandi,* occurs next to the fern. Even small-scale sociological inventories yield random lists of quite heterogeneous ecological types, shallow-rooted and deep-rooted, succulent and non-succulent, tied to quite different niches. Annual therophytes are of no informative value; for they develop during the short rainy season, when all soils are moist, where they are protected from competition in an open place, but very variable from year to year.

◘ **Fig. G-49** Comparison of the original natural vegetation structure on the island of Gran Canaria (**A**) with the present-day one altered by humans (**B**). Vegetation belts: **1** Succulent semi-desert (today mostly cultivated land in lower, flat areas), **2** Laurel forest or Myrico-Ericetum, **3** Pine forest (today partly *Cistus* heaths), **4** Broom heaths, **5** *Cistus-*broommixed stands(modified after Sunding 1972).

◘ **Fig. G-50** Climate diagrams: Santa Cruz de Tenerife at sea level, La Laguna at the lower cloud level boundary, Izaña at the upper forest line**Fig. G-51** Vegetation map of Tenerife: **1** *Zygophyllum-Launea* desert,**2** *Kleinia-Euphorbia* belt ofsucculent semi-desert, **3** Laurel forest and *Erica* beltin the north (trade wind side), **4** Pine forest-broom heath belt, **5** *Spartocytisus mountain* semi-desert(temperate), **6** Rocky debris belt with *Viola* and *Silene,* **7** Mountain desert with cryptogams (cold). **A-B** course of the profile on ► Fig. G-52 (modified after Walter 1968).

◘ **Fig. G-52** NNW-SSE profile through the island of Tenerife (► Fig. G-51-G) with indication of elevational belte. Colour legend ► Fig. G-51-G (modified after Walter 1968).

◘ **Fig. G-53** Trade wind cloud in the area of fog forests of *Pinus canariensis* on the northern slope of the island of Tenerife (ca. 1,800 m asl). The leeward side of the mountain (photo location) is free of forest (photo: Rafiqpoor).

◘ **Fig. G-54** *Echium wildpretii* (Boraginaceae) in the alpine belt of the Teide massif, Canary Islands (photo: Rafiqpoor).

Only a careful ecological analysis, taking into account the rooting and watering of the soil in different seasons, can clarify the presence of certain ecological types. Such an analysis is very lengthy. It requires very careful observations with targeted experiments in the field during a long period in all seasons.

In this elevational belt of the succulent semi-deserts, the palms *(Phoenix canariensis)* probably also grew in former times, of which wild specimens no longer exist. It is the palm that is found in the parks in the area of ZB IV, partly also ZB V. It is more ornamental than the related date palm *(Phoenix dactylifera),* but has inedible fruit. It was certainly bound to sunny locations with easily accessible groundwater, i.e. in the water-draining ravines.

Also the famous dragon tree of the Canary Islands *(Dracaena draco)* probably occurred on similar biotopes. Today, however, it is almost only found planted in gardens and parks.

12 Afghanistan at the eastern edge of the winter rain zone

The treatment of the ZB IV remains incomplete if one is content with the description of the winter rain areas in California, the Mediterranean area, Chile, Cape region and SW Australia. The Eurasian winter rain zone extends from the Atlantic coasts of the Iberian Peninsula over the entire Mediterranean rim towards Asia Minor, the Near East, Iran and Afghanistan. The winter rains are caused by the cyclones of the planetary westerly wind belt, which shifts its position slightly to the south in winter due to the southward shift of the ITCZ and thus of the entire general circulation system.

The precipitation amounts resulting from this cyclogenesis show a strong W-E gradient in the Eurasian Mediterranean zone; i.e. the further the cyclones move eastwards from the Atlantic, apart from the convective intensification effects over the warm Mediterranean, the lower their precipitation intensity also becomes, so that they arrive in Afghanistan only in a weakened form and can cause only sparse rainfall there (◘ Fig. G-55). An important difference, however, is the greater continentality, which leads to regular frosts in winter. We therefore place Afghanistan largely at ZE IV/VII.

The climate of Afghanistan and the spatial distribution of precipitation are strongly influenced by its high mountain character. The distribution of precipitation in Afghanistan is shown in ◘ Fig. G-56. They originate to a considerable extent from the cyclones of the westerly wind drift. But in summer a narrow strip in the east of the country additionally comes under the influence of the Indian summer monsoon. An analysis of the percentages of summer precipitation to total precipitation shows (◘ Fig. G-57) that as the distance from the Afghanistan-Pakistan border to the west increases, the percentages of summer precipitation successively decrease (Rafiqpoor 1979, Lauer et al. 1983). In the Khost basin in E Afghanistan, of the total annual precipitation, about 30% (>600 mm) falls in summer; whereas in Kabul, less than 3% (0-20 mm) of the annual precipitation is recorded in summer. C and E Hindu Kush record considerable summer precipitation (Breckle & Frey 1976), the exact amounts of which are unfortunately not yet known due to lack of measurements. In the central mountainous areas in the deserts and semi-deserts of N and SW Afghanistan there is no rain at all in summer.

◘ **Fig. G-55** In the climate diagrams of Lisbon, Heraklion and Kabul, the decrease in precipitation and the increase in continentality and winter frosts from west to east in the winter rain areas is clear.

◘ **Fig. G-56** Mean annual precipitation in Afghanistan.

Thermally, Afghanistan is characterized by a high degree of continentality with very low absolute temperatures in winter (Panjao: -52 °C) and very high temperatures in summer (Zaranj: +52 °C) and thus a temperature fluctuation of >100 K (Breckle, 2004). A map of the climate diagrams of Afghanistan (◘ Fig. G-58) provides a quick orientation on the ecological conditions of the country, showing the annual cycles of precipitation and temperature as well as the months with water deficit in different areas of Afghanistan.

The enormous differentiation of abiotic factors (climate, topography, geology, soils) in Afghanistan leads to a strong diversification of sites for a rich flora (Breckle et al. 2013). The latter found that, due to the geodiversity of the country, according to current knowledge, Afghanistan has about 5,000 different plant species, of which 25% are endemic. Thus, Breckle et al. (2013) characterized central and eastern Afghanistan as a biodiversity hotspot in the Near East. The flora of Afghanistan, like its climate, varies greatly from west to east, from north to south, and from the plains to the high mountains, and is influenced by different floral elements (◘ Fig. G-59).

◘ Figure G-60 (Barthlott et at. 2014) gives the biodiversity of Eurasian winter rainfall areas. ◘ Table G-2 shows the diversity numbers and their degree of endemism for the taxa occurring in Afghanistan. ◘ Figure G-61 gives the number of species in the families with more than 40 species.

◘ **Fig. G-57** The proportion of summer rainfall in total annual precipitation in Afghanistan.

This shows that more than half of the species in Afghanistan are contained in seven families. Figure G-62 shows the number of genera and Fig. G-63 the number of species in the extended families. Again, it is evident that the seven extended families harbour more than half of the genera and species, although the ranking of the families now shifts a little here. The floristic diversity of Afghanistan is largely based on the spatial configuration of the plant geographic regions: About 92% of the country's area comprises the Irano-Turanian floral region, and about 7% is part of the Sino-Japanese floral region. Although temperature conditions in both regions are very similarly continental, precipitation has a different seasonal distribution. The latter floral region is favored by a second summer rainy season (see above). A very small region (predominantly the Jalalabad basin in east Afghanistan) is Saharo-Sindian. Saharo-Sindic elements are also mixed with Irano-Turanian in S and SW Afghanistan. In the mountains, Central Asian floral elements occur in the upper levels, Himalayan in the east, but also Euro-Siberian, boreal and even Arctic floral elements.

The plant geographic classification is not seen consistently by different authors (Hedge & Wendelbo 1970, Léonard 1988, Browicz 1997, Breckle 2004). The differentiation of the floristic regions of Afghanistan presented here is mainly based on Freitag et al. (2010).

12.1 Irano-Turanian floral elements

In accordance with the very different site conditions from the various lowland semi-deserts to the montane tree-slopes and alpine meadows, the occurrence of the individual species varies considerably. Many genera are distributed between C Anatolia and the E Hindu Kush at similar sites, usually with very different species. Especially the large genera, such as *Astragalus, Cousinia, Acanthophyllum, Acantholimon, Allium,* and *Eremurus* (◘ Fig. G-64) occur at all altitudes, but each with different species.

◘ **Fig. G-58** Climate diagram map for identifying regions of the same climate (homoclimates) based on the ecological climate diagrams in Afghanistan.

◘ **Fig. G-59** The distribution of natural vegetation in Afghanistan (after Freitag et al. 2010).

◘ **Fig. G-60** Spatial diversity patterns of vascular plants in SW Asia (from Barthlott et al. 2014).

◘ **Fig. G-61** Number of species in the major vascular plant families of the Afghan flora (from Breckle et al. 2013, 2019).

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| **◘ Table G-2** Number of families, genera, species, taxa and endemics in the Afghan flora, according to the checklist by Breckle et al. (2013, 2019). | | | | | | | | | |
| **Taxon group** | **Number** | | | | | | **Endemics (%)** | **Sub-endemics (%)** | **Endemics Total (%)** |
| **Families** | **Genera** | **Species** | **Taxa** | **Endemics and sub-endemics** | **Immigrant species** |
| **Pteridophytes (56)** | 11 | 23 | 50 | 56 | 0 | 0 | 0 (0 %) | 0 (0 %) | 0 (0 %) |
| **Gymnosperms (24)** | 4 | 8 | 24 | 24 | 2 | 3 | 0 (0 %) | 2 (8.0 %) | 2 (8.0 %) |
| **Monocotyledons (840)** | 28 | 195 | 817 | 840 | 75 | 40 | 57 (6.8 %) | 18  (2.1 %) | 75 (8.9 %) |
| **Dicotyledons (4,115)** | 106 | 860 | 3,935 | 4,115 | 1,138 | 148 | 898 (21.9 %) | 243 (5.9 %) | 1,138 (27.8 %) |
| **Total (5,035)** | 149 | 1,086 | 4,826 | 5,035 | 1,215 | 191 | 955 (19.0 %) | 263 (5.2 %) | 1,215 (24.2 %) |

**Fig. G-62** Number of genera in the major vascular plant families of the Afghan flora

**Fig. G-63** Number of species in the major plant genera of the Afghan flora

◘ **Fig. G-64** Species density and distribution of *Eremurus* speciesas an example of Irano-Turanian distribution (Hedge & Wendelbo 1970).

The lowland species usually have a very wide distribution. Most species occur in S and N Afghanistan, but also in neighbouring Iran, Turkmenistan, Uzbekistan and Tajikistan. Others range from C Asia just to N Afghanistan, while a third group occurs mainly in the southern deserts of Iranian Baluchistan, S Afghanistan to Pakistan. In the mountain belts, because of the great habitat differentiation, the floristic diversity is much greater, the distribution patterns of the species much more variable, a few extending even to Pakistan, others having a much smaller range or being endemic. Endemic here means that they occur only in the Afghan mountains, although they may also spread to neighbouring mountain ranges in Tajikistan and Pakistan. However, many also occur only in a smaller part of the mountain range. Thus, due to the strong geographical isolation, other species have evolved in each chain; this explains the large number of species in the genera *Astragalus, Cousinia, Acantholimon, Allium* and some others.

12.2 Sino-Japanese floral elements

With the Himalayan subregion, the Sino-Japanese floral region extends into E Afghanistan (◘ Fig. G-65). Here it occupies mainly the lower elevational regions. Biodiversity is particularly high considering the inherently small area. Different forest types characterise the E and SE slopes of the Hindu Kush. Thus, Himalayan cedar *(Cedrus deodara),* pines *(Pinus gerardiana* and *P. wallichiana),* oaks *(Quercus baloot, Qu. dilatata* and *Qu. semecarpifolia),* fir (*Abies spectabilis)* and spruce *(Picea smitheana)* each form small-scale forests with numerous species in the understory, which also have a mostly eastern Afghan-Himalayan distribution. The rare *Rhododendron afghanicum* as understory in the upper coniferous forest belt and *Rh. collettianum* in the subalpine *Juniperus* beltare examples of narrow endemic species of the region (◘ Fig. G-66).

◘ **Fig. G-65** The distribution of *Quercus baloot* as a Sino-Japanese element from the montane elevational range of the Himalaya and E Hindu Kush (as cited by Browicz 1978).

◘ **Fig. G-66** Distribution of *Rhododendron afghanicum* and *Rh. collettianum* as two Himalayan elements in monsoon-influenced eastern Afghanistan (based on Flora Iranica data).

12.3 Saharo-Sindian and other floral elements in Afghanistan

The Saharo-Sindian floral region is less homogeneous, although the climatic conditions with high aridity are very similar from the W Sahara to Pakistan with very hot summers and mild but never quite frost-free winters. There is considerable variation in the distribution patterns of the individual species, perhaps explained by their large range but also by the different climatic histories in historical times. *Haloxylon salicornicum* (◘ Fig. G-67), *Cornulaca monacantha* (both Chenopodiaceae), and *Gymnocarpus decander* (Caryophyllaceae) are examples of particularly widespread lowland species. They overlap in range with Irano-Turanian species, or they are species that have penetrated far into the Saharo-Arabian deserts from Irano-Turanian floral regions, such as the chenopodiaceous shrubs *Haloxylon persicum* (white Saxaul) and *Seidlitzia rosmarinus.*

◘ **Fig. G-67** Distribution pattern of *Haloxylon salicornicum* as a lowland element of the Saharo-Sindian floral region with a wide spatial range of variation (as indicated by Browicz 1978).

◘ **Fig. G-68** Distribution pattern of *Nannorrhops ritchieana* as a representative of the subtropical lowlands just extending into E Afghanistan (as cited by Browicz 1978).

Only in the basin of Jalalabad and less clearly around Khost (Paktia) one finds quite a few Saharo-Sindian species due to the mild winters and summer rains. The thorn bushes or small trees of *Acacia modesta* (Mimosaceae), *Zizyphus nummularia* and *Z. oxyphylla* (Rhamnaceae) and the evergreen shrubs *Calotropis procera, Periploca aphylla* and *Rhazya stricta* (Apocynaceae) can be cited. Another southern floral element is characterised by sclerophyllous trees and shrubs such as *Olea ferruginea, Reptonia buxifolia* (Sapotaceaae), the dwarf palm *Nannorrhops ritchieana* (◘ Fig. G-68), *Maytenus royleanus* (Celastraceae), *Ebenus stellatus* (Fabaceae), and *Dodonaea viscosa* (Anacardiaceae). They occur from the driest parts of W Himalaya, the Suleiman ranges and Baluchistan to the E and S of the Arabian Peninsula (► Fig. G-68)*.*

12.4 Floristic elements of the Afghan high mountains

The alpine and nival elevational belts passes continuously through the C and E Hindu Kush, but become more isolated in the W, with outriggers in the Kohe Baba. At this altitude, C Asian floral elements are common, not infrequently mixed with Tibetan (e.g. *Delphinium brunonianum, Sibbaldia cuneata, Chorispora macropoda* and *Primula algida*), with Himalayan (e.g. *Anaphalis nubigena, Juncus membranaceus, Lamium rhomboideum, Primula macrophylla, Rheum tibeticum*) and with Irano-Turan mountain species. The uppermost belts are characterized mainly by Euro-Siberian, boreal (e.g., *Androsace villosa, Cerastium cerastioides, Cystopteris fragilis* incl. *C. dickieana, Lloydia serotina*), and arctic species (e.g., *Epilobium latifolium* (◘ Fig. G-69), *Smelowskia calycina, Koenigia islandica*) (Breckle 1974, 1988). However, in addition to cosmopolitan high altitude species such as *Luzula spadicea, Oxyria digyna, Polygonum viviparum, Phleum alpinum,* there are also narrowly restricted endemics in the alpine belt such as *Didymophysa fedtschenkoana, Papaver involucratum, Polygonum myrtillifolium, Polygonum chitralicum, Aconitum rotundifolium, Corydalis metallica, Gentiana longicarpa, Gynophorea weileri, Potentilla coelestis* or *Potentilla collettiana.*

To illustrate the elevational belts of the vegetation, two schematic profile diagrams are shown, each of which also reveals the typical asymmetrical character of the elevational belts (◘ Fig. G-70 and ◘ Fig. G-71). This is particularly striking in the formation of the elevational gradients on the SE slope of the Hindu Kush and Safed Koh, where the influence of the Indian summer monsoon becomes clear (Breckle & Frey 1976a,b).

In general, the vegetation mosaic is determined on the one hand by the total amount of precipitation, which can vary greatly depending on the windward or leeward position, and locally by the accentuated topography, but on the other hand, especially under monsoon influence, by the additional occurrence of summer rains. Only then do dense forest belts form (Neubauer 1954 a,b, Volk 1954, Freitag 1971a,b). In the remaining parts of the Hindu Kush one finds (today almost completely disappeared) at most very open tree vegetation, woods with wild almonds and pistachios. Most parts of the mountains are accordingly characterised by open scrubland, mountain steppes and semi-deserts. The elevationall levels of the individual mountains are strongly stratified by plant geography (Breckle & Frey 1974, Breckle 1974, 1983, 1988, Agakhanjanz & Breckle 2002). The respective climatic influence also has an effect on the alpine belt. On the one hand, mountain semi-deserts or on the other hand, mats with a krummholz belt are the opposite expressions. ► Figure G-70 gives an overview of the elevational zonation in the W compared to the SE Hindu Kush in ► Fig. G-71. The well-developed forest formations with several altitudinal belts in the SE mountain slops also show a plant-geographical stratification.

◘ **Fig. G-69** Distribution pattern of *Epilobium latifolium* as a boreal element absent only from Europe and W Asia (according to Flora Iranica).

◘ **Fig. G-70** Schematic arrangement of the elevationalbelts of vegetation in the mountains of C Afghanistan between Zaranj and Amu-Darya (adapted from Freitag 1970 and Breckle 2004, 2007).

◘ **Fig. G-71** Schematic arrangement of the elevational belts of vegetation in the mountains of E Afghanistan between Jalalabad and Amu-Darya (based on data from Freitag 1970 and Breckle 2004, 2007).

◘ **Fig. G-72** Remnants of the woody floras of *Cercis griffithii* near Topdarah in Charikar Province, Afghanistan, show that this formation must once have been very widespread (photo: M. Keusgen).

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| **Tab. G-3** Regional occurrences of the 65 species of the family Poaceae with heavy seeds in their importance for cultivation. It can be seen that the majority of occurrences are concentrated in the Mediterranean regions (according to Diamond 2012). | |
| **Region** | **Number of species** |
| W-Asia, Europe, N-Africa | 33 |
| of which in Mediterranean area | 32 |
| England | 1 |
| E-Asia | 6 |
| Africa south of the Sahara | 4 |
| America | 11 |
| of which in N America | 4 |
| Central America | 5 |
| South America | 2 |
| N-Australia | 2 |
| **Total** | **56** |

The difference is particularly marked in the middle belts with the (originally) dense forest areas on the monsoon side and the dry steppe- to semi-desert-like mountain parts of the NE, N and W slopes (► Fig. G-71). But also in the W and C Hindu Kush, in the Kohe-Baba, in the Paghman Mountains, etc., there are sometimes great differences between the N and S slops, which are expressed in different occurrences of various open scrub vegetation. In the N one still finds *Pistacia vera* woodlandswith the wild form of the edible pistachio. In C Afghanistan and further to W, woodlands with wild almonds and thorny dwarf almond shrubs (*Amygdalus species*) occasionally occur, and more rarely with *Cercis griffithii* (◘ Fig. G-72), a tree species that must still have been very common in the mountains around Kabul in the last century. On other mountain slopes one encounters isolated remnants of *Pistacia cabulica,* a species also endangered by fuelwood scarcity and by overgrazing. Single trees at sacred places (“Ziarat vegetation”) indicate the once wider distribution.

Diamond (2012) notes that of the 56 total wild grasses with heavy seeds, 32 occur in the Mediterranean zone of western Eurasia alone, only 1 in England, 4 North America, 2 South America, and 2 in Australia (◘ Table G-3). Seed heaviness ranges from 10 mg to 40 mg. Diamond considers this advantage as one of the reasons why this area developed into an early center of civilization.

13 Man in the Mediterranean

The Eurasian winter rainfall zone shows major differences compared to the winter rainfall areas in California, Chile, Cape Land and SW Australia. It occupies a considerably larger space and has a rich landscape differentiation both horizontally and vertically because of the W-E orientation of the Tertiary mountains of the former Thethys geosyncline (Pyrenees, Alps, Balkans, Carpathians, the Pontides, Caucasus, Taurus, Zagros, Suliman Mountains to Hindu Kush-Karakoram-Himalayan system). This favors an enormous floristic diversity, which Barthlott et al. (2014) summarize into a "Caucasus-SW Asia Centre of Diversity". Culturally and historically, this area is also the cradle of domestication of domestic animals and crops, especially starchy bread cereals (wheat, barley), compared to all other winter rain areas of the world, which was domesticated in the area of the Fertile Crescent and radiated from here to the other regions of the world.

The influence of humans in the Eurasian winter rain zone is therefore very old, starting with the early advanced civilizations in the Near East, and has also been very great for thousands of years (◘ Table G-4). Deforestation as early as several thousand years ago (for example by the Phoenicians in Dalmatia) led to the large-scale loss of the original sclerophyllous forests. Regeneration is no longer possible due to the completely eroded soil down to the bedrock. Soil formation on the exposed bare rock requires millennia. Grazing and early agriculture in the Orient have led to a strong selection of species. Thorny and poisonous plants have spread.

The diversity of species was probably not significantly changed by man at first, some species were introduced, additionally promoted, so the olive tree probably came from northern East Africa and/or southern Arabia several millennia ago; but today it is considered a character tree of the actual Mediterraneis. From the New World came agaves and opuntias, from South Africa aloesand Crassulaceae, from Australia acacias and eucalypts. The "eucalyptisation" of Portugal has dangerously increased the risk of forest fires there.

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| **Table G-4** Time scale for the influence of humans in Mediterranean ecosystems; the figures given are years before today (after Groves et al. 1983). | | | | | |
|  | **Mediterraneis** | **Australia** | **South Africa** | **Chile** | **California** |
| **First appearance of humans: Hunter/gatherer, fire use** | 400.000 | 40 - 70.000 | 500.000 | 11.000 | 14.000 |
| **First appearance of pets** | 10-6.000 | 150 | 20.000 | 400 | 400 |
| **First appearance of agriculture** | 10-6.000 | 150 | 300 | 1.000? | 150 |
| **Intensive farming** | 2.000-1.000 | 50 | 300-200 | 400 | 50 |

For large parts of the Mediterranean region (Mediterraneis), forms of use had mostly developed over the centuries that were quite well adapted to the ecological conditions. The widespread cork and holm oak stands in the W Mediterranean (◘ Fig. G-73), where firewood was cut, grazing animals were herded into them, and cork was also peeled (► Fig. G-6), were quite fire-resistant. They were interspersed with other small-scale crops, which provided even more fire protection. Today, many of these cultivated areas are abandoned, they become overgrown with bushes, and other areas are reforested with fast-growing *Pinus pinea* or *Pinus maritima,* which drastically increases the fire hazard.

With increasing human influence, biodiversity and ecosystem dynamics (the number of functional groups, interspecific interactions, etc.) clearly decrease, as shown in the diagram in ◘ Fig. G-74. However, the rich mosaic of diverse land uses, the mixture of small-scale agriculture, pastoralism, coppicing, transhumance, etc. of the late Middle Ages may have had the highest biodiversity until the beginning of this century (Blondel & Aronson 1995). Macchia, garigue and asphodel rock heaths are also often still very rich in species. However, increased degradation and overuse, and the industrialisation of agriculture, have recently led to considerable impoverishment, at least for many groups of organisms and in many landscapes.

◘ **Fig. G-73** *Quercus ilex* forestsin their uppermost distributional range on the eastern slope of the High Atlas Mountains in Morocco (photo Rafiqpoor).

◘ **Fig. G-74** Biodiversity, ecosystem dynamics and human influence in Mediterranean formations in the western Mediterranean region (modified after Blondel & Aronson 1995).

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[IMAGE]

Laurel forests in Japan with a temple near Kyoto, Japan (Photo: Breckle).

[IMAGE]

Laurel forest (zonobiom V) on the slopes of El Bailladero mountain on the island of La Gomera, Canary Islands with garlands of epiphytic mosses (Photo: E. Fischer)

[IMAGE]

Tertiary relict forest (zonobiome V) in the Surami Mountains in Colchis (Georgia) with endemic ivy (*Hedera colchica*) on *Fagus orientalis* (Photo: Rafiqpoor)