# Chapter 2
# Lusitania

**Dalila Espírito-Santo, Jorge Capelo, Carlos Neto, Carlos Pinto-Gomes, Sílvia Ribeiro, Ricardo Quinto Canas, and José Carlos Costa**

**Abstract** The present study attempts to illustrate the large phytocoenotical diversity of forests, pre-forest, high-scrub and most of the corresponding sub-seral communities of the Lusitania territories and enables the identification of their clumped pattern of occurrence as landscape mosaics. These communities are syntaxonomically included in the Quercetea ilicis, Querco-Fagetea sylvaticae, Salici purpureae-Populetea nigrae, Alnetea glutinosae, Nerio-Tamaricetea, Calluno vulgaris-Ulicetea minoris, Cisto-Lavanduletea stoechadis and Rosmarinetea officinalis vegetation

D. Espírito-Santo (✉) • J.C. Costa
Instituto Superior de Agronomia, Universidade de Lisboa,
Tapada da Ajuda, 1349-017 Lisbon, Portugal

Centro de Investigação em Agronomia, Alimentos, Ambiente e Paisagem
(LEAF – Linking Landscape, Environment, Agriculture and Food),
Tapada da Ajuda, 1349-017 Lisbon, Portugal
e-mail: dalilaesanto@isa.ulisboa.pt

J. Capelo
Instituto Nacional de Investigação Agrária e Veterinária, Av. da República, Quinta do Marquês, 2780-157 Oeiras, Portugal

Centro de Investigação em Agronomia, Alimentos, Ambiente e Paisagem
(LEAF – Linking Landscape, Environment, Agriculture and Food),
Tapada da Ajuda, 1349-017 Lisbon, Portugal

C. Neto
Instituto de Geografia e Ordenamento do Território, Centro de Estudos Geográficos,
Universidade de Lisboa, Edifício IGOT,
Rua Branca Edmée Marques, 1600-276 Lisbon, Portugal

C. Pinto-Gomes
Departamento de Paisagem, Ambiente e Ordenamento (DPAO), Escola Ciência e Tecnologia,
Instituto de Ciências Agrárias e Ambientais Mediterrânicas (ICAAM), Instituto de Ciências da Terra (ICT), Universidade de Évora, Évora, Portugal

S. Ribeiro
Centro de Investigação em Agronomia, Alimentos, Ambiente e Paisagem
(LEAF – Linking Landscape, Environment, Agriculture and Food),
Tapada da Ajuda, 1349-017 Lisbon, Portugal

R. Quinto Canas
Departamento de Ciências Biológicas e Bioengenharia, Faculdade de Ciências e Tecnologia,
Universidade do Algarve, Faro, Portugal



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classes and span a large spectrum of environmental variables, being present in a wide range of bioclimatic stages and edaphic conditions. The grasslands, that represent seral stages of the Quercion broteroi and Quercion pyrenaicae and are included in the Stipo giganteae-Agrostietea castellanae class, are also described. In Lusitania, on soils rich in bases, without hydromorphy and salinity, dry grasslands are widespread in the potential areas of *Quercus suber, Q. rotundifolia* and/or *Q. faginea*, and are included in the Festuco-Brometea vegetation class; associations of the Arrábida mountain and Algarve are especially rich in endemic species. The ephemeral pioneer communities are dominated by non-nitrophilous, small therophytes included in the Helianthemetea guttati class. Grasslands linked to heavy grazing are also described. In this group we include pastures, with adequate sheep pasture, grazed and manured, dominated by dwarf perennial grasses and other nutritious prostrate chamaephytes and hemicryptophytes, which encompass the associations of the Poetea bulbosae class. Other herbaceous communities, dependent on anthropic influence, are those dense meadows and reed-beds included in the Molinio-Arrhenatheretea class.The tall herbs of nitrified wood fringes and other semi-shaded anthropic biotope communities belong to the Galio-Urticetea class. The herbaceous ruderal vegetation is also described. Lastly, the coastal vegetation of sea cliffs and lithosols, dunes, and estuaries and saltmarshes is referred to, as well as the interior sandy soil or semi-fixed dune grasslands.

## 2.1 Introduction

Lusitania was one of the three provinces in the Roman Empire which encompassed the Iberian Peninsula. As a political-historical entity it does not correspond exactly to a natural homogeneous unit, but nevertheless, for the most part and in its general natural limits, it corresponds to the greater part of the Mediterranean Iberian Atlantic biogeographical territory (Rivas-Martínez et al. 2014), *i.e.* formally to the set of: (i) the whole of the Lusitania and Extremadura Subprovince (West Iberian Mediterranean Province); (ii) a part of the Andalusia and Lusitania Coastal Province, namely: (1) the whole of the Divisorio Portuguese Subprovince; (2) the Ribatejo and Sado; and (3) the Algarve Monchique Sectors of the Cádiz and Sado Subprovince. Its natural boundaries are, in the north, the foot of the Central Iberian Range, which is described in Chap. 13, in volume 1, and in the south the whole of the Marianic Range (Sierra Morena) also including the smaller Sierra de Aracena range. The Tagus (northern half) and Guadiana (southern half) basins are separated by the middle Oretan Range: the Sierra de Guadalupe and Toledo Mountains extending westwards to San Pedro and São Mamede (Portugal). Defined this way, its boundaries are approximately natural ones and also in terms of its cultural landscape.

### 2.1.1 Geological Features

The morphology of Lusitania is very diverse. Nevertheless, it is dominated by an almost flat surface (which resulted from the razing of the Hercynian reliefs) called 'Meseta Ibérica' (Iberian Plateau). The 'Meseta' is an almost perfect plane surface separated in two halves by the Central Iberian Range of Alpine orogeny. To the north of this range there is the plateau of Castile-the-Older with an average altitude of 800 m and drained by the river Douro (this is not part of Lusitania as defined here), and southwards the southern sub-Meseta, *i.e.* that of Castile-the-Newer, with an average altitude of 600–700 m, drained by the Tagus and Guadiana rivers, and penetrating the Portuguese political boundary by means of the Alentejo peneplain. On this polygenic planing surface some residual reliefs remain, such as hard ones of the inselberg type (Moradal 912 m and Alcaria 370 m), or marbles (Ficalho 518 m), or some resulting from the combined effects of hardness and tectonics, as in the São Mamede range (1025 m). On the margins of the south sub-Meseta in the Alentejo peneplain (150–250 m) some tectonic reliefs occur, usually associated with the Alpine tectonic cycle (Cercal 378 m, Grândola 383 m, Caldeirão 589 m).

From a geotectonic and morphological point of view there are three major units in Lusitania:

1. The *Hesperian shield* represents more than half of Lusitania. It consists of a Pre-Cambric and Hercynian cratonic block, also known as the Iberian Massif (whose orogeny – Variscan – is completely razed), displaced in *horst* and *graben* by Tertiary and Quaternary tectonics. The geological composition reflects the Palaeozoic and Precambrian orogenic cycles and allows the definition of three zones included in Lusitania (the Central Iberian Zone in the northern sector, dominated by a Schist Greywacke Complex of *flysch* type, striated with quartzite alignments and interrupted by major granitic intrusions; the Ossa Morena Zone in the centre, also comprised of the Schist Greywacke Complex and some Palaeozoic marbled carbonated rocks and also some magmatic intrusions (granites, gabbros and diorites), and the South Portuguese Zone which presents higher lithological homogeneity, being composed essentially by a large outcrop of *flysch* formations of Schist Greywacke and quartzite.
2. The *Western and Southern sedimentary borders*. Initially, this presented a continuity around the old Iberian Massif, but presently it only emerges in three areas: (a) from north of Lisbon to Espinho (mainly Cretaceous and Jurassic limestones constituting the northern and western part of Lisbon and the Estremadura limestone massif), (b) the limestone hills of Arrábida, and (c) the calcareous coastal platforms of the Algarve. Also belonging to unit 2 are the three sub-volcanic massifs of Sintra (528 m – Late Cretaceous) dominated by granite, syenite and gabbro, Sines (gabbros and diorites), and the most important of all, the massif of Monchique (900 m) dominated by syenites. Also included in the Western Portuguese sedimentary Border (Lusitanian Basin) is the volcanic complex of Lisbon from the Late Cretaceous, dominated by basaltic rocks. The reliefs that form the western Portuguese border have a paramount importance in the history

of vegetation in southwestern Europe also due to the strong climatic influence of the Atlantic Ocean.

3. *Tertiary and Quaternary sedimentary basins*. This corresponds to subsidence zones filled with fluvial, marine and aeolian sediments that are included in two large lithological sets: (a) sandstones, conglomerates and sands, aged from the Miocene to Holocene; (b) alluvium with a fluvial and fluvial-marine origin (Tagus and Sado flood plains) and estuarine muddy intertidal platforms (saltmarshes).

### *2.1.2 Climate and Bioclimate*

The most important determinants of the Lusitanian climate are latitude, altitude, proximity to the ocean, main river basins and disposition of main mountain barriers. The whole of Lusitania is under a Mediterranean macroclimate and therefore the coincidence between the dry and hot summer season strongly affects flora and vegetation patterns. Higher rainfall of orographic origin, by intersection of wet eastern-bound winds from the Atlantic, and dryer low-standing plains are the most outstanding characteristics of Lusitania. South of the central mountain range (Cordillera Central) areas with more than 800 mm of rainfall are rare; therefore, mountains are, in general, isolated ombrophile spots. An example of orographic rainfall intersection is the Divisorio Portuguese, an almost continuous alignment of littoral hills (Sintra, Montejunto and Aire and Candeeiros mountains) that presents values between 800 mm and 1200 mm of annual rainfall (subhumid to humid ombrotype). Southward, the highest values of precipitation are recorded in the littoral hills of Arrábida, Grândola, Cercal, Monchique and the Caldeirão mountains with values between 600 mm and 1000 mm, with the exception of Monchique where this value rises to slightly above 1200 mm; as for the plains north of the former range and extending east (Alentejo and Extremadura), most are located below 600 mm, with a minimum below 400 mm in the lower Guadiana valley (dry and punctually semiarid ombrotype). In turn, the Oretan and Marianic ranges form the main inland high rainfall nucleus in the SW Iberian Peninsula.

The temperature regime expressed by *thermicity* (see Thermicity Index and thermotypes in I.3) and *continentality* also set contrasts that are paramount to vegetation distribution. Coarsely, sublittoral territories are of the thermomediterranean thermoptype (higher average temperature, milder cold intensity with little frost) and this also penetrates from the mouths and the valleys of the rivers Tagus, Sado and Guadiana. As the effect of maritime winds disappears inland and eastwards, or else, if the altitude is higher in sublittoral areas, the thermotype is mesomediterranean (lower average temperature and greater cold intensity with frost); and this belt is the one covering the largest area in Lusitania. Only near the summits of mountains the supramediterranean belt is reached (Sierra de Guadalupe 1601 m, Toledo Mountains 1447 m, Sierra Morena 1324 m). Continentality, expressing the contrast in mean temperature between the coldest month (January) to the hottest (August), is low in

coastal areas (hyperoceanic) and increases to euoceanic at the interior half of Portugal and finally is higher (semi-continental) inland south of the Spanish south Sub-Meseta. In terms of biogeography and bioclimate, the Divisorio Portuguese, Cádiz and Sado Subprovinces are almost entirely thermo-Mediterranean hyperoceanic and, in turn, Lusitania and Extremadura form a large area of mesomediterranean thermotype and are euoceanic to semi-continental, except for a penetration of thermo-Mediterranean bioclimate into the lower part of the Guadiana valley.

## 2.2 Vegetation

### *2.2.1 Forests and Pre-forests*

#### 2.2.1.1 Terrestrial Forests, and Woodlands

The Potential Natural Vegetation of the territory of Lusitania is, for its largest part, made up of woodlands, *i.e.* forest communities. Exceptions to zonal forest potentiality are dune strips, littoral areas, wetlands, riverine forests and small rock outcrops. Also, its mountains never reach altitudes to meet a timberline limit. The actual extent of natural forests in the present time is much less than in pre-Neolithic times, as the territory had a long agricultural and pastoral history since Antiquity. As a result, the actual landscape is a mosaic of forest remnants alongside with large stretches of its shrub and herbaceous seral stages, human-induced vegetation and crops. As some seral vegetation types have a univocal correspondence to forest types, the actual vegetation mosaic, including shrub types, can be interpreted as expressing whole forest successional sequences (*i.e.* a *vegetation series*). Thus, in the present landscape, forest vegetation types may be advantageously distinguished also using their most frequent associated shrub edges.

Lusitanian zonal forests are composed mostly of oak (*Quercus*) species. The dominant *taxa* in forest ecosystems are: **(a)** hard-leaved evergreen oaks: *Quercus rotundifolia* (holm oak), *Quercus suber* (cork oak) and *Quercus rivasmartinezii* (tree-kermes oak); **(b)** late-deciduous or marcescent oaks: *Quercus faginea* subsp. *broteroi*, *Quercus estremadurensis* (= *Quercus robur* subsp. *estremadurensis*) and a species-complex including *Quercus gaditana, Quercus alpestris*, *Quercus marianica* and *Quercus canariensis*; **(c)** a deciduous oak: *Q. pyrenaica*. Some other trees may be co-dominant or locally dominant in special habitats, the main ones being *Olea europaea* subsp. *sylvestris* (tree oleaster) and *Ceratonia siliqua*; of secondary importance are *Acer monspessulanum*, *Juniperus oxycedrus* subsp. *lagunae, Pyrus bourgaeana* and *Fraxinus angustifolia.*

Mediterranean woodlands make up the Quercetalia ilicis order of the Quercetea ilicis vegetation class and stand for dense-canopied, several-layered, hard-leaved, tree-dominated communities, on medium-depth or deep soils with *mull*-type organic matter in humid to dry ombrotypes. This is phytocoenotically the most diverse and extensive group of communities in Lusitania with the exception of the deciduous

*Quercus pyrenaica* woodlands (in the Querco-Fagetea sylvaticae class). Evergreen and late-deciduous woodlands are organized accordingly into two community groups (alliances) while the deciduous ones form a third one:

(i) **Sublittoral Thermomediterranean Hyperoceanic Forests**

Querco-Oleion sylvestris – exclusively sub-littoral Andalusian and Lusitanian Coastal thermomediterranean hyperoceanic (sometimes semi-hyperoceanic) woodlands. These may be, according to ombrotype and substratum, dominated by the evergreen hard-leaved taxa *Quercus rotundifolia, Quercus suber, Quercus rivasmartinezii*, *Olea europaea* subsp. *sylvestris* and *Ceratonia siliqua*. Their most noteworthy characteristic is the exuberant understorey of large, leathery shiny-leaved or spiny shrubs and climbers including many thermophile, almost non-frost-tolerant taxa, many of paleo-subtropical origin in the Tertiary. Examples are the climbers *Clematis cirrhosa, Aristolochia baetica, Smilax aspera* var. *altissima*; the herbs *Avenella stricta, Arisarum simorrhinum, Teucrium scorodonium* subsp. *baeticum, Gennaria diphylla, Arum neglectum*, *Prasium majus*, *Senecio lopezii, Picris spinifera, Centaurea vicentina, Centaurea crocata*, *Hyacinthoides hispanica*; the shrubs *Asparagus aphyllos, A. albus, Chamaerops humilis, Juniperus turbinata, Osyris lanceolata, Rhamnus oleoides, Quercus lusitanica, Morella faya, Rhododendron ponticum* subsp. *baeticum, Lavandula viridis, Bupleurum fruticosum*.

Several forest community types can be recognized within this group: Aro neglecti-Quercetum suberis are cork oak (*Quercus suber*) forests on podzol sandy soils derived from Pleistocene paleodunes in the basins of the rivers Sado, lower Tagus and along paleodune strips reaching the Algarve. Notably, they associate with juniper communities: *Juniperus turbinata, J. navicularis, J. oxycedrus* subsp. *macrocarpa*. The present woodland landscape is mostly exploited parkland where crops, grazed annual meadows and *Halimium* and *Cistus* scrub of the sandy soil group is successionally characteristic, *i.e.* Stauracantho-Halimietalia commutati of the Cisto-Lavanduletea acid scrub vegetation class; common species are *Ulex australis* subsp. *welwitschianus*, *Halimium halimifolium, Halimium calycinum, Stauracanthus* sp. pl., *Armeria* sp. pl., *Thymus capitellatus, Thymus mastichina* subsp. *donyanae, Thymus camphoratus*. On hard silicate substrates (schist, sandstone), a northernmost cork oak forest stretching from the Mondego river to most of the Tagus' basin occurs, the Asparago aphylli-Quercetum suberis (Fig. 2.1). *Quercus faginea* subsp. *broteroi* and *Quercus rivasmartinezii* (tree-kermes) might be also co-dominant. Strawberry tree hedges (Bupleuro fruticosae-Arbutetum unedonis) are characteristic of the mosaic and most seral stages are of gorse/heathland including either *Ulex australis* subsp. *welwitschianus* (low Tagus and Sado), *Ulex jussiaei* (north of the Tagus) and *Ulex airensis* (North-central Tagus). Along with heathlands, the mat-forming Erico scopariae-Quercetum lusitanicae is found and is a characteristic community of this cork oak woodland's seral stages. In the middle Tagus, as substrates become paleozoic (schist, quartzite), still thermophile but dry to inferior subhumid, a distinct cork oak forest with *Juniperus oxycedrus* subsp. *lagunae* is found: the Smilaco asperae-Quercetum suberis. Conversely, around the SW mountains

**Fig. 2.1** Cork extraction from cork-oak woodland (Asparago aphylli-Quercetum suberis) at the Serra da Carregueira (Sintra), Portugal (© P. Arsénio)

(Monchique, Caldeirão ranges) another forest-type occupying schist, the Lavandulo viridis-Quercetum suberis, is analogous, but with a wealth of endemic taxa either in the forest or in its seral stages. The woodland may include *Quercus marianica, Quercus faginea* subsp. *broteroi, Quercus estremadurensis* and their hybrids. The *Arbutus unedo* hedge (Cisto populifolii-Arbutetum unedonis), the mat-forming *Quercus lusitanica* and *Centaurea crocata* community (Centaureo crocatae-Quercetum lusitanicae), the forb clearing communities of *Picris spinifera* and *Picris algarbiensis* with *Senecio lopezii*, the endemic gorse-cistus community (*Ulex argenteus:* Cisto ladaniferi-Ulicetum argentei) are characteristic of this woodland's successional stages. The wetter parts at higher altitudes in the SW mountains of Monchique-Caldeirão correspond to a *Quercus marianica* and *Q. suber* mixed forest: the Avenello strictae-Quercetum marianicae (Vila-Viçosa et al. 2014). Its most outstanding feature are the *Adenocarpus anysochilus* and *Cytisus baeticus* broom hedge, the *Stauracanthus boivinii* heathlands and catenal contacts with a rare hygrophile oakland of *Quercus canariensis* near streams with a temporary water-table (Euphorbio monchiquensis-Quercetum canariensis) (Fig. 2.2). *Arbutus unedo* hedges of the latter, contacting with alder forests might include *Rhododendron ponticum* subsp. *baeticum* and *Morella faya*. An extensive type of thermomediterranean live oak (*Quercus rotundifolia*) in superior semi-arid to dry ombrotype on silicate is found in the SW Iberian Peninsula occupying a great part of Alentejo and the

**Fig. 2.2** View of the Euphorbio monchiquensis-Quercetum canariensis in the Monchique Sierran District (© D. Espírito Santo)

lower-Guadiana basin: the Myrto communis-Quercetum rotundifoliae. *Clematis cirrhosa, Rhamnus oleoides* and *Osyris lanceolata* are common understorey species in the woodland. Hedges are those of the Asparago albi-Rhamnetum oleoidis; the broom community of *Genista polyanthos* and the *Cistus ladanifer, Cistus monspeliensis, Genista hirsuta* subsp. *hirsuta* scrub (Genisto hirsutae-Cistetum ladaniferi cistetosum monspeliensis) are usually found as characteristic of the parklands deriving from this forest-type. Thermophile forests also occur on substrates other than silicate. Limestone-derived soils, either from neogenic Cretaceous and Jurassic origin or paleogenic metamorphic marbles, in the thermo-Mediterranean hyperoceanic sublittoral bear either holm oak (*Quercus rotundifolia*), tree-kermes oak (*Quercus rivasmartinezii*) or late-deciduous oak forests depending on annual rainfall (dry to inferior sub-humid: *Quercus rotundifolia*; higher rainfall: late-deciduous oaks; these will be presented next in alliance 2). Although not specifically a limestone-prone species, *Quercus rivasmartinezii* (tree-kermes oak) dense forests are found mostly on dolomite-rich limestone (magnesium and calcium carbonate), notably in the Arrábida range outcrop at the mouth of the Sado river: the Viburno tini-Quercetum rivasmartinezii (Fig. 2.3). *Cistus albidus* with *Phlomis purpurea* (Phlomido purpureae-Cistetum albidi) is the common seral stage of the tree-kermes oak forest. Limestone thermomediterranean holm oak forests can also be found on the W-E running, low-altitude range of Algarve limestone (Barrocal): the Rhamno

**Fig. 2.3** View of the Viburno tini-Quercetum rivasmartinezii at the Arrabida Sierran District (© D. Espírito Santo)

oleoidis-Quercetum rotundifoliae. These forests are many times low-thermo-Mediterranean, meaning that highly thermophile understorey plants are found: *Aristolochia baetica, Chamaerops humilis* (mediterranean dwarf palm tree), *Clematis cirrhosa*. Kermes oak (*Quercus coccifera*), *Asparagus albus*, dwarf palm tree and *Juniperus turbinata* high scrub (Aristolochio baeticae-Juniperetum turbinatae) is the most abundant seral stage. In turn, the most common scrub stages (limestone garrigues) are those of the Sideritido lusitanicae-Genistetum algarbiensis and Thymo lotocephali-Corydothymetum capitatae, rich in endemic *Lamiaceae*. At the base of rock outcrops with clay-rich crevices, within the scope of the later zonal forest, another woodland is found, the Vinco difformis-Ceratonietum siliquae, a carob tree-dominated community. A second thermophile upper thermo-Mediterranean holm oak forest is found in the inland, in the basin of the Guadiana river, already in the Marianese Sector (around Elvas and Badajoz cities) outside the Andalusia and Lusitania Coastal Province in semi-hyperoceanic to euoceanic belts, on paleozoic clay-rich metamorphic marbles: the Rhamno laderoi-Quercetum rotundifoliae. The high scrub hedge of *Quercus coccifera* (Asparago albi-Quercetum cocciferae) and the *Lavandula sampaiona – Cistus albidus* scrub are the most common seral stages. A relevant and last type of substratum for the thermophile forests are the deep and heavy clay soils (*vertisols*, montmorilonite clay-rich). On these substrata *Quercus*-dominated forest communities are not found; instead, there are

forests of tree oleaster (*Olea europaea* subsp. *sylvestris*). In the Lisbon region, on heavy clay soils of volcanic origin, a mixed forest of *Olea europaea* subsp. *sylvestris* and *Ceratonia siliqua* is found: the Viburno tini-Oleetum sylvestris. The correspondent (vicariant) communities are, in Algarve: the Aro neglecti-Oleetum sylvestris and in the Marianese Sector: the Asparago albi-Oleetum sylvestris. Nowadays, as most of the oleaster forests have been grafted with domestic olive (*Olea europaea* subsp. *europaea* cultivars), oleaster forests tend to be rare.

(ii) **Thermo-mesomediterranean semi-hyperoceanic to semi-continental forests**

Quercion broteroi – Mediterranean Iberian Atlantic woodlands dominated by all of the above-cited evergreen and late-deciduous *Quercus* species in mesomediterranean (few areas in upper thermomediterranean) and semi-hyperoceanic to semi-continental belts. Dominant trees may be *Quercus suber, Quercus rotundifolia, Quercus faginea* subsp. *broteroi*, *Quercus estremadurensis, Quercus marianica, Quercus alpestris, Quercus canariensis, Quercus gaditana*, their hybrids and hybrids with *Quercus pyrenaica*. Characteristic understorey flora includes *Genista tournefortii, Luzula forsteri* subsp. *baetica, Paeonia broteroi, Sanguisorba hybrida* and *Pyrus bourgaeana*. Within the Quercion broteroi alliance, two subgroups (sub-alliances) can be recognized: (ii.a) Oceanic sub-humid to humid forests of the mentioned late-deciduous oaks and cork oak, and (ii.b) Semi-continental dry to humid forests of *Quercus rotundifolia*. The former corresponds to thermophile Tertiary relic-rich oaklands in sublittoral refugia during the Pleistocene. The latter has a poorer understorey and was shaped in a continental Late Glacial landscape.

This group of forests thrives in dry to humid ombrotypes and is of a less hyperoceanic thermophile character than those of the thermomediterranean hyperoceanic forests discussed above (i.e group i). They include thermo-lower mesomediterranean semi-hyperoceanic to euoceanic forests of *Quercus suber* or late-deciduous oaks (subgroup ii.a) and mesomediterranean semi-continental forests (subgroup ii.b). Most of the sub-littoral N-S oriented limestone ranges north of Lisbon to Coimbra are occupied by forests of Portuguese oak: *Quercus faginea* subsp. *broteroi*: the Arisaro simorrhini-Quercetum broteroi. These forest communities are sometimes mixed with other oaks (*Quercus suber, Quercus pyrenaica, Quercus estremadurensis* and their hybrids) and bear a wealth of nemoral-thermophille plants in the understorey (*Luzula forsteri* subsp. *baetica, Vinca difformis, Cheirolophus sempervirens, Rosa sempervirens, Smilax aspera* var. *altissima* (clearings) with some relic elements of Querco-Fagetea sylvaticae forests (e.g. *Polygonatum odoratum*). The most conspicuous high-scrub stage is that of the Melico arrectae-Quercetum cocciferae, with scrub stages varying according to local (districtal) endemism: the Salvio sclareoidis-Ulicetum densi (*Ulex densus*, the dominant, cushion-shaped, endemic gorse) or the Lavandulo luisiseri-Ulicetum jussiaei (also an endemism of the Divisorio Portuguese Sector). Bay-dominated tall hedges may also be common (Vinco difformis-Lauretum nobilis). Various vicariant woodland communities dominated by *Quercus faginea* subsp. *broteroi* are recognized in the Andalusia and Lusitania Coastal Province, namely the Quercetum alpestris-broteroi on the Algarve limestones, or the Ulici welwitschiani-Quercetum

broteroi, the latter a woodland that is linked to sites with temporary variable water tables in the Ribatejo and Sado Sector. On the other hand, inland and away from littoral influence, lie the euoceanic to semi-continental, mesomediterranean (rarely supramediterranean) territories of the basins of the Tagus (Toledo and Tajo Sector) and Guadiana (Marianese Sector). Together, they form the Lusitania and Extremadura Subprovince. Also, along these river basins some *Quercus faginea* subsp. *broteroi* forests are found: the Pistacio terebinthi-Quercetum broteroi, mostly mesomediterranean and both on silicate and limestone; in turn, the Pyro bourgaeanae-Quercetum broteroi is found in the Toledo Mountains and meso-supramediterranean mountains of the Marianese Sector. In the latter territory, a relic temporarily water-logged African oak (*Quercus canariensis*) community, the Doronico plantaginei-Quercetum canariensis, is also found near streams. A forest association in the mesomediterranean humid belt on karst limestone north of Lisbon (Aire and Candeiros ranges) is the Lonicero implexae-Quercetum rotundifoliae. Its seral stages are a high scrub of kermes oak (*Quercus coccifera*) and *Quercus x airensis,* a tall, endemic, sclerophyllous shrub species, building the Quercetum coccifero-airensis); and furthermore, the gorse-heath scrub, the Erico scopariae-Ulicetum airensis and a discontinuous chamaephyte thyme community (Teucrio capitati-Thymetum sylvestris) dominated by *Thymus zygis* subsp. *sylvestris*. The orchid-rich grasslands of *Brachypodium phoenicoides* (Phlomido lychnitidis-Brachypodietum phoenicoidis) are usually a seral stage of these live oak woodlands, successionaly preceding the low shrub stages. The latter grasslands might be shared between the Arisaro-Quercetum broteroi, and, in the Divisorio Portuguese Sector, at low altitudes, the Lonicero-Quercetum rotundifoliae.

By far, one of the most extended forest associations of this group is the Sanguisorbo hybridae-Quercetum suberis, a forest type of mesomediterranean, upper dry to subhumid, mostly silicate-prone (schist, granite, greywacke, sandstone) sites, but occasionally occurring on leached soils on limestone. Its potentiality, or the derived, human-made parklands (*dehesa* or *montado*), occupy large stretches of the whole of the Lusitania and Extremadura Subprovince. The tall strawberry tree hedges (Phillyreo angustifoliae-Arbutetum unedonis) and several *Cistus* scrub and heathlands, varying locally as districtal units, are seral of these cork oak woodlands: the Halimio ocymoidis-Ericetum umbellatae, the Ulici eriocladi-Ericetum umbellatae and, the most common, the Erico australis-Cistetum populifolii either dominated by *Cistus populifolius* or *Cistus ladanifer*. The variants of the Toledo and Tajo woodlands might have *Cytisus multiflorus* and *Retama sphaerocarpa* broom hedges, as the Marianese Sector may have *Cytisus bourgaei* and *Retama sphaerocarpa* broom communities. Dry variants might even share *Genista hirsuta – Cistus ladanifer* communities with mesomediterranean luso-estremadurensian holm oak successional sequences, especially in cases of soil erosion due to historical agricultural use (see next woodland). Also, very important for sheep-grazing, the *Poa bulbosa* swards (Poo bulbosae-Trifolietum subterranei, Poetea bulbosae vegetation class) might be present in the Sanguisorbo hybridae-Quercetum suberis subseral as dominant communities in zoo-anthropic forest-derived land mosaics. Equaling the vast extent of the Sanguisorbo hybridae-Quercetum

suberis, but in lower annual rainfall areas, (low dry to low sub-humid) are the very extensive mesomediterranean luso estremadurensian holm oak woodlands on silicate soils, the Pyro bourgaeanae-Quercetum rotundifoliae. In a typical closed forest structure, pristine forests are composed of *Quercus rotundifolia, Pyrus bourgaeana, Quercus faginea* subsp. *broteroi*, along with common alliance plants. The most common subseral stage is the Genisto hirsutae-Cistetum ladaniferi scrub, which covers the Lusitania and Extremadura Subprovince over thousands of square kilometres. The community Retamo sphaerocarpae-Cytisetum bourgaei is a common broom hedge; and in areas grazed by sheep (already referred to above, at the Sanguisorbo hybridae-Quercetum suberis) the Poo bulbosae-Trifolietum subterranei swards had an enormous historical importance in maintaining large sheep herds providing wool for the textile industry in Flanders, through export via the Gulf of Biscay.

(iii) ***Quercus pyrenaica*forests**

Quercion pyrenaicae – of deciduous Pyrenean oak forests – is found in the Mediterranean bioclimate, at least subhumid, but of clear continental tendency (euoceanic to semi-continental) and mostly in the upper mesomediterranean or supramediterranean belts of the entire Mediterranean Iberian Atlantic territory, mostly in the Carpetana and Leonesa Provinces: north and outside Lusitania. It is found mostly in the upper mountain belts. In sub-littoral oceanic areas it might represent a relic of a post Late-Glacial, larger distribution. The communities of Pyrenean oak found in Lusitania share many Mediterranean understorey plants with evergreen and late-decidous oaklands but some characteristic elements may be found, such as *Genista falcata, Laserpitium thalictrifolium, Physospermum cornubiense, Arenaria montana, Hedera hybernica* and hybrid trees of *Quercus pyrenaica* with *Quercus faginea* subsp. *broteroi* (= *Q. x neomairei*).

In Lusitania, forests dominated by *Quercus pyrenaica* are deciduous woodlands under a Mediterranean euoceanic to semi-continental climate, found in areas with upper mesomediterranean and supramediterranean thermotypes. Thus, they occur in usually high rainfall areas, or at least humid, but which are colder than those occupied by cork oak woodlands. They may be also found as relics in semi-hyperoceanic territories. A wealth of nemoral Querco-Fagetea sylvaticae plants are found in their understorey - *Hedera hibernica, Linaria triornitophora, Aquilegia dichroa, Arenaria montana*, but combined with Mediterranean woodland elements (those of the *Quercetea ilicis* vegetation class: *Arbutus unedo, Luzula forsteri* subsp. *baetica*, etc.). The Arbuto unedonis-Quercetum pyrenaicae is found in the westernmost part of the Subbética Sector, reaching Portugal in the São Mamede mountains. Apart from sharing some seral communities with mesomediterranean woodlands (Sanguisorbo hybridae-Quercetum suberis), like the Phillyreo angustifoliae-Arbutetum unedonis tall hedges and the extensive heathlands of the Halimio ocymoidis-Ericetum umbellatae, some specific seral communities are also found: the broom community Cytisetum multiflori-eriocarpi*, Genista falcata* communities, the heath Halimio umbellatae-Ulicetum minoris and the Polygalo microphyllae-Cistetum populifolii. At the granite-syenite eruptive outcrop of Sintra and in the surroundings

of Lisbon, Évora and the middle Tagus basin, the Arisaro simorrhini-Quercetum pyrenaicae is found as a climatic relic. In the highest parts of the Sierra de Guadalupe, Toledo Mountains, and also in the supramediterranean highest altitudes of the Marianese Sector the Sorbo torminalis-Quercetum pyrenaicae forest is found.

**Traditional Uses in the Lusitanian Forests** It is important to mention the importance of the traditional exploitation forms of the forests in vast areas of the Lusitanian territory both in the Spanish area as well as in Portugal. A large part of the evergreen oak forests (*Quercus rotundifolia* and *Quercus suber*) have been transformed into wooded pastures which have been submitted to a mixed model of exploitation: sheep or cattle grazing and collection of firewood, acorns and other forestal products. In these areas this sort of landscape has received the names of *dehesa* in Spain and *montado* in Portugal (Fig. 2.4). In the case of cork oak (*Quercus suber*) woodlands, the bark of these trees (cork) is additionally harvested at regular intervals (Fig. 2.1), providing important incomes to the cork stopper industry.

#### 2.2.1.2 Pre-forest High Scrub

Most tall-shrub communities of Lusitania are the first seral stage, or the edges of natural forests. They are dominated by sprouters, large-seeded, slow-growing shrubs and small trees such as *Arbutus unedo, Quercus coccifera*, shrubby *Olea europaea* subsp. *sylvestris, Pistacia lentiscus, Rhamnus* sp. pl., *Asparagus* sp. pl. and *Juniperus* sp. pl. Such communities may sometimes, on rocky, very dry or thin soils, act locally as the most successionally mature community, in spite of the zonal ombroclimate being sufficient to support a forest community if soils had a normal depth. Nevertheless, in cliffs or on tertiary dunes the extent of such azonal communities is large enough to consider them as a territorial meaningful pre-forest natural potential vegetation type. These are the silicate canyon juniper pre-forests of the Guadiana and Tagus rivers, limestone sea-cliffs, tertiary active dunes (green dunes), paleodunes (Pleistocene) and inland limestone sea-cliffs. *Juniperus turbinata* subsp. *turbinata* is a scale-leaved juniper, a small tree or often a tall-shrub due to the physiological effects of permanent wind or soil dryness, and it occurs in several communities. On hard limestone and sometimes rare spots of schist or syenite, the Querco cocciferae-Juniperetum turbinatae occurs at the coast of the Portuguese Divisorian Sector, notably in the Arrabida Sierran District, south of Lisbon. *Juniperus turbinata* subsp. *turbinata, Quercus coccifera, Rhamnus oleoides, Jasminum fruticans, Pistacia lentiscus* and a wealth of limestone-prone plants of catenal and seral contacts (Rosmarinetea vegetation class), *e.g. Cistus albidus, Rosmarinus officinalis, Ulex densus, Thymus zygis* subsp. *sylvestris*, make up its typical floristic set. At the south coast of the Algarve, a vicariant community occurs, extending from Cape São Vicente to the mouth of the Guadiana, the Aristolochio baeticae-Juniperetum turbinatae. *Chamaerops humilis, Aristolochia baetica* and a distinct set of companion species from seral stages (e.g. *Ulex erinaceus, Genista hirsuta* subsp. *algarbiensis, Corydothymus capitatus, Thymus lotocephalus*) allow to distinct it from the

**Fig. 2.4** Holm oak wooded pasture (montado or dehesa) in Heredade da Contenda (Moura), Portugal (© P. Arsénio)

Querco-Juniperetum turbinatae. Inland, on the schist, greywacke and quartzite cliffs of the Guadiana river valley, the Phlomido purpureae-Juniperetum turbinatae may be found. The floristic combination includes *Phlomis purpurea* and *Genista polyanthos*. Large stretches of maritime dunes in the entire Lusitanian part of the Andalusia

**Fig. 2.5** View of the Osyrio quadripartitae-Juniperetum turbinatae in Tróia (Sado District) (© C. Neto)

and Lusitania Coastal Province bear also the Osyrio quadripartitae-Juniperetum turbinatae (Fig. 2.5). *Osyris lanceolata* (= *Osyris quadripartita*), *Corema album, Antirrhinum cirrhigerum* and a wealth of perennials of grey dune vegetation (Ammophiletea vegetation class) make up its characteristic species set. Inland, in the dry upper parts of deep Pleistocene paleodunes, two needle juniper communities occur: i) the Daphno gnidii-Juniperetum navicularis, dominated by *Juniperus navicularis,* which is an endemic juniper of the Andalusia and Lusitania Coastal Province, and ii) the Rhamno oleoidis-Juniperetum macrocarpae of the Gaditano-Onubensian territories, dominated by *Juniperus oxycedrus* subsp. *macrocarpa.* Within the latter, extensive maritime pine (*Pinus pinaster* subsp. *maritima*) and umbrella pine stands (*Pinus pinea*) are found. Paleoecological studies suggest that juniper, maritime pines, umbrella pines and heathlands co-existed as primary vegetation in dune strips. Nevertheless, actual pine forests are artificial stands that were planted as from the fourteenth century and mostly in the nineteenth century, so that the position of pine forests in natural vegetation is unclear.

#### 2.2.1.3 Riverine and Swamp Woodlands

The main hydrological conditions of Lusitanian water bodies allow for potentially four very distinct forest vegetation types.

1. Low *kinetic energy water bodies*, such as swamps, lagoons, including those in depressions near rivers, bear the Alnetea glutinosae vegetation class. These woodlands are dominated either by alder (*Alnus glutinosa*) or *Salix atrocinerea* in more or less permanently waterlogged biotopes with some degree of peat formation. The Carici lusitanicae-Alnetum glutinosae occurs where the water level is more constant, and with peat formation. Portuguese tussock sedge (*Carex paniculata* subsp. *lusitanica*), *Limniris pseudacorus* (= *Iris pseudacorus*), *Sparganium* sp. pl.*, Phragmites australis, Schoenoplectus tabernaemontani* and *Thelypteris palustris* are common species in swamp alder forests. Often, if the water is acid and low in nutrient content, peat or hygrophile heathland shrubs might appear as seral stages: *Ulex minor, Erica ciliaris, Erica lusitanica* and *Erica erigena*. Where disturbance by a variable water level is more intense or frequent, swamp forests are the Carici lusitanicae-Salicetum atrocinereae, analogous to the latter association, but dominated by *Salix atrocinerea*. Both communities are found in the estuary of the Sado and Tagus rivers. An analogous community, the Viti sylvestris-Salicetum atrocinereae occurs in depressions that are waterlogged during the winter, but more often they are part of the topographic sequence of communities of Mediterranean rivers under a sub-humid ombroclimate (see riverine forests 2).
2. *Rivers with moderately irregular flow (lotic) on silicate* (Salici purpureae-Populetea nigrae vegetation class). Most of the territory where the rainfall regime, although typical of the Mediterranean climate (winter rain – dry summer), still allows permanent flow in the rivers, a typical sequence of riverine forests (from land to the middle of the river bed, *i.e.* the stretch of the alluvial terrace) is found: (i) Vinco difformis-Ulmetum minoris, a silt-prone community where some residual effect of side transport of water is felt, dominated by *Ulmus minor*; (ii) Ranunculo ficariae-Fraxinetum angustifoliae, an extended narrow-leaved ash (*Fraxinus angustifolia*) forest under the influence of a temporary watertable with almost no water logging. On clay-rich soils on limestone the Irido foetidissimae-Fraxinetum angustifoliae is found instead. The narrow-leaved ash forests might be co-dominated by *Quercus pyrenaica* in the meso-mediterranean territories of the Lusitania and Extremadura Subprovince: the Querco pyrenaicae-Fraxinetum angustifoliae. Often, the latter community occurs not integrated as part of a riverine woodland sequence, but by itself in small depressions on granite. Also, on mesomediterranean limestone of sublittoral ranges in the Divisorio Portuguese the Oenantho crocatae-Quercetum pyrenaicae might appear as a relic in the typical position of the narrow-leaved ash forest. If the morphology of the alluvial terrace shows some topographic differentiation a *Celtis australis* community (Clematido campaniflorae-Celtidetum australis) occurs in the middle Tagus; (iii) the Viti sylvestris-Salicetum atrocinereae in the low-lying depressions where the water table is on the surface for a large part of the year*;* (iv) the Scophulario scorodoniae-Alnetum glutinosae (alder forest) on the embankment of the river. (v) Typically, in torrential river beds, a hedge of *Salix salvifolia* subsp. *australis* is found (Salicetum atrocinereo-australis) (Fig. 2.6). The latter community is adapted to irregular flows and in contrast to

**Fig. 2.6** View of the Salicetum atrocinereo-australis at Odelouca Stream (Monchique Sierran District) (© R. Canas)

the other communities containing nemoral flora, it lacks understorey because of substratum instability and strong sediment carriage. In the upper meso- and supramediterranean territories of Lusitania, the sequence, being equivalent, is replaced by the Galio broteriani-Alnetum glutinosae and Salicetum salviifoliae. In turn, in the SW (Algarve and Monchique Sector) the alder forest is very thermophile and with a SW endemic element: the Campanulo primulifoliae-Alnetum glutinosae.

3. *Lentic riverine forests of slow-moving waters at the mouth of large rivers* (Salici purpureae-Populetea nigrae vegetation class). In this case, found in large rivers only under meso- to eutrophic conditions (Tagus, Guadiana, Sado), the sequence of riverine forests is analogous to that of lotic rivers but there are no alder forests and instead there are forests of *Salix neotricha* (*S. alba* group), *Populus nigra* and *Populus alba* (Costa et al. 2011a). Briefly, the distribution of such communities is as follows: the Clematido campaniflorae-Salicetum neotrichae is of the lower Tagus and Sado river basins, the Salici atrocinereae-Populetum albae occurs in the Lusitania and Extremadura Subprovince and the Nerio oleandri-Populetum albae is associated with wider-level variations of the lower Guadiana river.
4. *Forest and pre-forest of Mediterranean rivers with very irregular flow or of brackish waters* (Nerio-Tamaricetea vegetation class). According to general eco-

logical conditions three groups of communities may be distinguished: (i) River beds with irregularly flowing fresh water support tall-scrub formations of *Nerium oleander* and *Tamarix africana* (Oenantho crocatae-Nerietum oleandri); (ii) Communities of *Fluggea tinctoria* (= *Securinega tinctoria*): the Pyro bourgaeanae-Fluggeetum tinctoriae on the rocky margins of large Mediterranean rivers (Guadiana basin) that are temporarily inundated in winter and dry throughout the rest of the year; (iii) communities of mesotrophic slow-moving brackish waters in estuaries (near salt marshes) dominated by *Tamarix africana* (Polygono equisetiformis-Tamaricetum africanae).

## *2.2.2 Shrubby Vegetation*

### 2.2.2.1 Tall Shrubby Broom-Like Vegetation (Cytisetea scopario-striati Class)

The nanophanerophytic vegetation of the Southwestern part of the Iberian Peninsula included in the class Cytisetea scopario-striati is mainly dominated by *Fabaceae* (*Leguminosae*) species of the genera *Genista*, *Cytisus*, *Adenocarpus* and *Retama*. Despite the wide distribution of this vegetation type in the West Mediterranean Subregion (Loidi et al. 1997), it is in the western part of the Iberian Peninsula that these shrubby legume plants have an important centre of evolutionary diversification and consequently form a large number of communities (Gavilán et al. 2011). This shrubby vegetation, called «giestais, codeçais, retamais, escovais» and «xesteiras, i.e. 'brooms'», occurs in a wide spectrum of sites, within different bioclimatic belts and geomorphological units. They are characteristic of mesotrophic to oligotrophic soils, but mostly occur on siliceous soils, generally with humus mull and without temporal hydromorphy (Gavilán et al. 2011, Costa et al. 2003, Loidi et al. 1997). The majority of this Cytisetea scopario-striati vegetation represents the shrubby mantle or first seral stage of different types of deciduous or sclerophyllous forests belonging to the order Quercetalia roboris and the alliance Quercion broteroi.

The diversity in ecological features correlates to a high floral heterogeneity that results in distinct floral assemblages, thus allowing the occurrence of numerous distinct communities of broom nanophanerophytic vegetation in Lusitania. In accordance with different bioclimatic gradients, soil conditions and biogeographic distributions, it is possible to distinguish different association groups. For each group, floristic composition, synecology and syncorology are briefly described.

1. In the drier areas of southern Portugal and Extremadura, the nanophanerophytic communities are mainly composed of *Retama sphaerocarpa* or *Genista polyanthos*. This group of associations appears under bioclimatic conditions ranging from upper semi-arid to lower subhumid ombroclimates in the thermomediterranean to mesomediterranean belts. The formations co-dominated by *R. sphaerocarpa* are distributed from Toledo and the Tajo to the Marianese Sectors.

An important charactistic of these communities is that they have been managed by man for a long time, being frequently used as pastures, after significant reduction of the scrubby layer. *R. sphaerocarpa* is not cut because it acts, by means of atmospheric nitrogen fixation, as a natural enhancer of soil fertility. Two associations are usually distinguished, both towards the interior of Lusitania: the Cytiso multiflori-Retametum sphaerocarpae with a north and central distribution and the south-eastern Retamo sphaerocarpae-Cytisetum bourgaei.

The Cytiso multiflori-Retametum sphaerocarpae occurs in the westernmost part of the Toledo and Tajo Sector, where it mainly occurs in the dry to subhumid mesomediterranean belt. This association is dominated by *Retama sphaerocarpa*, usually accompained by *Cytisus multiflorus*, growing on siliceous soils, specifically above granites. Meanwhile, in the easternmost part of the Toledo and Tajo Sector, this association is replaced by the Cytiso scoparii-Retametum sphaerocarpae. The Retamo sphaerocarpae-Cytisetum bourgaei is a nanophanerophytic broom association, characterized by *Cytisus scoparius* subsp. *bourgaei* with *R. sphaerocarpa*. Associated with them are some other characteristic species of the Cytisetea scopario-striati, such as *Pteridium aquilinum* and *Adenocarpus lainzii*. They are distributed in the High Alentejano and Andévalo territories (Marianese Sector), colonizing deep soils (with optimum development on soils derived from granitic rocks) and occurring in mesomediterranean dry to subhumid belts. It shows a more continental character than the Genistetum polyanthi. The latter develops on leptosols or quartzitic outcroups of the Guadiana basin, in the southeastern part of Portugal (Vila-Viçosa et al. 2013). This association is almost solely constituted by *Genista polyanthos*, which can develop dense formations in the thermomediterranean dry belt of Marianese Sector.

2. A second group comprises associations dominated by species from the genera *Cytisus* and *Adenocarpus*. They occupy areas where there is a noticeable increase in air humidity due to the influence of the Atlantic Ocean. The predominance of distinct species allows us to recognize two different subgroups of plant communities. The first subgroup corresponds to the associations co-dominated by *Cytisus* taxa, such as: the Erico scopariae-Cytisetum grandiflori, Lavandulo viridis-Cytisetum striati, Ulici latebracteati-Cytisetum striati and Cytisetum bourgaei-eriocarpi. The Erico scopariae-Cytisetum grandiflori is a Divisorio Portuguese association, which occurs in mesomediterranean subhumid to humid bioclimatic stages. Somewhat atypical, as the Cytisetea scopario-striati class is, by large of siliceous soils, this association occurs on limestone-derived soils. Nevertheless these soils are heavily bleached by high rainfall and have a neutral or slightly acidic pH. The main representative species is *Cytisus grandiflorus*, accompanied by *Cytisus striatus*, *Pteridium aquilinum*, *Ulex europaeus* subsp. *latebracteatus*, *Ulex jussiaei*, among others. In the mountains of southwest of Portugal (Monchique Sierran District) occurs the association Lavandulo viridis-Cytisetum striati, characterized by *Cytisus striatus* and *Lavandula viridis*. They occur on deep soils derived from schist or greywackes, in the thermomedi-

terranean to lower mesomediterranean belts under subhumid to humid ombrotypes. The Ulici latebracteati-Cytisetum striati is an association dominated by nanophanerophytes such as *Ulex europaeus* subsp. *latebracteatus* and *Cytisus striatus*. Its distribution area is restricted to the northwestern part of Lusitania, reaching the Littoral Beira District. They grow on deep soils derived from granite, and appear in the thermotemperate to mesotemperate belts, with subhumid to hyperhumid ombrotypes. In the mesomediterranean subhumid to humid bioclimatic belts of the Aracena Sierran to Tierra de Barros and Badajoz Districts (Marianese Sector), occurs the Cytisetum bourgaei-eriocarpi characterized by *Cytisus striatus* subsp. *eriocarpus*, and some differential species, such as *Cytisus scoparius* subsp. *bourgaei*, *Genista falcata*, *Genista triacanthos*, *Pterospartum tridentatum*, *Ulex eriocladus*. The second subgroup of associations is floristically distinct from the previous one by the co-dominance of species of the genus *Adenocarpus* (such as *Adenocarpus anisochilus*, *Adenocarpus lainzii* and *Adenocarpus argyrophyllus*), which usually grow on siliceous and deep soils developed from granitic or syenitic rocks. The Adenocarpo anisochili-Cytisetum scoparii appear on deep syenites soils of the mesomediterranean humid belt of the summit areas of the Monchique mountains (Monchique Sierran District). These broom formations are dominated by *Adenocarpus anisochilus* and *Cytisus scoparius* subsp. *scoparius* var. *oxyphyllus*. The formations co-dominated by *Adenocarpus anisochilus* also appear on the Sintra mountains (Sintra Sierran District), where Costa et al. (2012a) recognize the association Adenocarpo anisochili-Ulicetum latebracteati, well characterized by *Ulex europaeus* subsp. *latebracteatus*, *Cytisus striatus*, *Erica arborea*, *Ulex jussiaei* and the hybrid species resulting from *Ulex europaeus* subsp. *latebracteatus* x *Ulex jussiaei*. Formations dominated by *Adenocarpus lainzii* occur mostly in the mesomediterranean belt of the São Mamede mountain (São Mamede Sierran District), where at subhumid to humid ombrotypes it forms broom communities belonging to the association Genisto falcatae-Adenocarpetum lainzii. The characteristic species also include elements that are found in more continental territories, such as *Genista falcata*, *Cytisus multiflorus*, *Lavandula sampaioana* (Costa et al. 2000b). Specifically on rocky surfaces and lithosols of the quartzitic mountains in Extremadura (Lusitania and Extremadura Subprovince) occurs the Adenocarpetum argyrophylli, dominated by *Adenocarpus argyrophyllus* accompanied by *Cytisus multiflorus* (Rivas-Martínez et al. 2002).

3. The third group is found mostly in coastal areas of the southeastern part of the Algarve (Algarve District) and extends in the west to the Sado District. The main vegetation type is dominated by broom nanophanerophytic species, which are adapted to drier areas on littoral sandy soils or paleodune regosols. Along the southern Atlantic coast (in the Algarve, São Vicente Coastal and Sado Districts) occurs the Cytisetum cabezudoi, characterized by *Cytisus grandiflorus* subsp. *cabezudoi*, the dominant species of the association. Costa et al. (2003) have differentiated two biogeographic variants of the Cytisetum cabezudoi, one of which is included in the Algarve District (enriched with *Armeria macrophylla*, *Ulex subsericeus* and *Thymus albicans*) and the other in the São Vicente Coastal

**Fig. 2.7** Example of a broom community with *Cytisus striatus* subsp. *eriocarpus* and *C. multiflorus* (Cytisetum multifloro-eriocarpi) in Torre de Moncorvo (Serra de Reboredo), Portugal (© P. Arsénio)

and Sado Districts (accompanied by *Ulex australis* subsp. *welwitschianus*). Moreover, in coastal sands and dunes in the southeastern part of the Algarve (Algarve District) and in the westernmost part of the Sado District (Tróia Pensinsule) occurs the psammophytic broom association Pycnocomono rutifolii-Retametum monospermae. These formations are distinguished by the high abundance of *Retama monosperma* and by the regular occurrence of *Pycnocomon rutifolium*, growing on deep sandy soils.

Finally, there are the formations dominated by brooms of the genus *Cytisus*, included in the association Cytisetum multifloro-eriocarpi, linked to the Genistion floridae alliance (Fig. 2.7). Described by Rivas Goday (1964) for Spanish Extremadurese territories, it is well characterized by the co-dominance of *Cytisus multiflorus* and *Cytisus striatus* subsp. *eriocarpus* and other Cytisetea elements, such as *Pteridium aquilinum* and *Cytisus grandiflorus*. The association occurs in the mesomediterranean belt in subhumid to humid ombroclimates and it is mainly characteristic of the Toledo and Tajo Sector, on deep siliceous soils.

More information about these nanophanerophytic vegetation types can be found in Belmonte (2008), Braun-Blanquet et al. (1964), Capelo (1996), Costa et al. (1996, 2003), Galán de Mera et al. (1997), Meireles (2010), Vicente Orellana and Galán de Mera (2008), Pinto-Gomes et al. (2012) and Rivas-Martínez and Cantó (1987).

#### 2.2.2.2 Heathlands and Moorlands (Calluno vulgaris-Ulicetea minoris Class)

The heathlands and moorlands with dwarf shrubs, classified within the Calluno vulgaris-Ulicetea minoris class, are particularly well represented in the southwestern part of the Iberian Peninsula, and are important ecosystems for preserving plant diversity at both the species and landscape level. The remarkable extension that these seral communities acquired was due to the cumulative effect of various kinds of anthropic interference in deciduous, marcescent or sclerophyllous meso-macroforests, namely cutting followed by intensive grazing and wildfires. In coastal areas under frequent strong winds or on peat soils, the heathlands and moorlands could represent permanent communities. The dominant or preferential species in the heathland and moorland communities of Lusitania territories, as in the Atlantic or Mediterranean Oceanic parts of Europe and North Africa, include mostly *Ericaceae* (*Erica*, *Calluna*), *Fabaceae* (*Genista*, *Pterospartum*, *Ule*x, *Stauracanthus*) and *Cistaceae* (*Cistus*, *Halimium*, *Tuberaria*), found on moderately buffered to highly acid leptosols, eroded dystric cambisols or ferric podzols with very acid raw humus and occasionally with gleyic or stagnic properties (Rivas-Martínez et al. 2002).

Bioclimatic dissimilarity on a combined axis of edaphic variation and biogeographic position caused changes in species distribution and favoured speciation processes that, in turn, led to the diversification of heathland and moorland communities in the southwest of the Iberian Peninsula. Based on diagnostic species, as a response to different ecological and biogeographical attributes, and according to similar environmental conditions, it was possible to define four distinct groups of communities covering the Lusitania territories:

1. The first group encompasses hyperoceanic to euoceanic, thermomediterranean to mesomediterranean, subhumid to humid communities growing on acid to neutral soils and widely distributed throughout Portuguese territories, mainly in Lusitania and Extremadura, Divisorio Portuguese and Cádiz and Sado Subprovinces. In these territories various subgroups of communities with different ecomorphological requirements and distributions can be recognized:

Communities growing on sandy soils and soils derived from acid sandstone or conglomerate of the Ribatejo and Sado and Divisorio Portuguese Sectors (both included in the Andalusia and Lusitania Coastal Province), have an important number of lusitanic endemisms (*Ulex jussiaei*, *Ulex airensis* and *Ulex australis* subsp. *welwitschianus*). Thus, syntaxa included in this subgroup are: the Erico umbellatae-Ulicetum welwitschiani, a psammophilous heath-gorse community well characterized by the Portuguese endemic *Ulex australis* subsp. *welwitschianus*, often accompanied by other shrubs such as *Calluna vulgaris*, *Erica scoparia*, *Erica umbellata*, *Genista triacanthos*, among others, found in the thermomediterranean belt, with the dry to subhumid ombrotype of the Ribatejo and Sado and reaching the São Vicente Coastal territories; the Halimio lasianthi-Ulicetum minoris dominated by *Ulex minor*, which colonizes decapited soils on acid sandstone or conglomerates

and is distributed throughout Divisorio Portuguese territories with a thermomediterranean to mesomediterranean subhumid bioclimate; the Lavandulo luisieri-Ulicetum jussiaei dominated by *Ulex jussiaei*, an endemic Divisorio Portuguese association, which occurs in the thermomediterranean to mesomediterranean belt under subhumid to humid conditions; the Thymo villosi-Ulicetum airensis, on acid sandstone or conglomerate soils of the thermomediterranean to mesomediterranean subhumid belt of the Ribatejo District, where *Ulex airensis* is the dominant species.

In lowland areas of the Littoral Beira territories occurs a peculiar silicicate-prone shrub formation: the Erico umbellatae-Pterospartetum tridentati. It is a mesomediterranean, occasionally thermotemperate (submediterranean) humid silicicolous shrubland where *Pterospartum tridentatum*, *Drosophyllum lusitanicum*, *Lavandula luisieri*, *Scilla monophyllos*, *Erica scoparia* are differential species which separate this association, from the Pterosparto lasianthi-Ericetum cinereae and the Ulici minoris-Ericetum umbellatae (Costa et al. 2008).

Another subgroup comprises communities within an extensive West Iberian Mediterranean biogeographic area of Lusitania and which are best represented in the Lusitania and Extremadura Subprovince, being more sporadic in the Divisorio Portuguese Sector. Differences between heathland communities included in this subgroup derive from floristic variations in dominance rather than different bioclimatic conditions due to different edaphic features. The Pterosparto lasianthi-Ericetum cinereae is a mesomediterranean and infratemperate, humid to hyperhumid submediterranean heathland community, normally composed by *Erica cinerea*. It is essentially confined to oceanic and hyperoceanic septentrional areas of the West Iberian Mediterranean territories. The Halimio ocymoidis-Cistetum psilosepali is a sparse silicicolous shrub association dominated by *Cistus psilosepalus*, *Erica umbellata*, *Lavandula luisieri*, among others. This community is characteristic of the mesomediterranean to supramediterranean, subhumid to humid bioclimatic belts of the West Iberian Mediterranean territories.

In the Lusitania and Extremadura mesomediterranean subhumid territories occurs the Erico australis-Cistetum populifolii characterized by *Cistus populifolius* and *Erica australis*, in which more xerophytic taxa, such as *Pistacia terebinthus* and *Rosmarinus officinalis*, are also present (Rivas-Goday 1964), and the Polygalo microphyllae-Cistetum populifolii, a shrub community dominated by *Cistus populifolius* and *Polygala microphylla*.

Consistently associated with the mesomediterranean to supramediterranean, subhumid to humid bioclimatic belt of the Lusitania and Extremadura and Carpetana and Leonesa Subprovinces, occurs the Halimio ocymoidis-Ericetum umbellatae. It is a heathland characterized by *Erica umbellata* and *Halimium ocymoides*, growing on decapited siliceous soils, often acidic in the upper layer of the soils. The Ulici eriocladi-Ericetum umbellatae is another heathland, where *Erica umbellata* is also the dominant taxon, often accompanied by the endemic *Ulex eriocladus*, growing on eroded siliceous soils. It occurs in the thermomediterranean to mesomediterranean subhumid bioclimatic belts of the Tierra de Barros and Badajoz District (Marianese Sector).

The heathland characterized by the Andévalo's endemic *Erica andevalensis*, which colonizes natural sulfidic and mining areas of the Iberian Pyritic Belt, belongs to the association Ulici eriocladi-Ericetum andevalensis. It occurs on very acid soils, over fluvial terraces, mineral damps with ferric precipitates of intense red color and is found in the Marianese Sector (which extends widely in the southern Portuguese territories), inside the thermomediterranean subhumid bioclimatic belt (Fuente et al. 2002).

In the Monchique mountains (Monchique Sierran District) located in the hyper-oceanic areas of southwestern Portugal, three heathland associations are recognised. The Cisto crispi-Ulicetum minoris, a peculiar gorse formation exclusive to the mesomediterranean humid belt at the upper altitudinal area of the Monchique mountains. This community is distinguished by the abundance of *Ulex minor* var. *lusitanicus* and the occurrence of other species like *Cistus crispus* and *Genista triacanthos* subsp. *scorpioides*, and is developed on siliceous soils derived from syenites with slight, temporary hydromorphy. The Halimio calycini-Ericetum australis is a heathland community of sandy soils derived from syenites and is located in the favourable exposures (southern slopes) of the Monchique mountains. It is characterized by *Halimium calycinum*, *Erophaca baetica* and *Cistus crispus* with the co-dominant shrubs *Lavandula luisieri*, *Erica australis* and *Calluna vulgaris* (Deil et al. 2008). Largely confined to thermomediterranean subhumid to humid belts of sub-coastal reliefs of the Monchique, Caldeirão and Grândola mountains (Monchique Sierran District) on impoverished, skeletal schistose soils, occurs the Genistetum triachanthi-polyanthi. According to Vila-Viçosa et al. (2013) it is a thick broomland dominated by *Genista polyanthos* and characterized by the frequency of heathland species including *Genista triacanthos*, *Erica australis*, *Calluna vulgaris*, *Lavandula viridis*, *Lavandula luisieri*. It also supports a group of endemic species including *Ulex argenteus, Calendula suffruticosa* subsp. *lusitanica* and *Centaurea prolongoi*.

In the Sintra mountain (Sintra Sierran District) the Thymo villosi-Ulicetum latebracteati gorseland occurs, characterized by shrubs among which *Ulex europaeus* subsp. *latebracteatus*, *Ulex minor*, *Thymus villosus*, *Calluna vulgaris* and *Pterospartum tridentatum*. They also develop on eroded sandy soils derived from syenites in the mesomediterranean humid bioclimatic belts. Lastly, the Halimio umbellati-Ulicetum minoris, a gorse formation well characterized by *Ulex minor* and *Halimium umbellatum*, colonizes siliceous soils of the thermomediterranean to mesomediterranean subhumid belt in the Divisorio Portuguese territories.

2. The second group includes gorseland communities developed on littoral cliffs splashed moderately by marine salt spray and subjected to strong sea winds in the Divisorio Portuguese Sector. Due to the floristic variation and different ecological features, it is possible to distinguish in the group two associations: the Cisto salviifolii-Ulicetum humilis and Daphno maritimi-Ulicetum congesti. The Cisto salviifolii-Ulicetum humilis occurs on granitic sea cliffs and it is composed of *Ulex europaeus* subsp. *latebracteatus f. humilis*, *Cistus salviifolius*, *Erica umbellata*, *Genista triacanthos*, among others. It is a coastal Atlantic gorse

community, which occupies the thermotemperate (submediterranean) humid coastal areas of the Low Duriese Lusitanian and Coastal Duriese Districts, and spreads across the mesomediterranean subhumid coast of the Divisorio Portuguese Sector. The Daphno maritimi-Ulicetum congesti is well characterized by the Divisorio Portuguese endemic *Ulex jussiaei* subsp. *congestus*, accompanied by *Daphne gnidium* var. *maritima*, *Calluna vulgaris*, among others. Following Costa et al. (2000a, b, c), the Daphno maritimi-Ulicetum congesti is characteristic of granite and syenite soils and consolidated dunes in the southernmost coastal areas of the Portuguese Divisorian Sector.

3. The third association group is widely distributed through the Lusitania territories, and includes several hydromorphic heathlands, being especially common in soils with gleyic properties. Zonations of communities ascribed in this group are most frequently a reflection of bioclimatic and floristic variation. Of the various heathlands represented here, *Erica lusitanica* and *Erica ciliaris* are the most frequent co-dominant species of this group, which includes, in total, five associations.

Thus, there are two heathlands dominated by *Erica lusitanica*: the Lavandulo viridis-Ericetum lusitanici and the Cisto psilosepali-Ericetum lusitanici. The first is an edaphohygrophilous heathland dominated by *E. lusitanica* and *Ulex minor*, colonizing schistose soils. It occurs in the thermomediterranean subhumid to humid bioclimatic belts of the Marianese Sector, especially in canyons and flattened areas with hydromorphism, particularly in the areas of the Monchique Sierran District with the strongest oceanity and always on pseudogley soils (Vila-Viçosa et al. 2012). In distinct biogeographical territories (Toledano and Tajus Sector) occurs the Cisto psilosepali-Ericetum lusitanici dominated by *E. lusitanica* and *Cistus psilosepalus*, on silicolous humic soils with pseudogleyic properties (Rivas-Martínez 1979; Vila-Viçosa et al. 2012).

In the Ribatejo and Sado Sector occur two heathland types characterized by the dominance of *Erica ciliaris*. The Drosero intermediae-Ericetum ciliaris has its biogeographic optimum in the Ribatejo District and appears on sandy soils under long periods of waterlogging. The dominant species *Erica ciliaris* and *Ulex minor* coexists with *Erica scoparia*, *Erica lusitanica*, *Erica erigena*, *Drosophyllum lusitanicum*, *Potentilla erecta*, *Drosera intermedia*, *Pinguicula lusitanica*, *Anagallis tenella*, among others. On the other hand, the Cirsio welwitschii-Ericetum ciliaris, characterized by *E. ciliaris* and *Ulex minor* var. *lusitanicus*, grows on swampy peaty areas of the Sado District, with a Divisorio Portuguese Sector disjunction.

Finally, the Erico ciliaris-Ulicetum lusitanicae, described by Rivas-Martínez et al. (1980) from the Littoral Huelva District, is characterized by *Ulex minor* var. *lusitanicus*, which spreads over oceanic territories of southern Portugal, colonizing deep pseudogley soils.

4. The fourth group comprises communities on siliceous substrates in dry to humid territories of the thermomediterranean to mesomediterranean belts in the Cádiz and Sado Subprovince and Monchique Sierran District. They are the southwesternmost associations of the low-scrubby grouping in mainland Portugal,

well characterized by *Stauracanthus boivinii*, as well as a great number of local endemic species, such as *Cistus ladanifer* subsp. *sulcatus* (= *Cistus palhinhae*) and *Stauracanthus spectabilis* subsp. *vicentinus*. The differences between the four associations included in this group can be understood in terms of a complex of factors related to floristic, bioclimatic and edaphic variation. Two associations dominated by *S. boivinii* can be recognized: the Querco lusitanicae-Stauracanthetum boivinii and the Tuberario majoris-Stauracanthetum boivinii. The first association is dominated by *S. boivinii*, often accompanied by other species characteristic of heathland and moorland, such as *Thymelaea villosa, Halimium ocymoides, Erica umbellata*, *Calluna vulgaris*, *Genista triacanthos*, among others; it is developed on decapitated soils derived from schist or greywackes, in the thermomediterranean to lower mesomediterranean, subhumid to humid bioclimatic belts of the Monchique Sierran District. The second, the Tuberario majoris-Stauracanthetum boivinii, is dominated by *S. boivinii* and accompanied by the Algarvian endemic taxon *Tuberaria major*. It grows on hydromorphic ferruginous leptosols in coastal areas of the Algarve District, within the thermomediterranean dry bioclimatic belt.

In the south-westernmost coastal area of Portugal occurs the shrubby community Genisto triacanthi-Stauracanthetum vicentini, dominated by the Portuguese endemic *Stauracanthus spectabilis* subsp. *vicentinus*. This endemic association colonizes sandy soils or decapitated podzols in the thermomediterranean dry to subhumid bioclimatic belts of the São Vicente Coastal and São Vicente Cape Districts. Finally, the Genisto triacanthi-Cistetum palhinhae low-scrub formations, well characterized by the local endemic *Cistus ladanifer* subsp. *sulcatus*, only occurs in the south-western coastal areas of the São Vicente Coastal territory. It usually grows on hydromorphic ferruginous leptosols, with an attenuated euhyperoceanic to evident subhyperoceanic, thermomediterranean dry belt.

There is abundant information about these communities groups in Braun-Blanquet et al. (1964), Costa et al. (1993, 1997, 2000a, b, c, 2002, 2012b), Deil et al. (2008), Fuente et al. (2002), Meireles et al. (2012), Neto et al. (2009), Quinto-Canas et al. (2012), Rivas-Goday (1964), Rivas-Martínez (1979), Rivas-Martínez et al. (1980, 1990), and Vila-Viçosa et al. (2012, 2013).

#### 2.2.2.3 Acidic Scrub Communities (Cisto-Lavanduletea stoechadis Class)

Secondary Mediterranean scrub communities with plants adapted to a dry climate, especially of the genera *Cistus* (*Cistus ladanifer, Cistus crispus, Cistus salviifolius, Cistus monspeliensis, Cistus populifolius), Lavandula* (*Lavandula luisieri, Lavandula sampaioana* subsp. *sampaioana*) and *Halimium* (*Halimium viscosum, Halimium calycinum, Halimium halimifolium*), on predominantly siliceous substrates and eroded or immature acidic soils are included in the class Cisto-Lavanduletea stoechadis. This assemblage of communities occurs on siliceous,

cohesive, acid soils, with a loamy, sandy or coarse texture. In accordance with different bioclimatic gradients and soil conditions, it is possible to distinguish different association groups:

1. The first group of formations is dominated by species of the genera *Ulex*, *Cistus* and *Genista*, growing on decapitated soils derived from schist or greywacke. In thermomediterranean to mesomediterranean dry to subhumid bioclimatic belts of the Monchique Sierran District the association Cisto ladaniferi-Ulicetum argentei occurs. It is characterized by the endemic species *Ulex argentus,* accompanied by *Cistus ladanifer, Cistus salviifolius, Lavandula luisieri,* and others. *Genista hirsuta* and *C. ladanifer* assemblages compose the very widespread Genisto hirsutae-Cistetum ladaniferi. This association occurs in Lusitania and Extremadura, in the mesomediterranean dry belt. In the thermomediterranean areas in the Andévalo District, the subassociation *cistetosum monspeliensis* occurs; it is enriched with *Cistus monspeliensis*. The Ulici eriocladi-Cistetum ladaniferi is characterized by *Ulex eriocladus* and occurs throughout the Andévalo, Tierra de Barros and Badajoz, Aracena Sierran and Low Alentejo Districts, within the thermomediterranean to mesomediterranean dry to subhumid belts.
2. On eroded and decarbonated limestone soils another group of scrub communities is found: the Lavandulo sampaioanae-Cistetum albidi, Phlomido purpureae-Cistetum albidi, and Ulici airensis-Ericetum scopariae. The first is a mesomediterranean dry to subhumid association, dominated by *Cistus albidus, Cistus ladanifer* and *Genista hirsuta*, which occurs in La Vera and High Alentejo. The second occurs in the Algarve and Arrabida Sierran Districts in thermomediterranean dry to subhumid belts and is characterized by *Phlomis purpurea* and *Cistus ladanifer*. The last association is formed by species of the Cisto-Lavanduletea, Calluno-Ulicetea and Rosmarinetea classes, like *Ulex airensis*, *Erica scoparia*, *Cistus salviifolius*, *Cistus crispus*, *Rosmarinus officinalis* and *Cistus albidus*. It occurs in the mesomediterranean humid belt of the mountains of the Portuguese Extremenian District.
3. The third group comprises associations included in the Stauracantho genistoidis-Halimietalia commutati order and the sole Coremation albi alliance. They comprise thermomediterranean to mesomediterranean dry to subhumid hyperoceanic communities, rich in endemic species, characteristic of paleodunes and sandy soils, in the Andalusia and Lusitania Coastal territories. *Stauracanthus genistoides, Halimium calycinum*, *Halimium halimifolium, Lavandula sampaioana* subsp. *lusitanica, Lithodora lusitanica, Dianthus broteri* subsp. *hinoxianus, Fritillaria lusitanica* subsp. *stenophylla, Iberis ciliata* subsp. *welwitschii* are the characteristic species of the associations included in these group, such as the Cistetum libanotidis, which occurs on paleodunes in the Algarve District, within the upper thermomediterranean dry belt, characterized by *Armeria macrophylla, Cistus libanotis*, *Thymus albicans, Ulex subsericeus,* and others; the Stauracantho genistoidis-Corematetum albi is a mesomediterranean subhumid association,

which develops on paleodunes of the Littoral Extremenian and Berlengas Islands District, and contains *Stauracanthus genistoides*, *Halimium halimifolium*, *H. calycinum*, *Lavandula sampaioana* subsp. *lusitanica, Corema album* and characteristic species of the *Calluno-Ulicetea*, such as *Ulex europaeus* subsp. *latebracteatus*, *Calluna vulgaris*, *Genista triacanthos*, and others; *Thymus capitellatus*, *Ulex australis* subsp. *welwitschianus*, *Armeria rouyana*, *Stauracanthus genistoides* are the characteristic species of the Thymo capitellati-Stauracanthetum genistoidis. It occurs on sandy soils of the Sado District, within the thermomediterranean dry to subhumid bioclimatic belts; moreover, on paleodunes between Sines and Melides in the western coastal areas of Sado District, the Thymo camphorati-Stauracanthetum spectabilis occurs. In these areas, the association is characterized by *Stauracanthus spectabilis* subsp. *spectabilis, Thymus camphoratus* and it occurs within the thermomediterranean dry belt; *Stauracanthus spectabilis* subsp. *vicentinus, Thymus camphoratus*, *Armeria pinifolia, Celtica gigantea* subsp. *gigantea* characterize the Celtico giganteae-Stauracanthetum vicentini, which occurs in the São Vicente Coastal and São Vicente Cape Districts, within the thermomediterranean dry bioclimatic belt; on the sandy soils of the Ribatejo District, in the thermomediterranean humid belt, the Halimio verticillati-Stauracanthetum genistoidis can be found, dominated by *Stauracanthus genistoides, Halimium verticillatum, Armeria pinifolia,* and others.

#### 2.2.2.4 Basophilous Scrub Communities (Rosmarinetea officinalis Class)

Communities of incipient or eroded soils, derived from limestone or marl that are rich in calcium carbonate, are placed in the Rosmarinetea officinalis class. They represent highly degraded stages of the climax forests of the Quercetea ilicis. Based on diagnostic species and biogeographical attributes, it is possible to recognize two distinct groups:

1. The alliance Ulici densi-Thymion sylvestris is formed by chamaephytic communities on eroded soils, derived from Jurassic and Cretaceous limestones and dolomitic marls (chromic luvisols). The latter is characteristic of the Divisorio Portuguese Subprovince and Arrabida Sierran District (Cádiz and Sado Subprovince). The Salvio sclareoidis-Ulicetum densi (Fig. 2.8) is characterized by *Ulex densus*, *Rosmarinus officinalis*, *Salvia sclareoides*, *Anthyllis vulneraria* subsp. *maura*, *Bartsia aspera*, *Cistus albidus*, among others, on limestones in the Lisbon and littoral Extremenian territories, in the thermomediterranean subhumid belt. In the Portuguese Estremenho District, within the mesomediterranean humid to subhumid belts, the Teucrio capitati-Thymetum sylvestris occurs, characterized by *Thymus zygis* subsp. *sylvestris*, *Teucrium capitatum*, *Cistus albidus*, *Fumana thymifolia*, *Rosmarinus officinalis*, *Sideritis hirsuta* subsp. *hirtula*,

**Fig. 2.8** View of the Salvio sclareoidis-Ulicetum densi at Cabo Espichel (© C. Neto)

*Iberis procumbens* subsp. *microcarpa*, *Koeleria vallesiana*, and others. The Thymo sylvestris-Ulicetum densi is a thermomediterrenean association in the Arrabida Sierran District, with *Ulex densus*, *Thymus zygis* subsp. *sylvestris*, *Rosmarinus officinalis*, *Rosmarinus palaui*, *Sideritis hirsuta* subsp. *hirtula*, *Iberis procumbens* subsp. *microcarpa*, *Helianthemum marifolium*, and others.

2. In the Algarve territory the alliance Saturejo micranthae-Thymbrion capitatae is found. The Ulicetum erinacei can only be found in the São Vicente Cape District in the thermomediterrenean dry bioclimatic belt and is characterized by *Ulex erinaceus*, *Biscutella vincentina*, *Hyacinthoides vicentina*, *Sideritis algarbiensis* subsp. *algarbiensis*, *Teucrium vicentinum*, among others. On eroded calcareous soils or leptosols of the Algarve District, in the thermomediterranean dry to subhumid belts, the Thymo lotocephali-Coridothymetum capitati occurs. This association is characterized by *Thymbra capitata*, *Thymus lotocephalus*, *Asperula hirsuta*, *Genista hirsuta* subsp. *algarbiensis*. Moreover, on eroded marly soils of the Algarve District, the Siderito lusitanicae-Genistetum algarbiensis occurs. It is a thermomediterranean dry to subhumid association, dominated by *Genista hirsuta* subsp. *algarbiensis*, with *Sideritis algarbiensis* subsp. *lusitanica*.

### *2.2.3 Grasslands*

#### 2.2.3.1 Perennial Mesophytic Grasslands

The perennial meadows that develop on deep soils from clay to sandy texture, supporting flooding in the spring and some dryness in summer, are included in the Stipo giganteae-Agrostietea castellanae class. Grasses, such as *Agrostis castellana, Dactylis glomerata* subsp. *lusitanica, Gaudinia fragilis,* and *Sanguisorba verrucosa* generally dominate or co-dominate. These grasslands represent seral stages of the Quercion broteroi and Quercion pyrenaicae and have a Western Mediterranean distribution with Cantabrian-Atlantic and Madeiran disjunctions (Ribeiro et al. 2013). Grazed grasslands, often on sandy or loamy acid siliceous soils with a possible slight waterlogging period, in a thermo- to supramediterranean dry to humid bioclimate, and a Mediterranean West Iberian distribution, are included in the Agrostion castellanae alliance. They can be enriched in endemic species, such as *Armeria gaditana, Asphodelus bento-rainhae* subsp. *bento-rainhae* (Ribeiro et al. 2012a), *Avenula lodunensis* subsp. *cintrana, Avenula lodunensis* subsp. *gaditana* and *Narcissus willkommii,* and can form associations such as the Asphodelo aestivi-Armerietum gaditanae and Narcisso willkommii-Festucetum amplae. In valleys, depressions, and near springs that dry out in summer, where grasses mature in late summer, *Asphodelus aestivus, Centaurea amblensis* subsp. *tentudaica, Festuca ampla* subsp. *ampla, Holcus annuus* subsp. *annuus, Thapsia minor* and *Trifolium retusum* are also usual. One of the most frequent associations is the Festuco amplae-Agrostietum castellanae, usually associated with a high coverage of tall grasses, mainly *Festuca ampla* subsp. *ampla* and *Agrostis castellana* (Rivas-Martínez and Belmonte 1985; Belmonte 1986). This association is developed in similar ecological situations to that of the association Gaudinio fragilis-Agrostietum castellanae; however, the first needs more moisture and deeper soils. The Festuco amplae-Agrostietum castellanae forms extensive meadows, from cleared forests and seral shrub steps to the banks of water courses. In Lusitania it is observed often in the floodplains of rivers, thus enduring dryness during the summer and flooding during the winter. It is also observed in the fluvial terraces no longer affected by flooding. The association Gaudinio fragilis-Agrostietum castellanae stands for meadows dominated by *Agrostis castellana* and co-dominated by *Gaudinia fragilis.* Also of note is the abundance of *Crepis capillaris* var. *capillaris* and *Rumex acetosella* subsp. *angiocarpus*. It arises in low-lying areas of old alluvium and is well developed in hillside areas in clearings of seral woods or shrublands. It also requires deep soils with water compensation and clayey horizons but with soil compaction in early summer.

#### 2.2.3.2 Perennial Xerophytic Grasslands

In Lusitania, on soils rich in bases, without hydromorphy and salinity, dry grasslands are widespread in the potential areas of *Quercus suber, Q. rotundifolia* and/or *Q. faginea* forests where they stand for seral stages along with xeric shrublands. They are composed of tall, dense, perennial grasses with stiff leaves and deep roots. *Allium pallens, Allium sphaerocephalon, Arrhenatherum album*, *Bituminaria bituminosa*, *Brachypodium retusum, Convolvulus althaeoides, Dactylis glomerata* subsp. *hispanica, Dipcadi serotinum, Gladiolus italicus, Lavandula multifida* and *Phagnalon saxatile*, are the most frequent plants. Associations are included in the Festuco-Brometea vegetation class. Some orchids such as *Ophrys bombyliflora, Ophrys drys, Ophrys lutea, Ophrys speculum, Ophrys tenthredinifera* and other emblematic floral elements as *Tulipa sylvestris* subsp. *australis* and *Iris subbiflora* appear in such communities. Associations such as the Iberido microcarpae-Stipetum offneri (Arrábida mountain) and Bellevalio hackelii-Stipetum tenacissimae (Algarve) are especially rich in endemic species. They occur on deep, well-structured calcareous soils or on calcareous marls, often with a stony surface layer caused by erosion. Other associations with *Allium subvillosum, Andropogon distachyos, Andryala integrifolia*, *Andryala laxiflora, Daucus crinitus, Hyparrhenia hirta, Hyparrhenia sinaica, Lathyrus clymenum* and *Pseudarrhenatherum pallens* are also frequent, namely the Andryalo laxiflorae-Hyparrhenietum hirtae, Carici depressae-Hyparrhenietum sinaicae and Dauco criniti-Hyparrhenietum sinaicae, among others. These associations are usually dominated by *Hyparrhenia* sp. pl., largely on deep soils, on cliffs or rocky clayey and abandoned crop fields with some nitrification and also on steep slopes, mainly south-facing, where they prevent erosion processes. Other types of perennial slightly xerophytic to mesophytic grasslands are of anthropic influence or promoted by grazing, and develop on relatively deep, basophilous, neutral or slightly acid soils that are nutrient-rich and without hydromorphy. *Brachypodium phoenicoides* is the dominant species, in associations such as the Phlomido lychnitidis-Brachypodietum phoenicoidis and Galio concatenati-Brachypodietum phoenicoidis. Other species are *Armeria linkiana, Asphodelus ramosus*, *Centaurea bethurica, Galium concatenatum, Narcissus bulbocodium* subsp. *obesus, Orchis coriophora*, *Salvia sclareoides*.

The tall dry pastures dominated by *Celtica gigantea* are also frequent in the West Iberian Mediterranean and Lusitania and Andalusia Coastal Provinces. The latter are dominated by *Celtica gigantea* subsp. *sterilis* or *Stipa lagascae*, on overdeep, humic cambisols, and may have the presence of *Armeria x francoi, Arrhenatherum album* var. *erianthum, Elaeoselinum gummiferum* and *Helictotrichon hackelii*.

#### 2.2.3.3 Perennial Xerophytic, Saxicolous Vegetation

Small succulent chamaephytes and geophytes, accompanied by therophytes, are less frequent on lithosols and on the surfaces of rocks in Lusitania. The most frequent species is *Sedum sediforme,* which with other *Sedum* species colonizes pioneer earthy limestone terraces and rocky crevices with gravel and coarse sand, namely the very common Sedetum micrantho-sediformis association and similar impoverished communities. This type of vegetation is inserted in the Sedo albi-Scleranthetea biennis class.

#### 2.2.3.4 Interior Sandy Soil or Semi-fixed Dune Grasslands

In the clearings of bush and woodlands, on paleodunes or semi-fixed dunes, where the influence of sea salt spray is not felt, occurs the alliance Hymenocarpo hamosi-Malcolmion trilobae (Tuberarietea guttatae class), made up of delicate, annual plants with a low-biomass; the alliance is characteristic of the Andalusia and Lusitania Coastal Province. It is represented by several well-differentiated associations (Costa et al. 2011b; Neto et al. 2015): the Hymenostemmo pseudanthemidis-Arniceenarietum emarginatae on sandy soils, in the Littoral Gaditano district, with *Hymenostemma pseudanthemis, Arenaria emarginata, Scilla ramburei* and *Hippocrepis salzmannii*; the Malcolmio lacerae-Anthyllidetum hamosae, an association from fossil dunes on deep sandy soils of the Littoral Cádiz and Huelva sector, with *Malcolmia triloba, Hymenocarpos hamosus, Anthoxanthum ovatum, Evax asterisciflora*; the Tolpido barbatae-Tuberarietum bupleurifoliae on the littoral sands of the Algarve district, in the clearings of the Cistetum bourgaeani and Tuberario majoris-Stauracanthetum boivinii, with *Tuberaria bupleurifolia, Scilla odorata* and *Lotus castellanus* as differentials; the Corynephoro macrantheri-Arenarietum algarbiensis on the fixed dunes of the Sado district, characterized by *Arenaria algarbiensis, Corynephorus macrantherus, Malcolmia gracillima, Loeflingia baetica* var. *micrantha*; the Cerastio diffusae-Vulpietum fontqueranae, in the clearings of the Stauracantho genistoidis-Corematetum albi, exhibiting a conspicuous floristic combination with *Silene scabriflora* subsp. *scabriflora, Vulpia fontquerana, Erodium bipinnatum, Linaria spartea, Andryala arenaria, Lotus arenarius, Ononis broterana, Coronilla repanda, Agrostis tenerrima*, and *Rumex bucephalophorus* subsp. *hispanicus*; the Omphalodo kuzinskyanae-Evacietum ramosissimae is endemic to the Lisbon district, in dunes over calcareous coastal wave-cut platforms, and includes *Evax ramosissima, Erodium bipinnatum, Pimpinella villosa, Ononis dentata, Ononis broteroana* and the rare endemic species *Omphalodes kuzinskyanae* and *Jonopsidium acaule*.

Inland dunes and paleodune associations, with an Andalusia and Lusitania Coastal distribution, are characterized by the dominance of *Corynephorus canescens* subsp. *maritimus* and other hemicrypthophytic species, and are included in the

Corynephorion maritimi alliance. *Anagallis monelli* var. *linifolia* and *Anagallis monelli* var. *microphylla* stand out in the floristic combinations along with *Corynephorus canescens* var. *maritimus, Carex arenaria*, *Echium gaditanum, Herniaria ciliolata* subsp. *robusta, Herniaria maritima, Sesamoides spathulifolia.* Associations such as the Echio gaditanae-Corynephoretum maritimi and Herniario maritimae-Corynephoretum maritimi are also examples (Costa et al. 2011b).

#### 2.2.3.5 Annual Grasslands

The Tuberarietea guttatae class includes ephemeral pioneer communities appearing in spring and early summer which are dominated by non-nitrophilous small therophytes.

The plant species that compose these communities avoid the dry season; they have a short life cycle which allows them to colonize extreme ecological conditions frequently with incipient soils that often have a thin layer of surface gravel. Communities of this class are pioneering communities, usually with low biomass and low coverage and their optimal phenological stage is from early spring to early summer, occupying nitrogen-poor soils (Pérez Prieto et Font 2005; Ribeiro et al. 2012c). They appear mostly where perennials are unable to develop. These communities are found in the Mediterranean Region and are extremely diverse. It is possible to distinguish between acidophilous and basophilous communities. In the former we often observe: *Aira caryophyllea* subsp. *caryophyllea, Aira cupaniana*, *Andryala integrifolia* var. *corymbosa, Anthoxanthum aristatum, Aphanes cornucopioides*, *Aphanes australis*, *Briza minor*, *Campanula lusitanica* subsp. *lusitanica*, *Eryngium tenue*, *Filago lutescens*, *Helianthemum aegyptiacum*, *Hymenocarpos lotoides*, *Jasione montana* subsp. *gracilis*, *Lathyrus sphaericus*, *Linaria saxatilis* subsp. *saxatilis*, *Linaria spartea*, *Logfia gallica*, *L. minima*, *Lotus conimbricensis*, *Micropyrum tenellum*, *Moenchia erecta*, *Molineriella laevis*, *Ornithopus compressus*, *Ornithopus perpusillus*, *Psilurus incurvus*, *Rumex bucephalophorus* subsp. *bucephalophorus*, *R. bucephalophorus* subsp. *gallicus*, *Silene portensis*, *S. psammitis* subsp. *psammitis, S. scabriflora* subsp. *scabriflora*, *Teesdalia nudicaulis*, *Tolpis barbata*, *Trifolium arvense*, *Trifolium striatum*, *Trifolium strictum*, *Trifolium sylvaticum*, *Tuberaria guttata, Vulpia bromoide* and *Vulpia myuros*. The most common associations are the Trifolio cherleri-Plantaginetum bellardii and Holco annui-Brachypodietum distachyi. The first is characterized by the dominance of *Plantago bellardii* and other low-biomass and low-coverage therophytes such as *Trifolium cherleri*, *Ornithopus compressus*, *Ornithopus pinnatus* and *Hymenocarpus lotoides*, occupying oligotrophic siliceous soils, often with stoniness and sometimes with a clayey texture that leads to soil hardening in the summer. The second is dominated by *Brachypodium distachyon,* occurring on thin soils (leptosols) derived from schist with a shallow sandy or sandy loam texture, with low acidity. As to basophilous associations, common characteristic species are *Ajuga iva, Alyssum alyssoides, Ammoides pusilla, Atractylis cancellata, Brachypodium distachyon, Bupleurum*

*gerardi, Bupleurum semicompositum, Echinaria capitata, Euphorbia exigua, E. falcata, Hippocrepis biflora, Limonium echioides, Linum strictum* var. *strictum, Linum strictum* var. *spicatum, Micropus supinus, Neatostema apulum, Ononis pubescens, Ononis reclinata, Ononis viscosa* subsp. *breviflora, Polygala monspeliaca, Saxifraga tridactylites, Scabiosa stellata* subsp. *stellata, Scandix australis, Sideritis romana, Valantia hispida, Valerianella discoidea, Valerianella eriocarpa, Valerianella microcarpa* and *Xeranthemum cylindraceum.* One of the associations that spreads over the largest territory is the Velezio rigidae-Astericetum aquaticae: it is frequently dominated by *Brachypodium distachyon* and co-dominated mainly by *Ononis pubescens* and *Atractylis cancellata*. The association Saxifrago tridactylitae-Hornungietum petraeae is a broad-area association in the Mediterranean Iberian Peninsula occurring sporadically on the limestone and marl substrates of Lusitania.

#### 2.2.3.6 Grasslands Related to Heavy Grazing

In this group we include pastures with adequate sheep husbandry, pastures grazed and manured by sheep, and dominated by dwarf perennial grasses and other nutritious, prostrate chamaephytes and hemicryptophytes, such as *Poa bulbosa*, clovers and plantains, which encompass the associations of the Poetea bulbosae class (Galán de Mera et al. 2000; Rivas Goday et Ladero 1970). Such perennial grassland communities are very productive; they dry up in early summer but from the beginning of the autumnal rainy season they grow fast and remain green and fertile during winter. The most frequent association in Lusitania is the Trifolio subterranei-Poetum bulbosae, strongly related to grazing, especially by sheep (Ribeiro et al. 2012b). These are silicicolous pastures that grow on acid soils, both oligotrophic and eutrophic, compacted by cattle trampling and often nitrogen-enriched. Besides *Poa bulbosa* and/or *Trifolium subterraneum* subsp. *subterraneum*, other legumes stand out as common in these communities, such as *Biserrula pelecinus*. With the first rains, *Poa bulbosa* appears, and some geophytes with autumn phenology are also visible then, such as *Scilla autumnalis* and *Leucojum autumnale*. Species such as *Astragalus cymbaecarpos, Onobrychis humilis, Trifolium bocconei, Trifolium gemellum* and *Trifolium glomeratum* are also characteristic of these grasslands. On clay soils these communities are replaced by others dominated by *Plantago serraria*, forming the association Trifolio subterranei-Plantaginetum serrariae. On baso-neutrophilous, clayey, chromic luvisols in drier conditions occurs the Astragalo sesamei-Poetum bulbosae, rich in species such as *Astragalus echinatus, Astragalus epiglottis, Astragalus sesameus, Astragalus stella, Convolvulus lineatus, Lupinus micranthus, Medicago intertexta, Plantago albicans, Astragalus loeflingii* and *Trifolium scabrum.*

Dense meadows and reed-beds that grow in deep, wet, but rarely submerged soils, consisting of hemicryptophytic perennial species and which sometimes may be exploited by man, are included in the Molinio-Arrhenatheretea class. In Lusitania, this type of vegetation is common and almost always corresponds to an anthropic

replacement of riparian forests. In particular, on the banks of streams, *Cyperus eragrostis, Dorycnium rectum, Erica erigena, Hypericum tomentosum, Molinia caerulea* subsp. *arundinacea, Phalaris aquatica, Pulicaria dysenterica, Scirpoides holoschoenus* and *Thalictrum speciosissimum* are frequent. The association Festuco amplae-Brachypodietum phoenicoidis, dominated by *Brachypodium phoenicoides*, develops along the middle sections of large rivers but is also observed on banks of torrential water lines drying up in the summer, sometimes with dominance of *Scirpoides holoschoenus* indicating a watertable near the surface. *Scirpoides holoschoenus,* on deep acid soils, usually in old alluvium with a sandy to loamy texture, develops into dense reed beds, of high biomass, also with a high presence and dominance of *Trifolium resupinatum,* forming the association Trifolio resupinati-Holoschoenetum vulgaris. Reed beds are generally poor in characteristic species due to human influence; they are sometimes cut and put under intensive grazing, given the high fodder value of *Trifolium resupinatum. Scirpoides holoschoenus* is also common in estuaries of water lines, forming the association Holoschoeno-Juncetum acuti, a community of neutral to slightly acidic conditions dominated by *Juncus acutus*. On mesotrophic to eutrophic soils, rich in nitrogen and phosphorus, *Cynodon dactylon* meadows and clover may appear. Successionally driven by intensive grazing, rush communities can be observed forming the association Trifolio resupinati-Caricetum chaetophyllae with *Carex divisa* subsp. *divisa, Cyperus laevigatus* subsp. *distachyos, Lactuca saligna, Medicago arabica* and *Trifolium fragiferum*. On wet soils, often soggy and strongly nitrophilous, the rush community of Mentho suaveolentis-Juncetum inflexi with the characteristic species *Carex cuprina, Cyperus longus* subsp. *badius, Epilobium tetragonum* subsp. *tetragonum, Juncus inflexus* and *Mentha suaveolens* may be found. In the Tagus and Guadiana basins a community mainly composed by the geophyte *Cyperus longus* subsp. *badius,* co-dominated by *Mentha pulegium* and *Rumex conglomeratus,* called Mentho pulegii-Cyperetum badii association (Fig. 2.9), is common. It is found on alluvial margins of water courses of sandy-gravelly to clayey material, flooded in winter or late spring, and resisting long submerged periods.

Alluvial deposits mainly with a fine texture, waterlogged in spring and retaining a high humidity content during the early summer, develop extensive meadows often subjected to cutting and grazing in late summer. These meadows belong to the Mentho suveolentis-Holcetum lanati association which is dominated by *Holcus lanatus* and co-dominated by *Mentha suaveolens* and *Cyperus longus* subsp. *badius.*

An association with a more restricted distribution is the Junco rugosi-Ericetum andevalensis with *Erica andevalensis*; it is a shrub community with rushes on peaty sites with heavy metals, exclusive to the mining regions of St. Domingos and Riotinto.

**Fig. 2.9** Aspect of the Mentho pulegii-Cyperetum badii association in the Ocreza river (Castelo Branco) (© S. Ribeiro)

## *2.2.4 Other Herbaceous Communities Dependent on Anthropic Influence*

### 2.2.4.1 Nitrophilous Megaforbic Vegetation

The tall herbs of nitrified wood fringes and other semi-shaded anthropic biotopes are generally perennial hemicryptophytes and climbers and they compose communities of the Galio-Urticetea class. They occur on mesic sites with humid, nutrient-rich soils, on river banks and in swamp areas not subjected to desiccation. Some characteristic plants of these habitats are *Galium aparine, Lamium maculatum, Stellaria neglecta, Urtica dioica.* On deep soils these can be joined by *Geranium robertianum, Silene dioica, Smyrnium olusatrum, S. perfoliatum, Torilis japonica, Urtica membranecea,* and associations such as the Allio triquetri-Urticetum membranaceae and Urtico membranaceae-Smyrnietum olusatri are frequent. Under wet conditions it is common to see the association Galio aparines-Conietum maculati, and species such as *Asphodelus lusitanicus* var. *lusitanicus, Ballota nigra* subsp. *foetida, Dipsacus fullonum, Magydaris panacifolia* can also appear.

On hydromorphic soils, nitrophilous, perennial vegetation of tall herbs is very common. Generally there is the predominance of hemicryptophytes, helophytes and

scandent plants that reach some rivers in Lusitania. The Arundini donacis-Convolvuletum sepium is very widespread. Species such as *Arundo donax, Calystegia sepium* and *Cynanchum acutum* are characteristic.

Ephemeral, annual, shady, nitrophilous communities that develop in spring and summer, inside and at the fringes of forests and thickets in slightly nitrified and semi-shady habitats, on rich organic soils, can also be seen in Lusitania. The Cardamino hirsutae-Myosotidetum ramosissimae, Galio aparinellae-Anthriscetum caucalidis and Urtico membranaceae-Anthriscetum caucalidis are frequent. *Anthriscus caucalis, Cardamine hirsuta, Centranthus calcitrapa, Fumaria capreolata, Galium murale, Geranium dissectum, Geranium lucidum, Geranium purpureum, Geranium rotundifolium, Myosotis ramosissima, Torilis arvensis* subsp. *neglecta, Torilis leptophylla, Torilis nodosa, Valantia muralis* and *Vicia capreolata* can be found under these conditions.

In slightly nitrified, semi-shaded fringe communities, with *Galium minutulum, Mercurialis elliptica, Parietaria lusitanica, Parietaria mauritanica* and *Theligonum cynocrambe*, the associations Anogrammo leptophyllae-Parietarietum lusitanicae, Geranio purpurei-Galietum minutuli and Torilido nodosae-Parietarietum mauritanicae can be found.

Semi-shaded, humicolous, herbaceous, perennial communities of external fringes of woodlands and their pre-forestry mantles are rich in attractively flowered and aromatic plants, such as *Agrimonia eupatoria, Calamintha nepeta, Campanula rapunculus, Clinopodium vulgare, Inula conyza, Lathyrus sylvestris, Origanum virens, Ranunculus ollissiponensis, Silene latifolia, Vicia tenuifolia*. *Origanum virens* is, without doubt, the most characteristic, appearing in associations such as the Clinopodio villosae-Origanetum virentis, Pimpinello villosae-Origanetum virentis and Vincetoxico nigri-Origanetum virentis. On Andalusia and Lusitania Coastal limstones *Arabis lusitanica, Cheirolophus sempervirens, Cynara algarbiensis, Picris algarbiensis, Picris. spinifera, Prunella* x *intermedia, Stachys germanica* subsp. *lusitanica, Stachys officinalis* subsp. *algeriensis* are frequent, appearing in localized associations such as the Bartsio asperae-Origanetum virentis, Leucanthemo sylvatici-Cheirolophetum sempervirentis, Picrido algarbiensis-Cheirolophetum sempervirentis, Senecio lopezii-Cheirolophetum sempervirentis, and Stachyo lusitanicae-Origanetum virentis.

#### 2.2.4.2 Herbaceous Ruderal Vegetation

When we cross the long paths of Lusitania, in early spring, it is common to see, mainly in fallow grain crops, a white mantle of *Chamaemelum fuscatum*. The Chrysanthemo myconis-Anthemidetum fuscatae association, one of the first of the year to dominate the landscape, often occupies fallow agricultural crops, usually on sandy or sandy-loamy soils. To the view of white flowers, a colour also conferred by *Chamaemelum mixtum*, is joined the profusion of yellow marigolds, such as *Coleostephus myconis*, *Chrysanthemum segetum* and *Ch. coronarium* var.

*coronarium*, and many others that give a fantastic colour to the fields. In contact with them occur communities dominated by *Bromus rigidus* or *Bromus diandrus* and associations dominated by *Vulpia geniculata*, *Echium plantagineum* and *Galactites tomentosa*, with other characteristic species such as *Gastridium ventricosum*, *Medicago intertexta*, *Medicago murex*, *Melilotus elegans*, *Melilotus italicus*, *Reichardia intermedia*, *Silene fuscata* and *S. scabriflora* subsp. *tuberculata*. On uncultivated and fallow soils, on calcareous or on compressed lithosols derived from limestone, there is often a high dominance of the Aegilopo neglectae-Stipetum capensis, dominated by *Stipa capensis* and sometimes with a high abundance of *Brachypodium distachyon*. On siliceous soils this association is replaced by another, the Bromo tectorum-Stipetum capensis, which also colonizes eroded and poor soils, often with stoniness. When summers are dry and the continentality is pronounced, the neutrophilous to basophilous association Medicagini rigidulae-Aegilopetum geniculatae occurs, dominated by plants with low biomass such as *Atractylis cancellata* subsp. *cancellata*, *Echinops strigosus*, *Linum strictum* and *Crupina vulgaris*. In ruderal areas or fallow land of cereal crops, often subject to grazing, on siliceous soils with a sandy-loamy texture, the association Trifolio cherleri-Taeniatheretum capitis-medusae develops (in an impoverished form), and is replaced on limestone soils rich in bases by the association Medicagini rigidulae-Aegilopetum geniculatae. Species such as *Vulpia bromoides*, *Trifolium glomeratum*, *Trifolium striatum*, *Trifolium arvense*, *Trifolium campestre* and *Logfia minima* are some of those that can be found in these areas. When walking in very nitrophilous places, like ruderal vacants, the occurrence of species of the genus *Chenopodium*, *Amaranthus* and *Malva* is common. In Lusitania there are particularly frequent associations such as the Emici spinosae-Malvetum parviflorae, Sisymbrio irionis-Lavateretum creticae and Hyosciamo albi-Malvetum parviflorae, very common in places with debris accumulation. Where organic matter accumulates, either of animal or of vegetal origin, there establishes a spiny vegetation of high biomass, formed by annual and biannual thistles, such as *Carduus broteri, Carthamus lanatus* subsp. *baeticus, Cynara humilis, Cynara tournefortii, Echinops strigosus, Nothobasis syriaca, Onopordum macrocanthum, Onopordum nervosum* subsp. *nervosum* and *Scolymus maculatus*. The associations Galactito tomentosae-Cynaretum humilis and Nothobasio syriacae-Scolymetum maculati are the most common. If there is enough soil mouisture, *Silybum marianum* dominates the thistle communities accompanied by *Cynara cardunculus* and *Oxalis articulata*. This permits the distinction of the association Carduo bourgeani-Silybetum mariani.

In ruderal places, on roads and often-trampled areas communities occur dominated by therophytes of medium size of which *Hordeum murinum* subsp. *leporinum* dominates; they form the associations Anacyclo radiati-Hordeetum leporini, Bromo scoparii-Hordeetum leporini or Hordeo leporini-Glossopappetum macroti. *Anacyclus clavatus, Anacyclus radiatus, Asphodelus fistulosus, Bromus scoparius, Chrysanthemum coronarium var. coronarium, C. coronarium* var. *discolor, Convolvulus siculus*, *Crepis taraxacifolia*, *Daucus muricatus, Diplotaxis virgata, Erodium chium, Geranium molle, Lamarckia aurea, Hirschfeldia incana, Lepidium graminifolium, Malva sylvestris, Medicago polymorpha, Plantago lagopus, Reseda*

*alba* subsp. *alba, Rostraria cristata, Rumex pulcher* subsp. *pulcher* and *R. pulcher* subsp. *woodsii* are also frequent plants in their floristic composition. When the verges of roads allow the installation of perennial communities it is expected that associations occur with *Centaurea aspera* subsp. *stenophylla, Dittrichia viscosa* subsp. *revoluta, D. viscosa* subsp. *viscosa*, *Piptatherum miliaceum* subsp. *miliaceum*, *P. miliaceum* subsp. *thomasii, Scabiosa atropurpurea*, and *Verbascum litigiosum,* with the association Dittrichio viscosae-Piptatheretum miliacei being one of the most frequent.

Another type of road and nitrophilous vegetation is the one that is installed on footpaths and even on the sidewalks of villages, especially well adapted to trampling, and included in the Polygono arenastri-Poetalia annuae class. The plants are usually annual and they generally are of small height or are prostrate. In Lusitania the associations Crassulo tillaeae-Saginetum apetalae, Polycarpo tetraphylli-Cotuletum australis and Solivetum stoloniferae are particularly common; they are characterized by the presence of *Bryum argenteum, Coronopus didymus, Cotula australis, Crassula tillaea, Crepis pusilla, Gymnostyles stolonifera, Matricaria aurea, Plantago coronopus* subsp. *coronopus, Poa annua, Poa infirma, Polycarpon tetraphyllum, Polygonum arenastrum, Polygonum aviculare, Sagina apetala, Spergularia rubra* and *Spergularia purpurea.*

## *2.2.5 Coastal Halophilous Vegetation*

### 2.2.5.1 Cliffs

Chasmophytic vegetation of sea cliffs and lithosols, consisting of geophytes, hemicryptophytes, chamaephytes, usually succulent, splashed by marine salt spray, subject to strong edaphic dryness and a permanent influence of sea winds laden with salt, is distributed along the whole Lusitanian coast. *Asteriscus maritimus, Crithmum maritimum* and *Plantago macrorhiza* are characteristic species. The beautiful sea-lavenders *Limonium virgatum, Limonium nydeggeri, Limonium plurisquamatum* and *Limonium multiflorum,* as well as the beautiful roman-claves *Armeria pseudarmeria, Armeria welwitschii* subsp. *cinerea* and *Armeria pungens* subsp. *major* characterize these habitats.

From North of Lisbon to Cape Carvoeiro all the coastal communities are submitted to a strong influence of estival smog that allows an input of water that can be used by the plants in the dry period. Lithologically we can separate the sea cliffs into two groups: (a) From Lisbon to Sintra and between North of Sintra and Cape Carvoeiro, cliffs consist of limestone; (b) The cliffs of Cape Roca (Sintra Sierrian District) are predominantly of syenite and granite, and as regards the Berlengas archipelago, they consist of granites in the Berlenga-Estelas archipelago, and of diorites schists and micaschists in the small islands of Farilhões. On the karstic limestone cliffs of Cape Carvoeiro (Litoral Estremenho and Berlengas Islands

District) the wind-supplied, halophytic (aerohalophytic) and chamaephytic vegetation is dominated by *Limonium plurisquamatum* (Dactylo marinae-Limonietum plurisquamati) and occurs in a thermomediterranean bioclimate (however submitted to estival smog). From south of Cape Carvoeiro to the Sintra mountains, in a thermomediterranean dry bioclimate (with a high predominance of estival smog), marly and limestone cliffs are characterized by the presence of *Limonium multiflorum*, *Limonium virgatum*, *Dactylis smithii* subsp. *marina* and *Daucus carota* subsp. *halophilus* (Limonietum multifloro-virgatii). The distribution of this community is interrupted by the acid cliffs of Cape Roca but reappears in calcareous cliffs between Sintra and Lisboa (Lisboa District) (Costa et al. 2014).

On Cape Roca the syenite and granite cliffs (more than 100 m high) are the westernmost sector of the Sintra Mountains (Sintra Sierran District) and due to their promontory situation have a mesomediterranean bioclimate and a very high incidence of estival smog. The wind-supplied halophytic and rupicolous chamaephytic vegetation is characterized by the presence of *Armeria pseudoarmeria, Daucus carota* subsp. *halophilus, Dactylis smithii* subsp. *marina, Limonium virgatum, Spergularia rupicola* (Diantho cintrani-Daucetum halophili).

On the Berlenga Islands (Litoral Estremenho and Berlengas Islands District) cliffs are submitted to a strong influence of northwesterly waves and also strong winds throughout the year. These extreme conditions, which characterize sea cliffs of the whole archipelago, allow a community that is poor in aerohalophytic and rupiculous species, characterized however by some rare and local species (*Armeria berlengensis* and *Herniaria lusitanica* subsp. *berlengiana* which are endemics from the Berlenga archipelago) and also *Angelica pachycarpa* and *Spergularia rupicola* (Spergulario rupicolae-Armerietum berlengensis).

From south of Cape Espichel (Arrabida Sierran District) to Cape São Vicente District the cliffs belong to either of three main lithological groups: Arrabida-Cape Espichel (Jurassic limestone cliffs); Pego Beach (Sado) to the Cape of Sines (sandstone and conglomerate cliffs); South of Sines to the São Vicente Coast (Paleozoic schists, quartzites and dykes of quartz); Cape São Vicente (Algarve) (Jurassic limestone cliffs). The the difference between the stable limestone and schist cliffs on the one hand and the instability of the sandstone cliffs on the other, and the exposition to the influence of the sea are the major factors that determine the vegetation's distribution. Thus, Cape Espichel is characterized by the presence of the aerohalophytic and calcicolous plants *Helianthemum apenninum* subsp. *stoechadifolium*, *H. apenninum* subsp. *apenninum* (which only occur in the Cape Espichel – Arrabida Sierran District) and *Limonium virgatum* (Helianthemo stoechadifolii-Limonietum virgati). The sandstones and conglomerate cliffs (between Pego beach and Sines) are characterized by a floristically poor community due to the instability of the cliff wall and the presence of an oligotrophic mineral soil (Dactylo marinae-Armerietum majoris – Sado District), characterized by the presence of *Armeria pungens* subsp. *major* (Neto et al. 2005). On the schist cliffs there occur also two endemic plant communities from the Alentejo coast (São Vicente Coast District): a) the most exposed sector of the cliffs is occupied by an aerohalophytic community (Spergulario rupicolae-Limonietum virgatae) dominated by *Limonium virgatum*

**Fig. 2.10** Vincentine Promontorius. The lapias platform that develops on top of the limestone cliffs (100 m high) under semi-arid dry conditions, but submitted to a strong influence of estival smog, is colonized by the association *Dauco halophili-Astragaletum vicentini* with some endemic and rare species of Portugal, such as *Silene rothmaleri* and *Astragalus tragacantha* subsp. *vicentinus* (© C. Neto)

and *Helichrysum decumbens* which are absent from the limestone cliffs of Cape São Vicente (SW Portugal); b) at the top of the cliffs in a less exposed situation occurs a community dominated by the chamaephyte *Dittrichia maritima* (Dittrichietum maritimi). In contact with the Paleozoic schist and the Quaternary paleodunes occurs an outcrop of ferruginous sandstone colonized by the rarest and unique plant of the Portuguese cliffs *Plantago almogravensis* (community of *Plantago almogravensis* - between Vila Nova de Milfontes Beach and Almograve Beach).

On the limestone cliffs of the Cape São Vicente District, sometimes more than 100 m high, the aerohalophytic vegetation, characterized by chamaephytic plants, is dominated by *Myriolimon ferulaceum* and *Limonium ovalifolium* (Myriolimetum ferulacei). The presence of *Myriolimon ferulaceum* (which occurs also in salt-marshes) indicates the very important influence of salt spray as a consequence of the combined effect of the strong winds and strong waves that are very frequent along the limestone cliffs of Cape São Vicente. Also in Vincenti Promontorius, on the lapiaz coastal terrace originated by the uplift of the wave-vut platform that develops on top of the limestone cliffs under semi-arid dry conditions, other endemic and rare species of Portugal appear, such as *Silene rothmaleri* and *Astragalus tragacantha* subsp. *vicentinus,* forming the association Dauco halophili-Astragaletum vicentini (Fig. 2.10).

Finally, the sea cliffs of SW Portugal (mainly south of the Cape of Sines but also present from north of Lisbon to São Martinho do Porto) have a very special mosses-dominated community of the Adiantetea class (Didymodon spadicei-Adiantetum capilli-veneri), which is fairly independent of rainfall and temperature and more conditioned by a particular geomorphological evolution which allows rainwater to circulate and to supply water continuously throughout the year (Neto et al. 2007). The rainwater falling in autumn and winter infiltrates the sand dunes at the top of the cliffs and generates numerous springs that allow for a community dominated by bryophytes (*Eurhynchium speciosum*, *Didymodon spadiceus*) and including *Sphagnum auriculatum* with some vascular plants like *Adiantum capillus-veneris* and *Samolus valerandi*. The abundance of *S. valerandi* indicates the influence of salt spray, which is common in this coastal cliff habitat.

#### 2.2.5.2 Dunes

The community nearest to the sea, growing on sandy beaches in the area with a high accumulation of organic debris brought by the sea, is constituted by pioneer halo-nitrophilous annual plants and included in the Cakilion maritimae (Cakiletea maritimae class). On the Lusitanian coast, south of Cape Carvoeiro, *Beta maritima* var. *maritima, Cakile maritima* subsp. *maritima, Chamaesyce peplis* and *Salsola kali* are frequent, and characterize the association Salsolo kali-Cakiletum maritimae. North of Cape Carvoeiro, *Cakile maritima* subsp. *integrifolia* dominates and the Atlantic association Honckenyo-Euphorbietum peplis (Atriplicion littoralis) substitutes the previous one.

The second strip of mobile embryonic dunes is characterized by pioneer communities that are subject to the mechanical action of the waves during high tides and storms, the constant mobility of sands and a high salinity of the substrate and air (Fig. 2.11). *Elytrigia juncea* subsp. *boreoatlantica, E. juncea* subsp. *juncea* and *Honckenya peploides* are the dominant species under these conditions and they form associations of the Honckenyo peploidis-Elytrigion boreoatlanticae. Where the salinity of the soil and of the air become moderate, the perennial rhizomatous grass *Ammophila arenaria* subsp. *arundinacea* (Ammophilion arundinaceae alliance) is dominant (Martins et al. 2013). Some chamaephytes that are able to resist strong winds, such as *Anthemis maritima, Calystegia soldanella, Cyperus capitatus, Eryngium maritimum, Euphorbia paralias, Euphorbia portlandica, Lotus creticus, Medicago marina, Otanthus maritimus, Pancratium maritimum* and *Polygonum maritimum*, are also frequent. Semi-fixed dunes or grey dunes are characterized by their floristic richness with several chamaephytes that usually have attractive flowers and grey leaves, included in the Helichrysion picardii: *Aetheorhiza bulbosa* subsp. *bulbosa, Armeria pungens, A. welwitschii* subsp. *welwitschii, Artemisia crithmifolia, Crucianella maritima, Euphorbia boetica, Helichrysum picardii, Iberis procumbens, Leontodon taraxacoides* subsp. *taraxacoides, Linaria lamarckii, Linaria polygalifolia, Malcolmia littorea, Matthiola sinuata, Ononis ramosissima, Scrophularia frutescens, Seseli tortuosum* and *Thymus carnosus,* some of them

**Fig. 2.11** Alvor Beach (Algarve). The foreground shows the vegetation of embryonic dunes, the Elytrigietum junceo-boreoatlanticae, dominated by *Elytrigia juncea* subsp. *boreoatlantica* and *Elytrigia juncea* subsp. *juncea*. In the background the mobile dunes (white dunes) are dominated by the perennial rhizomatous grass, *Ammophila arenaria* subsp. *arundinacea* (*Loto cretici-Ammophiletum arundinaceae*) (© C. Neto)

being endemic. All these plants that occur on mobile dunes are part of assocations included in the Euphorbio paraliae-Ammophiletea australis class (Neto et al. 2008).

Numerous annual plants appear in spring in mosaics between these communities, such as *Chaenorhinum serpyllifolium* subsp. *lusitanicum, Cutandia maritima, Erodium laciniatum, Hedypnois arenaria, Herniaria algarvica, Linaria ficalhoana, Linaria munbyana* subsp. *pygmaea, Linaria pedunculata, Malcolmia ramosissima, Ononis cossoniana, Ononis variegata, Polycarpon alsinifolium, Polycarpon diphyllum, Pseudorlaya minuscula, Pseudorlaya pumila, Silene littorea* subsp. *littorea, Silene nicaeensis, Silene ramosissima* and *Vulpia fasciculata,* which form widespread associations included in the alliance Linarion pedunculatae. The Herniario algarvicae-Linarietum ficalhoanae in the Sado and São Vicente Coast dunes is the association that is richest in endemic species. For lithified calcareous dunes, a subassociation characterized by *Chaenorhinum serpyllifolium* subsp. *lusitanicum* appears in a much reduced territory between Porto Côvo and S. Teotónio. Another association, the Pseudorlayo minusculae-Polycarpetum alsinifolii (between Lisbon and Aveiro) substitutes the Violo henriquesii-Silenetum littoreae which colonizes the dunes of Galiza until Aveiro (Costa et al. 2011b). This is as a result of an extension of more than 100 km of rocky cliffs, coastal limestone and granitic coastal platforms, between Lisbon and Cape Carvoeiro (Peniche), a lithological discontinuity

that is critical for the distribution of the psammophilic plant communities. There are also important climatic differences, like a higher number of foggy days in spring and summer, stronger influences of fronts, lower temperatures throughout the year and higher levels of rainfall, in the north. As a result, thermophilic plants have difficulty in moving north and this creates clear floristic differences and leads to another association. *Pseudorlaya minuscula*, *Polycarpon alsinifolium*, *Hedypnois cretica, Silene nicaeensis, Ononis dentata* and *Pimpinella villosa* are species that are found only south of Aveiro until Cascais (Litoral Estremenho and Berlengas Islands and Lisboa Districts, Divisorio Portuguese Sector).

#### 2.2.5.3 Estuaries and Saltmarshes

On sandy coasts, in estuaries and continental depressions on wet or inundated saltmarshes, the vegetation consists of saline grasslands and rushlands, with *Apium graveolens, Aster tripolium* subsp. *pannonicus, Carex extensa, Juncus acutus, Juncus maritimus, Spartina versicolor.* The most frequent association is the Polygono equisetiformis-Juncetum maritimi (Juncetea maritimi class). The Cotulo coronopifoliae-Triglochinetum barrelieri inhabits openings in *Juncus maritimus* formations, normally small pools temporarily inundated with brackish water (Costa et al. 2009a, b). In some places, subjected to strong winds from the sea and flooding over a period of time, pioneering and ephemeral vegetation appears, with species such as *Catapodium marinum, Centaurium spicatum, Frankenia pulverulenta, Parapholis filiformis, Parapholis incurva, Sagina maritima, Spergularia bocconei*. When these habitats are nitrophilized as a result of human activity or grazing, *Agrostis nebulosa, Hainardia cylindrica, Hordeum marinum, Polypogon maritimus* appear.

Coastal perennial salt marshes and salt pan communities, with dominance of *Sarcocornia pruinosa*, a succulent shrub that thrives in moist, saline soils that are at least temporarily subject to flooding by salt or brackish water, can be seen in the estuaries of all rivers. *Cistanche phelypaea, Halimione portulacoides, Triglochin bulbosa* subsp. *barrelieri* are characteristic species. The Cistancho phelypaeae-Sarcocornietum fruticosae is a frequent association exclusive to northern Portugal. Where the rhizomatous shrub *Sarcocornia perennis* subsp. *perennis* dominates, occupying the lower marsh and therefore exposed to prolonged submersion, and *Limonium vulgare* and *Puccinellia iberica, Sarcocornia perennis* subsp. *perennis* occur, the association Puccinellio ibericae-Sarcocornietum perennis is found. When the time of submergence is very short, as south of the Tagus estuary, in a higher located salt marsh, another succulent plant appears, *Arthrocnemum macrostachyum*; other sea-lavenders also occur under those conditions, such as *Limonium algarvense* and *Myriolimon ferulaceum* (= *Limonium ferulaceum).* The nitrophilous associations that occupy the highest positions on the coast, that are only briefly inundated by salt water, there and where the tides deposit the debris, and also on cliffs dotted by salt water, on slopes, walls of salines and where salty soils are removed, *Suaeda*

*vera* is the characteristic species. The association Cistancho phelypaeae-Suaedetum verae is the most frequent.

In littoral and temporary wet inland areas with a high salinity, perennial grasses and *Limonium* species continue to be predominant. On well drained sandy soils, the *Limoniastrum monopetalum* community is frequent. Halophilous communities, with rosulate and prostrate chamaephytes that colonize the upper tideland of salt marshes reached by the sea water only during the highest tides, with *Limonium algarvense, Limonium daveaui, Limonium lanceolatum, Myriolimon diffusum* (= *Limonium diffusum*) form several endemic associations.

In estuaries and coastal lowlands the vegetation consists of perennial halophytic grasses, which occupy the low kinetic energy sedimentary environments, with calm waters protected from direct waves. They are pioneers, establishing communities on marine sediments or on the river-sea contact areas, with more or less fine sediments, subject to a daily tidal influence, occupying the lower areas of the marshes. Immersion times are longer than in the other marsh ecosystems. *Spartina densiflora* and *Spartina maritima* are the characteristic species of almost mono-specific associations.

The halophytic pioneer vegetation, constituted by succulent therophytes that thrive in saline soils of temporarily flooded marshes and coastal areas, can be of several types. The communities that colonize the Atlantic coast of Europe, with *Salicornia fragilis*, extend to Lusitania (Costa et al. 2009a, b). However the association Halimiono portulacoidis-Salicornietum ramosissimae, with *Salicornia ramosissima,* is common. *Salicornia patula* appears at the highest positions in the salt marshes. These biotopes are inundated by rainwater in winter, but are subjected to strong summer drying. The Suaedo splendentis-Salicornietum patulae is the specific association under these conditions.

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