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Plant Biogeography and Vegetation of High Mountains of Central and South-West Asia

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Introduction

Biological diversity in the highlands is generally richer than in most lowlands of the same area (Körner 2002, 2003) and quite a number of mountain areas are hotspots of biodiversity (Hoorn et al. 2018). Although mountains cover only about 12.3% of the Earth's terrestrial surface outside Antarctica (Körner et al. 2011), they support an estimated one third of the terrestrial biological diversity (Spehn et al. 2011) and harbour a considerable number of endemic species (Barthlott et al. 1996; Körner 2003; Hobohm 2014). Mountains play an important role in the evolution and diversification of species (Badgley et al. 2017), due to their high topographic complexity, diverse climates and strong altitudinal gradients (Antonelli et al. 2018). Mountains affect the regional climates, facilitate species migration and speciation, and can act as sources of new species to adjacent areas (Hoorn et al. 2013; Merckx et al. 2015).

Central and SW Asia have complex topographies and possess huge mountain ranges with large elevational amplitudes (Fig. 1). The heterogeneous topography and diverse climates in different regions of Central and SW Asia resulted in a very rich biodiversity and many different vegetation types (Zohary 1973; Djamali et al. 2012b). Boissier (1867), in the nineteenth century, already mentioned that the Central and SW Asian highlands harbour the richest flora of the Near East. The mountains of this region contain huge numbers of rare and range-restricted genera and species (Zohary 1973; Takhtajan 1986; Türe and Böcük 2010; Nowak et al. 2011; Şekercioğlu et al. 2011; Sales and Hedge 2013; Solomon et al. 2013; Eken et al. 2016; Manafzadeh et al. 2017; Noroozi et al. 2019). They are well-known as centres of diversification and development of many plant taxa (Zohary 1973; Takhtajan 1986; Manafzadeh et al. 2017). More than 160 genera are endemic to the region (Sales and Hedge 2013), and some of the species-rich genera, including *Astragalus* (Fabaceae), *Cousinia* (Asteraceae), *Acantholimon* (Plumbaginaceae), *Centaurea* (Asteraceae), *Allium* (Alliaceae), *Heliotropium* (Boraginaceae), *Nepeta* (Lamiaceae) and *Salvia* (Lamiaceae), have evolved and diversified in this region (Zohary 1973; Knapp 1987; Manafzadeh et al. 2014; Bagheri et al. 2017; Moharrek et al. 2017). These mountainous areas have been sources of plant species to the adjacent areas to the west and south, i.e. the Saharo-Sindian and Mediterranean regions, and have been corridors for the migration of flora between the east and west

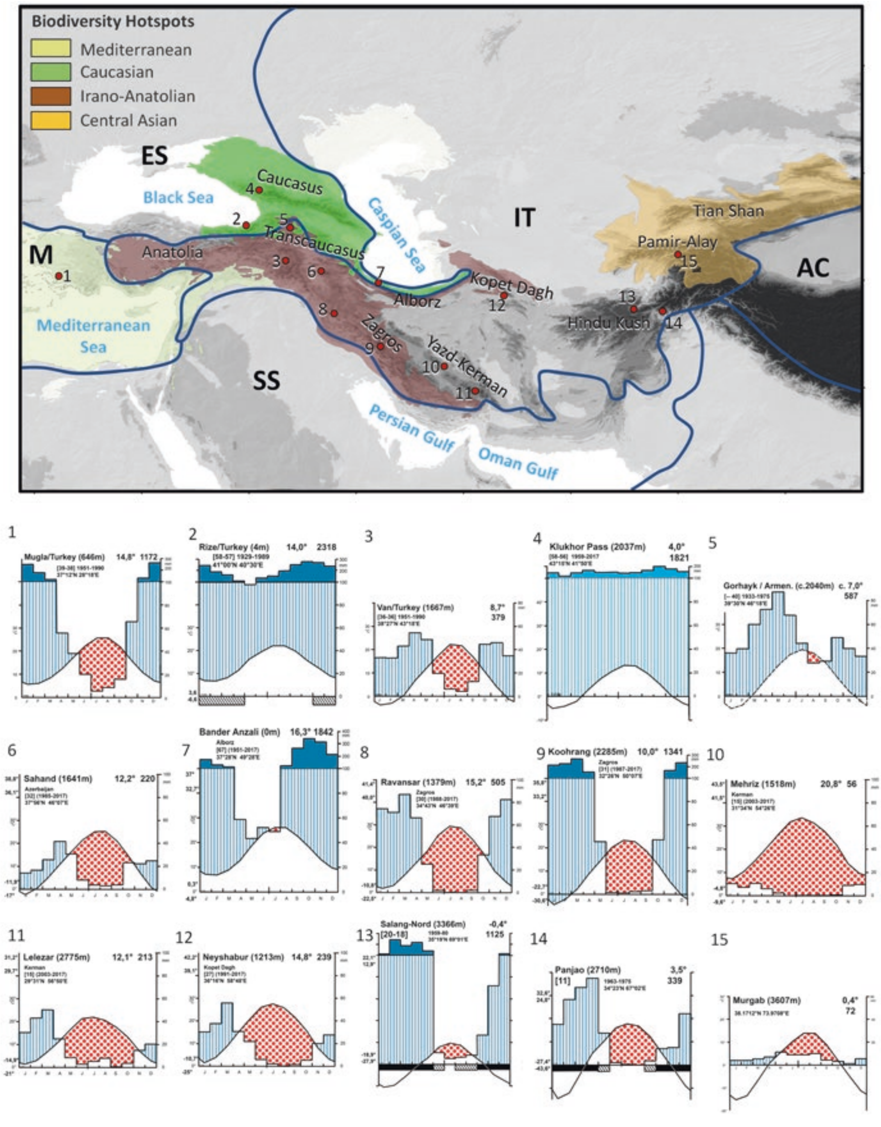

Fig. 1 Phytogeographical regions separated by the dark-blue lines (*IT* Irano-Turanian, *ES* Euro-Siberian, *M* Mediterranean, *SS* Saharo-Sindian, *AC* Central Asiatic) according to modified version of White and Léonard (1991), Global Biodiversity Hotspots (Mittermeier et al. 2011), the high mountain ranges and different climatic diagrams (1–15) from the Central and SW Asia

parts of the Holarctic Kingdom (Zohary 1973; Manafzadeh et al. 2014, 2017). Due to the relatively low latitude of this region and the opportunity provided by the topography for vertical shifts of species along altitudinal gradients, most of the plant taxa did survive the glacial and postglacial climate oscillations of the late Quaternary, and extinctions were not as strong as in the Euro-Siberian region (Djamali et al. 2012a).

All mentioned phenomena caused the high mountains of Central and SW Asia to be one of the areas of richest biodiversity on the planet, with a very high proportion of narrowly distributed species. As a result, the area comprises a number of the hotspots of evolutionary and biological diversity of the Old World (Zohary 1973; Hedge 1976; Manafzadeh et al. 2017). From the 35 global biodiversity hotspots (Mittermeier et al. 2011), 4 are located fully or partly in this region (Fig. 1), demonstrating the importance of the region for generating biodiversity and for conservation. The Irano-Anatolian biodiversity hotspot is the largest one, covering the high mountains of the Kopet Dagh, Yazd-Kerman Massifs, Zagros, Alborz, Anatolia and Transcaucasus. The high mountains of the Pamir-Alay and Tian Shan are known as the Central Asian hotspot. The Caucasus hotspot covers parts of SW Russia, the entire Caucasus Mountains, the eastern part of the Pontic Mountains of northeast Turkey and the north-facing slopes of the Alborz mountain range. The Mediterranean hotspot, in its eastern limit, reaches to southwest Turkey and the high mountains of that region.

While there are many publications on the plant diversity of these mountain ranges, they provide mostly local or regional bits of information and there are no general overview publications covering the overall patterns of plant diversity of these mountain ranges in somewhat more detail. The aim of this book is to present such a general review of the flora, biogeography, endemism, vegetation types and conservation status of the high mountains of Central and SW Asia, each mountain system in a separate chapter. Moreover, the climatic and geological characteristics of each mountain range are briefly presented. This book will be helpful for all who are interested to have general and comparative information on the plant diversity and habitats of these mountain ranges.

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Contents

Chapter 1
The Pamir-Alai Mountains (Middle Asia: Tajikistan)

Arkadiusz Nowak, Sylwia Nowak, and Marcin Nobis

Abstract The Pamir-Alai Mountains are extremely diverse in terms of climate, landscape and habitat conditions. With one of the largest altitudinal amplitudes in the world, long gradients of precipitation and temperatures, different soil substrates and a diverse geology, the Pamir-Alai promotes a great number of plant species and diverse vegetation types. Currently almost 4300 vascular plant species have been reported from the area. The flora of the Pamir-Alai is clearly dominated by Irano-Turanian species (ca. 70%) followed by Mediterranean (10.6%) and Euro-Siberian species (9%). Out of a ca. 4300 known vascular plants naturally occurring in Tajikistan, 1486 are endemics belonging to 60 families and 188 genera. There are 12 endemic and 14 subendemic genera in Tajikistan. *Astragalus* is the richest genus with 173 unique species. The Pamir-Alai vegetation is fairly diverse and can be generally divided into 21 types: mesophilous deciduous forests, riverside forests, river-bed forests, xerothermophilous shrubs, subalpine coniferous forests, river-bed shrubs, meadows and pastures, segetal vegetation, alpine meadows and swards, steppes and so-called semi-savannas, xerothermophilous swards, xerothermophilous dwarf shrubs, desert and semi-desert vegetation, fen-spring vegetation, tall-herbs, littoral vegetation, aquatic vegetation, scree and sliding rock vegetation, rock vegetation and salt-marsh vegetation. Within these vegetation types approximately 200 plant associations were distinguished. The Pamir-Alai territory is regarded as one of the most sensitive areas in the world to climate change and biodiversity loss.

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Urgent action plans with the establishment of specific priorities and management for the hotspots of plant diversity are necessary to raise the effectiveness of phytodiversity conservation in the Pamir-Alai.

1.1 Introduction

The Pamir-Alai Mountains are located between the continental Asian deserts on the west and south, and the great mountain ranges of the Tian-Shan, Kunlun, Hindu-Kush and Karakorum in the north, east and south-east, having all vertical belts from hot to permafrost deserts. The Pamir-Alai has a typical alpine relief dominating in the western sections of the mountain ridges with deep V-shaped valleys and rugged summits. In the eastern part it changes into a high-altitude plateau with gentle slopes and hilly mountain tops. Alpine landscapes of high mountains with ponds, lakes, glaciers, rock cliffs, screes, fans and swiftly flowing streams are typical features of the Pamir-Alai. More than 50% of the area is elevated above 3000 m a.s.l. (Nedzvedskiy 1968). The higher parts of the Pamir-Alai are largely composed of extrusive rocks, mainly granite, granitoid and syenite. Some igneous outcrops also occur in the Darvaz Mts., Kuraminian Mts. and in the western Pamir ranges. In the Zeravshan and Turkestan Mts., Cambrian and Silurian sediments predominate. Their rocks are generally limestone, marble, dolomite, dolomitic shale, clay shale, phyllitic schist and argillaceous slate (Nedzvedskiy 1968).

These mountains are extremely diverse in terms of climate, landscape and habitat conditions (Narzikulov and Stanyukovich 1968), offering an outstanding range of biotopes for plants and vegetation types (Stanyukovich 1982). With one of the largest altitudinal amplitudes in the world, long gradients of precipitation and temperatures, different soil substrates and diverse geology, the Pamir-Alai promotes a great number of plant species and their communities. This is due to the speciation of many altitudinal and ecological vicariants occurring in many cases in single, isolated valleys or mountain ridges (Nowak et al. 2011). To some extent, this high richness is also related to the position taken within the phytogeographical knot of the Irano-Turanian region, as divided by Grubov (2010) and Takhtajan (1986) into a Western Asian Subregion (with the Turkestanian Province encompassing the Pamir-Alai) and a Central Asian Subregion (with the Tibetan Province encompassing the Pamir-Alai from the east).

The extraordinary complexity of climatic influences, phytogeographical divisions and diverse geomorphology of the land affect the floristic composition and richness of plant species of the Pamir-Alai Mountains. As the area of the Pamir-Alai ranges correspond mainly to the territory of Tajikistan (with only the Kuraminian range passing over from the Tian-Shan system and the Alay range in the borderland with Kyrgyzstan), one can approximately assess the vascular flora of the Pamir-Alai to consists of ca. 4500–5000 species assigned to 994 genera and 116 families. Approximately 30% of the vascular plant species known from the Pamir-Alai are generally accepted as endemics. Almost 1200 species meet the criteria for being a national endemic of Tajikistan and a further 300 may be regarded as subendemics that occur also in the adjacent areas though not outside the adjacent borderlands (e.g. mountain ranges or valleys). Many of those species have strongly restricted distribution areas.

The considerable richness and uniqueness of the Tajik's flora attracted many famous scientists conducting pioneer botanical research in the area in the nineteenth and twentieth centuries. They include A. Leman (1838–1841), A.P. Fedtschenko and O.A. Fedtschenko (1868–1871), A.E. Regel (1928), W.R. Rickmers (1913), N.I. Vavilov (1916), W.L. Komarov (1892–1894), V.I. Lipskii (1896–1905), B.A. Fedtschenko (1910–1925), O.E. Knorring-Neustrueva (1908–1915), M.G. Popov (1920–1940), O. Paulsen (1900–1905) and J. Bornmüller (1930–1940). The nineteenth century studies were not so intensive, but the first half of the twentieth century was very fruitful in terms of synthetic monographs, e.g. regarding plant taxonomy, phytogeography and vegetation research (Fedtschenko and Fedtschenko 1905, 1909–1916; Fedtschenko 1915, 1925; Lipskii 1902–1905, 1904; Ovchinnikov 1948, 1957, 1963, 1968, 1975, 1978, 1981; Stanyukovich 1949; Pisyaukova 1951; Grigorev 1944; Kaletkina 1971; Konnov 1974; Chukavina 1984; Kinzikaeva 1988; Kochkareva 1986; Rasulova 1991). The present decade is characterized by detailed classification works on the Pamir-Alai vegetation conducted by polish botanists (e.g. Nowak et al. 2014a, 2015a, 2016a) and by taxonomical studies focusing mainly on grasses (Nobis 2013; Nobis et al. 2013).

Because of its floristic richness, the Pamir-Alai as a core area of the mountains of Central Asia is recognized by Conservation International as a global biodiversity hotspot and one of the eleven most important focal points of future plant diversity studies and conservation (Mittermeier et al. 2006, 2011).

1.2 Geology

The Pamir-Alai mountain system (Fig. 1.1) was upheaved during the Cenozoic and is part of the long orogenic belt of Asia that involves the western outskirts of the Himalayan, Karakorum and Hindukush line (Lohr 2001). Sedimentary deposits of ca. 20–25 km thickness, have been shifted northwards by approximately 300 km. This massive crustal displacement surely originates from continental collision. Still, the Indian subcontinent presently causes the Pamir Plateau to slide 20 mm per year northwards over the Alay fault (Lohr 2001).

The geological profile of the Pamir-Alai is very complex. Between the Tajik and Tarim basins a lot of faults, sutures and subduction zones as well as sedimentation areas occur. As a result, the geological structure is made up of outcrops of rocks formed from the Precambrian to the present age, that are very diverse in composition and structure. Only few geological surveys have been published on Tajikistan (cf. Nedzvedskiy 1968; Lohr 2001). The northern part of the area (the Trans-Alay and Alay ranges) are mainly made up by Carboniferous igneous and sedimentary

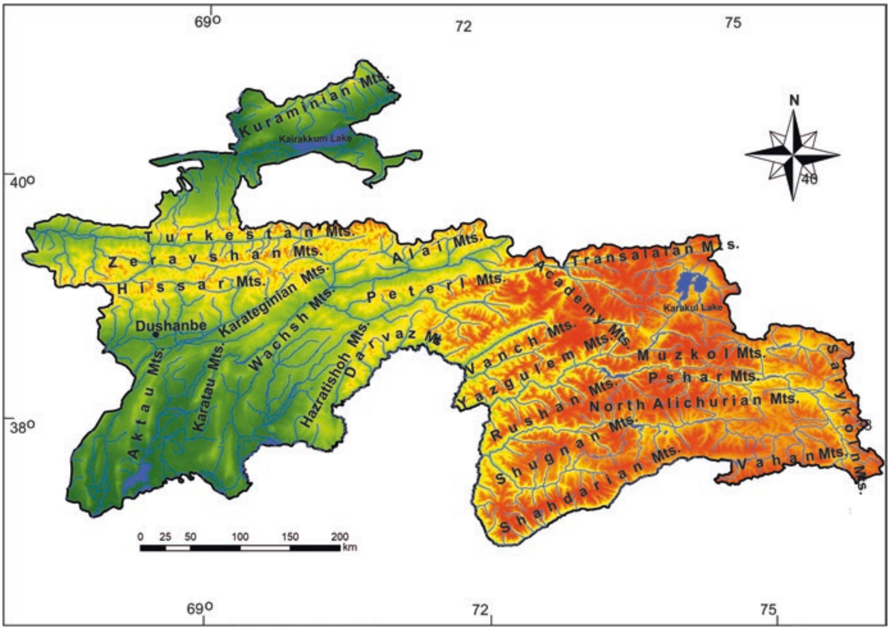

Fig. 1.1 Topographic map of the Pamir-Alai within Tajikistan showing the main ranges, cities and rivers

rocks of an oceanic origin. These are predominantly mafic rocks and tholeiitic basalts covered by limestone, siltstone and sandstone (Budanov and Pashkov 1988; Leven 1981). In the south-western parts of the system, in the Darvaz Range, a serpentine melange crops out accompanied by basalts, conglomerates and limestones (Pospelov 1987). The montane and alpine zones of the Hissar Mts. are largely composed of extrusive rocks, mainly granite, granitoid and syenite. The southern ranges of the Pamir-Alai system are composed of metamorphic Precambrian rocks and Mesozoic and Paleogene granites (Pashkov and Budanov 1990). The older rocks, e.g. late Carboniferous to early Permian sandstone, siltstone, clay and limestone, are overlaid by Triassic limestone, radiolarite and siltstone with intrusions of basaltic lava and tuff.

The soil cover of the Pamir-Alai mountains is considerably affected by the relief (30% of the territory has slope inclinations of 20 degrees or more) and the geological history of the particular sites. Also the precipitation and the related vegetation cover influence the soil type significantly. Soils are mostly constituted of debris materials, ranging from sand to coarse gravel and rocks in the mountains. The typical soils of the montane and subalpine belts of the Pamir-Alai are kastanozems, with a considerable content of organic matter; they allow the development of steppe communities. In sandy regions of the Ferghana Basin and the Tajik depression, as well as in the Eastern Pamir mountain semi-deserts, arenosols and even poor sandy dunes may develop. According to Leontieva (1968) within Tajikistan four main soil zones were distinguished: grey soils of uplands and montane areas (mainly brown calcareous), soils of moderately high mountains (generally brown acidophilous), soils of alpine mountain belts with steppes and glaciers (weakly developed leptosols) and underdeveloped soils of high mountain deserts.

1.3 Climate

According to the bioclimatic classification, which mainly takes into account precipitation and temperature values, the Pamir-Alai area belongs to the Mediterranean type of macrobioclimate (Rivas-Martínez et al. 2011). This type of climate is characterised by a summer drought lasting for at least two consecutive months in which precipitation is twice as low as the corresponding temperature values (Fig. 1.2). Also, other bioclimatic features (e.g. the average annual temperature) of the study area classify it within the Mediterranean macrobioclimate (Rivas-Martínez et al. 2011). Recent research on the SW and Central Asian bioclimate suggests that the Irano-Turanian bioclimatic zone differs from the Mediterranean one by a higher degree of continentality, a lower precipitation (particularly during winter), a longer dry season and lower winter temperature minima. The SW and Central Asian bioclimate also differs from the Mediterranean climate by having lower and varying precipitation values (with an apparent spring peak), a drier summer season and a lower continentality (Djamali et al. 2012). The area generally receives a high level of solar insolation (2090–3160 sunshine hours), has a low cloud cover, a considerable fluctuation in temperature over the year, and moderate humidity and precipitation values, with the exception of the spring period, when there is a considerable amount of rainfall (Latipova 1968). In the alpine belt of the high mountains, the climate is much harsher, with average temperatures in July between 9.7 and 13.5 °C. The annual precipitation ranges in the western Pamir-Alai from ca. 350 mm (Zeravshan Mts.) to ca. 600 mm in the Hissar Range (in some locations up to 2000 mm). In the western part of the country, the lower limit of the permanent snow lies at an altitude

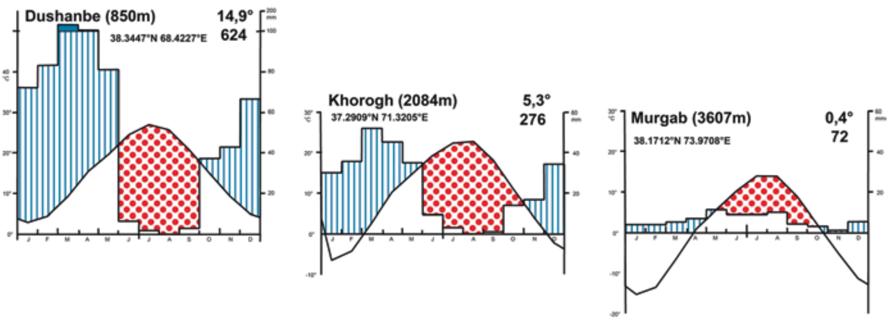

Fig. 1.2 Climatograms of the main bioclimatic provinces in Tajikistan: south-western Pamir-Alai (Dushanbe), western Pamir (Khorogh) and Eastern Pamir (Murghab)

of 3500–3600 m a.s.l.; in its eastern regions at 5800 m a.s.l. (Latipova 1968; Narzikulov and Stanyukovich 1968; Safarov 2003; Fig. 1.2).

1.4 Flora and Phytogeography

The geographical location of the Pamir-Alai Mountains in Tajikistan is favourable for a high floristic diversity. With one of the largest altitudinal amplitudes in the world, extreme precipitation and temperature fluctuations, a considerable glacier cover and a diverse geology, the Pamir-Alai favours a great number of plant species. Restricting the area of the Pamir-Alai to Tajikistan, the flora of this territory consists of approximately 4500–5000 vascular plant species (Ovchinnikov 1957; Rasulova 1991; Stanyukovich 1982) assigned to 116 families (Table 1.1). Richest in species are Asteraceae (660 species), Fabaceae (520), Poaceae (336), Brassicaceae (248), Lamiaceae (196) and Apiaceae (171; Rassulova 1991, supplemented). The most species-rich genera are *Astragalus* (Fabaceae; 276 species), *Cousinia* (Asteraceae; 121), *Allium* (Alliaceae; 100), *Taraxacum* (Asteraceae; 60) and *Oxytropis* (Fabaceae; 58; Rassulova 1991, supplemented). The number of vascular plant species of the region is still not final as regularly some new species from Tajikistan are being reported.

Currently, the native flora of Tajikistan consists of 4291 plant species (including 47 subspecies), but ongoing studies regularly report new finds. The species are not evenly distributed across geobotanical subregions (see Fig. 1.3); the richest areas are Zeravshanian B (1499 taxa), Hissar-Darvasian A (1440), South-Tajikistanian B (1407) and South-Tajikistanian A (1324; Fig. 1.4). As regards the number of species per unit area of the geobotanical subregions the richness pattern is somewhat different: the small regions of the Mogoltausian Mts., the eastern Turkestan range and the southern outskirts of the Darvaz range are richest, while the large subregions with harsh climatic conditions reveal species poverty, with the Eastern Pamir being poorest (Fig. 1.5).

Table 1.1 Taxonomic richness and uniqueness of the vascular flora of Tajikistan

Family	Number of taxa	Number of genera	Number of endemics	% of endemics
Asteraceae	660	118	250	38
Fabaceae	520	40	297	57
Poaceae	336	91	68	20
Brassicaceae	248	85	73	29
Lamiaceae	196	38	98	50
Apiaceae	171	66	77	45
Rosaceae	132	27	46	35
Caryophyllaceae	151	26	69	46
Chenopodiaceae	144	39	27	19
Boraginaceae	130	32	43	33

After Nowak and Nobis (2010), Nowak et al. (2011), supplemented

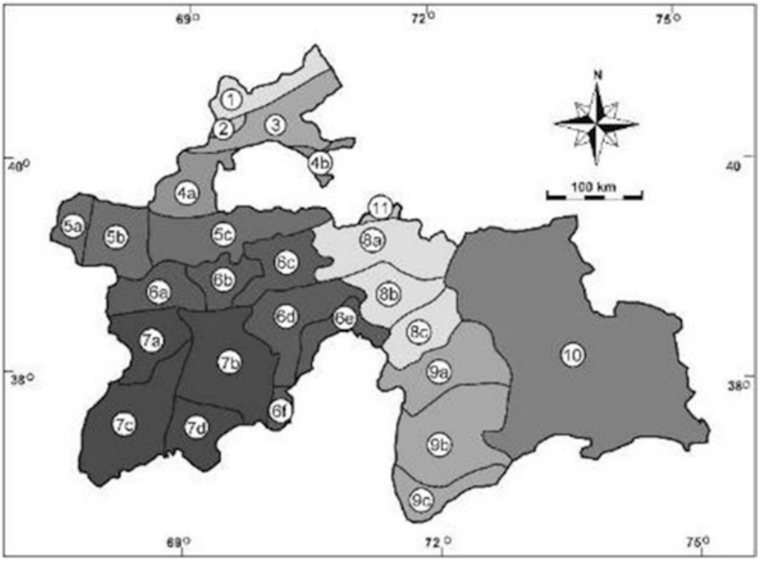

Fig. 1.3 Geobotanical division of Tajikistan: *1* – Kuraminian; *2* – Mogoltausian; *3* – Prisyrdarian; *4a* – Turkestanian A, *4b* – Turkestanian B; *5a* – Zeravshanian A, *5b* – Zeravshanian B, *5c* – Zeravshanian C; *6a* – Hissar-Darvasian A, *6b* – Hissar-Darvasian B, *6c* – Hissar-Darvasian C, *6d* – Hissar-Darvasian D, *6e* – Hissaro-Darvasian E, *6f* – Hissaro-Darvasian F; *7a* – South Tajikistanian A, *7b* – South Tajikistanian B, *7c* – South Tajikistanian C, *7d* – South Tajikistanian D; *8a* – East Tajikistanian A, *8b* – East Tajikistanian B, *8c* – East Tajikistanian C; *9a* – West Pamirian A, *9b* – West Pamirian B, *9c* – West Pamirian C; *10* – East Pamirian; *11* – Alayan

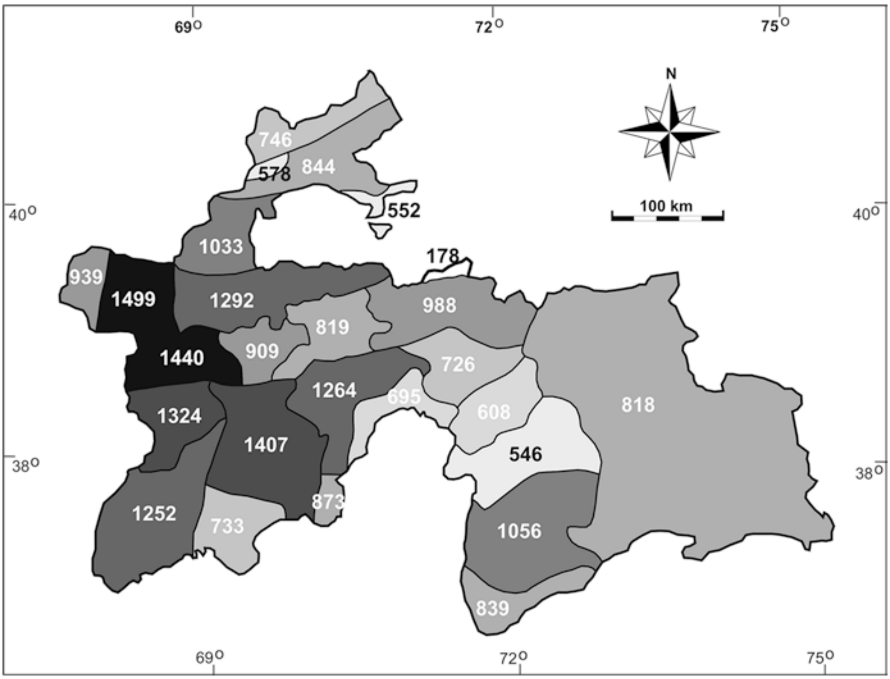

Fig. 1.4 Floristic richness of the phytogeographic subregions of Tajikistan – number of vascular plant species per subregion

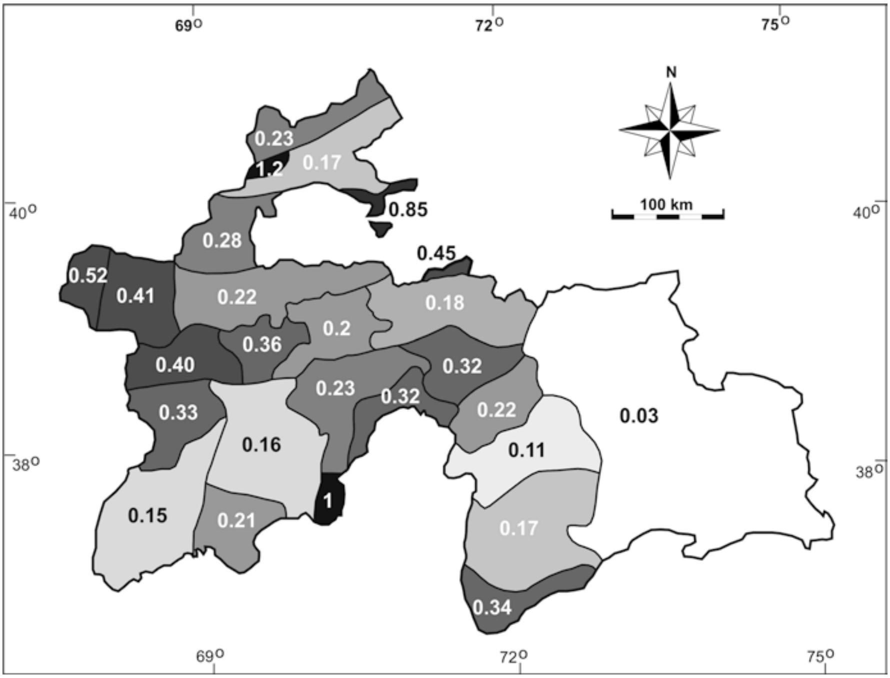

Fig. 1.5 Relative floristic richness of the phytogeographic subregions of Tajikistan

By far the great majority of the species are native to Tajikistan. But the long human presence in the Pamir-Alai caused some inevitable changes in the composition of the flora. In Tajikistan, 159 species are of alien origin (3.7% of the total flora), including 83 neophytes, 10 suspected archaeophytes and 65 ephemerophytes (van Kleunen et al. 2019; Fig. 1.6). The most widely distributed neophytes are, e.g., *Amaranthus retroflexus*, *Aster salignus*, *Bidens frondosa*, *Cannabis ruderalis*, *Cuscuta campestris*, *Datura stramonium*, *Galinsoga ciliata*, *Isatis tinctoria*, *Medicago romanica*, *Rubus praecox*, *Rudbeckia laciniata*, *Salix babylonica* and *Ulmus pumila*. The neophytes are mainly of American and Mediterranean origin and occur in agroecosystems (fields, fallow lands, intensively used pastures), on road verges, in city centres and other disturbed habitats. Only a few are of Australian (e.g. *Acalypha australis*) or African origin (e.g. *Sorghum sudanense*). Though the neophytes occur widespread across the country, they are considerably more frequent in the lowland and foothill zones where agricultural and ruderal habitats occupy the largest proportion of the territory (Fig. 1.6). The archaeophytes were probably introduced before 1500 AD and include e.g. *Adonis aestivalis*, *Agrostemma githago*, *Armoracia rusticana*, *Chrysanthemum segetum*, *Lathyrus sativus* and *Sorghum halepense*. They have a strong affinity to segetal plant communities, but also occupy ruderal sites.

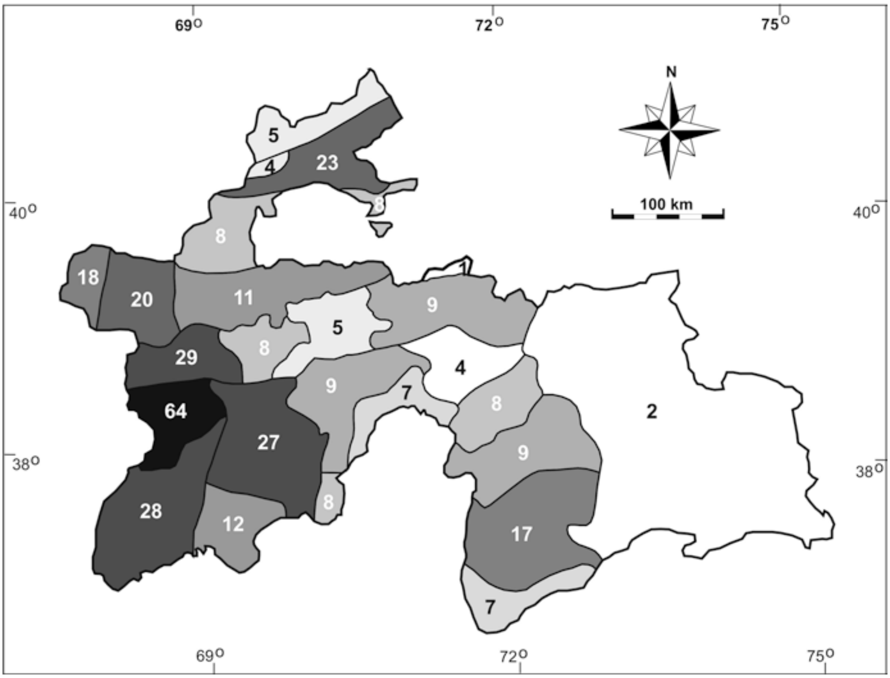

Fig. 1.6 Frequency of alien species established in Tajikistan across the geobotanical subregions

1.4.1 Phytogeographic Composition of the Pamir-Alai Flora

The flora of the Pamir-Alai is clearly dominated by Irano-Turanian species (Nowak et al. 2011). This group comprises ca. 65% of the total species number. Additionally, Central Asian species (a group of Irano-Turanian species with their main distribution area in continental and highly elevated Central Asia) account for a further 5.3%. Thus, with a contribution of more than 70%, the Irano-Turanian element strongly predominates the Tajik flora. Besides the 1487 endemic taxa in the flora of Tajikistan, there are plant species that are restricted to the area between the south-western part of Tajikistan and the Iranian Plateau, e.g. *Allium praemixtum*, *Amygdalus bucharica*, *Artemisia turanica*, *Eleocharis turcomanica*, *Euphorbia turcomanica*, *Iris sogdiana*, *Ladyginia bucharica*, *Microcephala turcomanica*, *Nonea turcomanica*, *Prangos bucharica* and *Veronica bucharica*.

Of the eastern Irano-Turanian species, that have their main distribution in the mountains, steppes and high plateaus of Central Asia, the most frequent ones in the Pamir-Alai are *Acantholimon diapensioides*, *Artemisia pamirica*, *A. skorniakowii*, *Astragalus badachschanicus*, *Carex pamirensis*, *Ephedra tibetica*, *Ermania pamirica*, *Leontopodium nanum*, *Ranunculus badachschanicus*, *Stipa glareosa* and *Youngia diversifolia*.

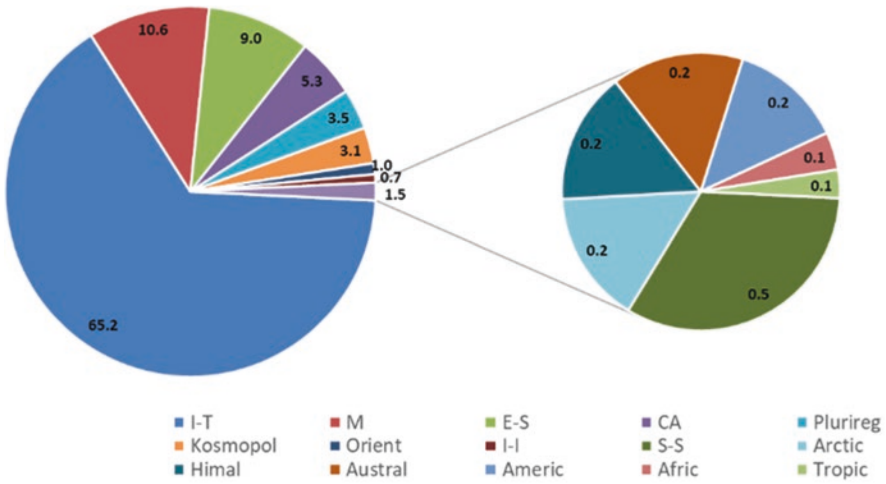

Fig. 1.7 Phytogeographical composition of the flora of Tajikistan. Explanations: *I-T* Irano-Turanian, *M* Mediterranean, *E-S* Euro-Siberian, *CA* Central Asian, *Plurireg* pluriregional, *Kosmopol* cosmopolitan, *Orient* Oriental, *I-I* Indo-Indochinese, *S-S* Saharo-Sindian, *Himal* Himalayan, *Austral* Australian, *Afric* African, *Tropic* Tropical

Species with their main distributional ranges in the Mediterranean area have a significant share in the flora of Tajikistan (10.6%; Fig. 1.7). This is related to the similarities in climatic conditions and the origin of the Irano-Turanian floras (see Kamelin 2017). These species occupy preferably the lower alpine, montane and submontane zones of the western sections of the Pamir-Alai ranges. Examples of typically Mediterranean taxa are *Althaea ludwigii*, *Avena meridionalis*, *Centaurium spicatum*, *Crambe orientalis*, *Cressa cretica*, *Cynoglossum creticum*, *Desmazeria compressa*, *Lallemantia iberica*, *Parietaria serbica*, *Phleum graecum*, *Rochelia retorta* and *Salix aegyptiaca*.

The next largest group in the Tajiks flora are species with their core distribution area in the temperate Euro-Siberian zone. They reach the southernmost limits of their range in the northern Pamir-Alai Mts, often inhabiting the relatively cold sub-alpine and alpine belts, *Asparagus officinalis*, *Carex diandra*, *Potentilla gelida*, *Rumex thyrsiflorus*, *Salix pentandra*, *S. triandra*, *Stipa capillata* and *Trifolium repens*.

Pluriregional species are not so numerous and comprise 3.5% of the total flora. They are distributed across the whole Old World, particularly in the Euro-Siberian, the Mediterranean, Irano-Turanian, Eastern Asian, Indo-Chinese, North African and sometimes Circumboreal provinces. Examples are *Alliaria petiolata*, *Catabrosa aquatica*, *Centaurium pulchellum*, *Conyzanthus graminifolius*, *Echium vulgare*, *Erodium cicutarium*, *Plantago major*, *Potamogeton friesii*, *Prunella vulgaris*, *Solanum nigrum* and *Vicia angustifolia*.

Also cosmopolitan species (with a worldwide distribution) are as yet not so numerous in the Pamir-Alai flora. They are often related to anthropogenic habitats like fields, road verges or ruderal places. Many of them are aquatic or littoral and have a high potential to spread intercontinentally. Examples are *Anagallis arvensis*, *Artemisia annua*, *Capsella bursa-pastoris*, *Cichorium intybus*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Eragrostis amurensis*, *Malva neglecta*, *Potamogeton crispus*, *Ricinus communis* and *Sigesbeckia orientalis*.

There are also East Asian (Oriental) species in the Pamir-Alai flora: *Eucommia ulmoides*, *Morus alba*, *Muhlenbergia huegelii*, *Polygonum alatum*, *P. orientale*, *Pyrus ussuriensis*, and reported from the rice fields *Sagittaria trifolia*. Also *Ulmus pumila*, that was probably planted, but then escaped and became established in many sites, is of East Asian origin.

Rice fields and other crop fields are the main habitat for species of Indo-Chinese origin. The most common are weedy taxa of paddy fields, such as *Ammania auriculata*, *A. multiflora*, *Dopatrium junceum*, *Eriocaulon sieboldianum*, *Fimbristylis quinquangularis*, *Schoenoplectus juncoides*, *Sphenoclea zeylanica* and *Strigosella brevipes*. Some species of that group, originating from Southeast Asia, presently occur in man-made habitats across the Tropics and Subtropics, e.g. *Ammania baccifera*, *Eleusine indica*, *Najas graminea* and *Ludwigia perennis*.

The south-western outskirts of the Pamir-Alai ranges, e.g. the Hazratishoh or Babatag Mts., provide suitable habitats for Saharo-Sindian taxa, that have their core distribution areas far to the west in southern Iraq, Egypt and other deserted lands of northern Africa. Examples are *Barkhausia kotschyana*, *Gossypium herbaceum*, *Heliotropium supinum*, *Nanorrhinum ramosissimum* and *Sorghum sudanense*.

Some other plant geographical groups are represented by small numbers of species. Arctic-alpine species include *Carex microglochin*, *Chamaerion latifolium*, *Lloydia serotina*, *Melandrium apetalum*, *Saxifraga hirculus*, *Sagina saginoides*, *Saxifraga oppositifolia*, *Torularia humilis* and *Trichophorum pumilum*. These plants grow at the highest elevations in chionophilous grasslands or fens of the Eastern Pamir and are sometimes restricted to mountain summits. Another group of species typical of the highest altitudes are Himalayan, e.g. *Aconitum rotundifolium*, *Alopecurus himalaicus*, *Bergenia stracheyi*, *Rumex nepalensis*, *Saxifraga stenophylla*, *Sedum ewersii*, *Sibbaldia tetrandra* and *Silene wallichiana*.

The Pamiro-Alayan flora has a transitional character as it is located between the vast, desertic areas towards the south-east and the highly elevated ranges and plateaus towards the west and north-west. Accordingly, the phytogeographic pattern of the area is complex. It is located on the borders of major phytogeographic units, in an area with an extraordinary complicated relief with valley bottoms at 500–800 m a.s.l. and summits higher than 7000 m a.s.l.

Also, the long tradition of livestock grazing in the area has importantly affected the floristic composition of the Pamir-Alai. Examples of prominent genera that evolved effective defence strategies against ungulates and are prominent in steppe vegetation are *Stipa* spp., *Bromus* spp., *Avena* spp., *Elymus* spp., *Elytrigia* spp., *Agropyron* spp. (Table 1.2). At higher elevations, particularly in the Eastern Pamir and the alpine belt in the western Pamir-Alai ranges, *Kobresia* sp. and *Poa* sp. dominate the summer pastures.

The mountainous landscape of Tajikistan is dominated by rocks, screes and landslides that occupy more than 30% of the territory. Those chasmophytic habitats are

Table 1.2 Relative contribution of species typical for various habitat types in the Pamir-Alai expressed as a percentage of the total flora

Habitat	Percentage of flora [%]	Habitat	Percentage of flora [%]
Steppes	30.8	Pastures	3.2
Screes	24.7	Broad-leaved forests	3.1
River-beds	15.6	Salt shrubs	2.8
Fields	14.7	Alpine semi-deserts	2.4
Rocks	11.5	Littoral vegetation	2.3
Xeric shrubs	11.1	Nival fens	2.0
Semi-savannas	10.9	Moraines	1.9
Scree shrubs	10.3	Alpine grasslands	1.8
Juniper stands	8.9	Fallow lands	1.5
Ruderal	7.5	Springs	1.5
Fens and mires	7.5	Orchards	1.2
Loose sand screes	6.3	Dunes	1.0
Salt marshes	6.1	Lakes	0.9
Forbs	6.1	Deserts	0.7
Alpine steppes	5.9	Alpine ponds	0.7
Riverside forests	5.7	Nival vegetation	0.6
Meadows	5.0	Alpine riverside forests	0.6
Semi-deserts	5.0	Nitrophilous rock footings	0.4
Maple dry forests	4.5	Rivers	0.3
Alpine meadows	4.1		

very important hotspots of the plant diversity and harbour together approximately 1500 species. This group comprises a huge number of endemics in *Asperula* sp., *Campanula* sp., *Dionysia* sp., *Parrya* sp., *Rosularia* sp., *Scutellaria* sp. and *Tanacetopsis* sp. on rock faces. Typical genera for screes are *Acanthophyllum*, *Chesneya*, *Cousinia*, *Melissitus*, *Nepeta*, *Onosma*, *Piptatherum* and *Scrophularia*. A kind of species trap are river-beds with different gravel, pebble and sandy debris. These habitats are supplied by plants originating from different neighbouring vegetation like screes, rocks, riverside forests and anthropogenic habitats. Among the most frequent examples are *Paramicrorhynchus procumbens*, *Sapponaria griffithiana*, *Trifolium fragiferum*, *Tripleurospermum disciforme* and *Verbascum songaricum*.

One of the most valuable and iconic plant groups related to the Pamir-Alai mountains are bulbiferous geophytes. Almost thirty species of tulips originate from the Pamir-Alai Mts., of which 90% are endemic. They make up the spring aspect of the meadow, steppe and forb vegetation, mainly in the colline, montane and subalpine zones. Even more diverse is the genus *Gagea*. Of the 33 species, 13 taxa have the status of national endemics. *Gagea exilis*, *G. gymnopoda*, *G. holochiton*, *G. incrustata* and *G. pseudoerubescens* have the narrowest distribution. Another ornamental group of geophyte species are foxtail lilies (*Eremurus* sp.). The Pamir-Alai is a centre of their distribution with 29 *Eremurus* taxa, half of them endemic to Tajikistan. There are several other decorative bulbous species with a blooming period in early spring, e.g. *Juno* (13 species), *Rhinopetalum* (4 species), *Fritillaria* (3 species), *Ungernia* (3 species) and *Korolkovia* (1 species). During summer, the showiest taxon is *Allium*. With more than 130 species, the genus *Allium* is an important genus, that has its centre of distribution in Middle Asia (Khassanov et al. 2007).

Moreover, the Pamir-Alai is the homeland of many cultivated species and plants of considerable economic value. Among the most important species are for example *Ficus carica, Fritillaria regelii, Hordeum bulbosum, Punica granatum* and *Tulipa subquinquefolia*. Commonly known wild fruits originating from Tajikistan are wild apple (*Malus sieversii*), walnut (*Juglans regia*), pistachio (*Pistacia* sp.), plum (*Prunus* sp.) and almond (*Amygdalus* sp.).

1.5 Endemism

1.5.1 Endemic Flora

The Pamir-Alai mountain range is located in the boundary zone of different phytogeographical subregions; moreover, it has an exceptionally variable orography, with its relief covering a great range of altitudinal belts, and it is affected by various climate types. Thus, the Pamir-Alai has extraordinary and specific environmental conditions that promote a high rate of endemism (Nowak et al. 2011). Out of 4291 vascular plants naturally occurring in Tajikistan, 1486 are endemics (sensu stricto and subendemics). That equals about 35% of the total flora of this country (Nowak and Nobis 2010; Nowak et al. 2011). These numbers are comparable with data from the literature for some other mountainous areas with a Mediterranean climate (Médail and Verlaque 1997) as well as other Middle Asian countries, e.g. Afghanistan (Breckle 2007). An additional explanation for the extraordinary richness of the Pamir-Alai is the fact that during the Quaternary glaciations, ice sheets did not destroy the valley vegetation with mesophilic forests, which have become a refuge for Tertiary floras (Safarov 2003).

The Tajik endemics belong to 60 families and 188 genera. The families richest in endemic taxa are Fabaceae, Asteraceae, Lamiaceae, Apiaceae, Liliaceae, Brassicaceae, Caryophyllaceae, Poaceae, Rosaceae and Boraginaceae (Table 1.3). In 17 families there is only a single endemic species. But, as regards the proportion of endemic taxa per family, the Betulaceae, Iridaceae, Santalaceae and Liliaceae lead.

There are no families endemic to the Pamir-Alai Mts, but there are 12 endemic and 14 subendemic genera in Tajikistan (Table 1.4). The subendemic genera include species that generally occur in the Pamir-Alai, but they occur also in western sections of the Tian-Shan ranges in Kyrgyzstan.

Astragalus is the richest genus in endemic species (173 species). It is the species-richest genus in the world having its centre of occurrence in Middle and South-West Asia. *Astragalus* species are important elements in mountainous and steppe habitats. The exceptional richness of *Astragalus* probably is related to niche diversification in the middle to late Pleistocene when the environmental conditions in the mountain regions of Southwest and Central Asia shifted repeatedly between dry and more humid conditions (Bagheri et al. 2017).

A lot of endemic species were also recorded in the genera *Cousinia* (82 species), *Allium* (44), *Oxytropis* (35), *Silene* (25) and *Scutellaria* (25). Most of endemics in

Table 1.3 Endemic species richness per family

Family	Number of endemics	%	Family	Number of endemics	%
Fabaceae	297	53.4	Convolvulaceae	4	20.0
Asteraceae	250	36.0	Gentianaceae	4	12.5
Lamiaceae	98	49.2	Rhamnaceae	4	50.0
Apiaceae	77	43.8	Ephedraceae	3	26.3
Liliaceae	74	62.7	Onagraceae	3	16.7
Brassicaceae	73	29.1	Orobanchaceae	3	11.5
Caryophyllaceae	69	45.1	Papaveraceae	3	20.0
Poaceae	68	22.4	Rutaceae	3	18.8
Rosaceae	46	30.5	Zygophyllaceae	2	16.7
Boraginaceae	43	35.4	Capparaceae	2	33.3
Amarylidaceae	43	51.7	Caprifoliaceae	2	11.8
Ranunculaceae	43	38.4	Linaceae	2	28.6
Scrophulariaceae	32	30.2	Santalaceae	2	66.7
Chenopodiaceae	27	20.5	Aceraceae	1	20.0
Limoniaceae	27	58.7	Araceae	1	33.3
Rubiaceae	24	41.4	Asclepiadaceae	1	33.3
Polygonaceae	21	21.4	Balsaminaceae	1	33.3
Iridaceae	17	82.1	Cornaceae	1	33.3
Betulaceae	15	83.3	Cucurbitaceae	1	6.7
Primulaceae	13	32.5	Cupressaceae	1	10.0
Euphorbiaceae	12	30.8	Dryopteridaceae	1	20.0
Campanulaceae	11	55.0	Eleagnaceae	1	25.0
Fumariaceae	10	58.8	Geraniaceae	1	5.0
Crassulaceae	9	31.0	Ophioglossaceae	1	50.0
Valerianaceae	8	28.6	Polypodiaceae	1	11.1
Violaceae	7	46.7	Potamogetonaceae	1	6.7
Berberidaceae	5	38.5	Saxifragaceae	1	5.6
Cuscutaceae	5	20.0	Solanaceae	1	4.5
Cyperaceae	5	5.7	Thymelaceae	1	25.0
Salicaceae	5	14.7	Vitaceae	1	25.0

After Nowak et al. (2011), supplemented

Tajikistan are herbaceous perennials (1184 species). Much less numerous are bushes and shrubs (121 species), annuals (93), biennials (52) and trees (35).

1.5.2 Distribution Patterns of Endemic Plant Taxa in the Pamir-Alai

The number of endemics varies between the geobotanical regions in the Pamir-Alai. The richest, in terms of number of endemic species, are two areas in north-western Tajikistan, i.e. Hissar-Darvasian A and Zeravshanian B (Fig. 1.8).

Table 1.4 Endemic and sub-endemic genera in the flora of Tajikistan

Endemic genera	Sub-endemic genera
Catenularia (Brassicaceae; 1 sp.)	*Cephalorhizum* (Limoniaceae; 3 sp.)
Cryptocodon (Campanulaceae; 1 sp.)	*Cephalopodum* (Apiaceae; 1 sp.)
Iskandera (Brassicaceae; 1 sp.)	*Chaetolimon* (Limoniaceae; 2 sp.)
Kafirnigania (Apiaceae; 1 sp.)	*Cylindrocarpa* (Campanulaceae; 1 sp.)
Kuhitangia (Caryophyllaceae; 1 sp.)	*Dichasianthus* (Brassicaceae; 1 sp.)
Lagoseriopsis (Asteraceae; 1 sp.)	*Dimorphosciadium* (Apiaceae; 1 sp.)
Lipskya (Apiaceae; 1 sp.)	*Fergania* (Apiaceae; 1 sp.)
Malacurus (Poaceae; 1 sp.)	*Korolkovia* (Liliaceae; 1 sp.)
Neopaulia (Apiaceae; 2 sp.)	*Mediasia* (Apiaceae; 1 sp.)
Spirostegia (Scrophulariaceae; 1 sp.)	*Modestia* (Asteraceae; 2 sp.)
Tetracmidion (Brassicaceae; 2 sp.)	*Mogoltavia* (Apiaceae; 1 sp.)
Thlaspidium (Fabaceae; 1 sp.)	*Restella* (Thymelaceae; 1 sp.)
	Sergia (Campanulaceae; 1 sp.)
	Sympegma (Chenopodiaceae; 1 sp.)

After Nowak et al. (2011), supplemented

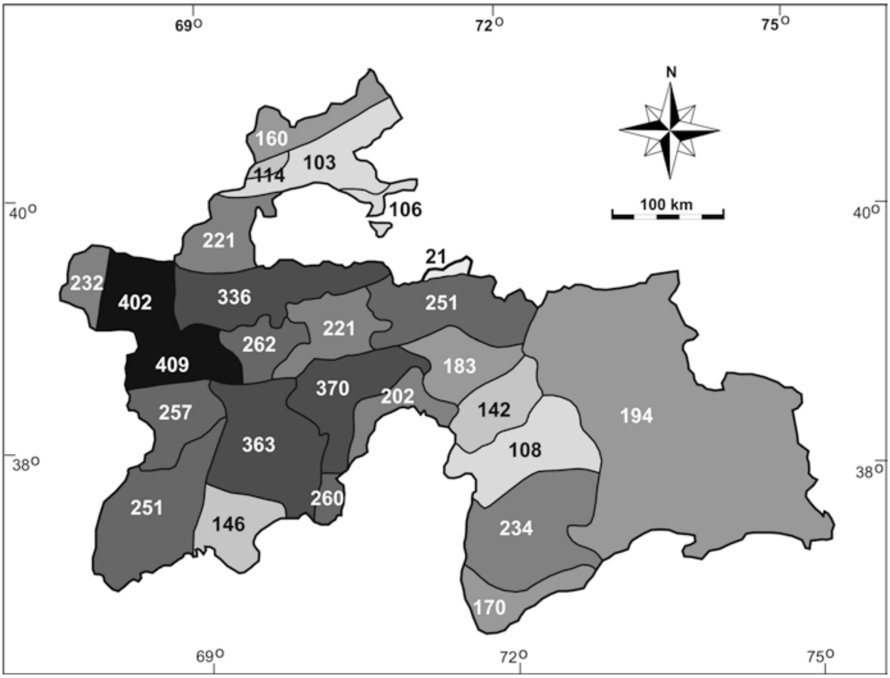

Fig. 1.8 Distribution of endemic vascular taxa in geobotanical regions

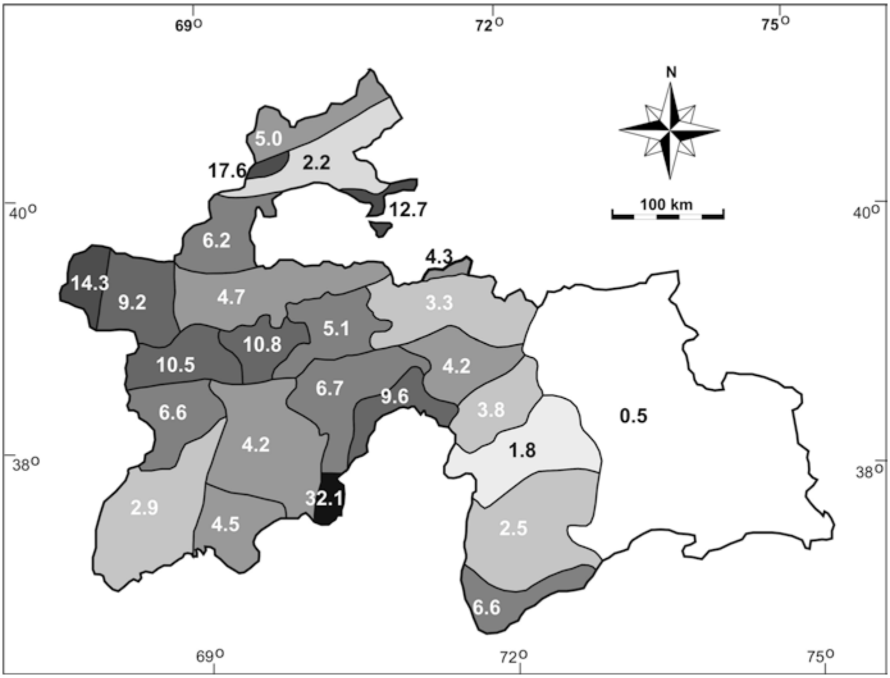

Fig. 1.9 Endemic species per 100 km^2 in each of the geobotanical regions of Tajikistan

In the east, the highest number of endemics was recorded in the East Tajikistanian A and West Pamirian B regions. As the surface areas of the geobotanical regions differ in size, the richness of endemics was weighted per area of 100 km^2. In this way endemism is richest in Hissar-Darvasian F, Mogoltausian, Zeravshanian A, Turkestanian B, Hissar-Darvasian A and B (Fig. 1.9). As regards number of exclusive endemics, south Tajikistanian C leads, where 54 species strictly are endemic to this area.

Most endemics in Tajikistan are narrowly distributed and inhabit only one or two geobotanical regions. Only a few occur in more than 5–6 regions and the widest distribution have *Heracleum lehmannianum*, *Korshinskya olgae* and *Linaria popovii* which occur in more than 20 subregions. Endemics with a somewhat wider distribution are *Amygdalus bucharica*, *Artemisia porrecta*, *Astragalus xanthomeloides*, *Aulacospermum roseum* (18 regions) and *Dianthus tetralepis* (19 regions).

1.5.3 Habitat Preferences and Altitudinal Amplitude

Endemic species are generally tied to one particular type of biotope or plant community. The highest number of endemic species have been reported from rock and screes, but also from steppes and semi-savannas, alpine Juniper forests, thermophilous shrublands (Shiblyak), alpine meadows, on rocks and in dwarf bushes (Table 1.5). For the 430 endemics occurring exclusively in one vegetation type, very important biotopes are scree habitats, rock habitats, alpine swards as well as steppe-grasslands.

Table 1.5 Distribution of Tajik endemic species across habitats

Habitat type	Number of endemics	Number of exclusive endemics
Scree vegetation	822	169
Steppes	371	13
Alpine Juniper forests	355	15
Thermophilous shrublands (Shiblyak)	273	19
Alpine meadows and swards	271	35
Rock vegetation	231	64
Xerophilous dwarf shrublands (Rosaria)	208	7
River-bed vegetation	184	22
Semi-savannas	173	30
Broad-leaved forests (chernolesya)	147	7
Meadows and pastures	147	13
Riverside forests (bielolesya)	85	15
Tall forb vegetation	65	1
Fen-spring vegetation	55	7
Salt marsh vegetation	53	8
Agrocoenoses	32	2
Deserts and semi-deserts	28	1
Gallery forests	9	1
Littoral vegetation	9	1
Aquatic vegetation	1	1

After Nowak et al. (2011), supplemented

Habitats that harbour the highest number of endemic taxa are characterised by a patchy and sparse stand structure and a low productivity. This confirms that endemics are taxa with a low ecological flexibility (Kruckeberg and Rabinowitz 1985) and competitiveness (Wilson and Keddy 1986), preferring areas of loose and patchy communities, early stages of succession or extreme habitats.

In the Pamir-Alai, with increasing elevation, the number of native species first increases up to the subalpine belt, and then decreases. This hump-shaped relationship is also apparent if the percentage of endemic species is concerned, though slightly skewed to the higher elevations in the alpine belt (Figs. 1.10 and 1.11). If not weighted by area, this relation is typically hump-shaped with the largest group of endemics associated with altitudes of about 1800, 2000 and 2500 m a.s.l. More than 500 endemic species occur in the zone between 1500 and 2000 m a.s.l. and more than 400 between 1000 and 3000 m a.s.l. (Figs. 1.10 and 1.11).

Considering the number of endemic species in altitudinal belts, the peak of endemism in the Pamir-Alai occurs in subalpine belts, and then, in accordance with Rapoports rule, is decreasing as species occupy wider ranges at higher altitudes. The same pattern holds true for the total flora. This pattern is generally similar in other mountainous regions of the world with the highest number of stenochorous taxa at the medium elevations of the subalpine zone (Agakhanjanz and Breckle 2002; Van der Werff and Consiglio 2004; Essl et al. 2009).

A decrease in the number and proportion of endemics is seen in the nival zone, where more severe microclimates prevail and the history of the vegetation is considerably shorter (Agakhanjanz and Breckle 1995).

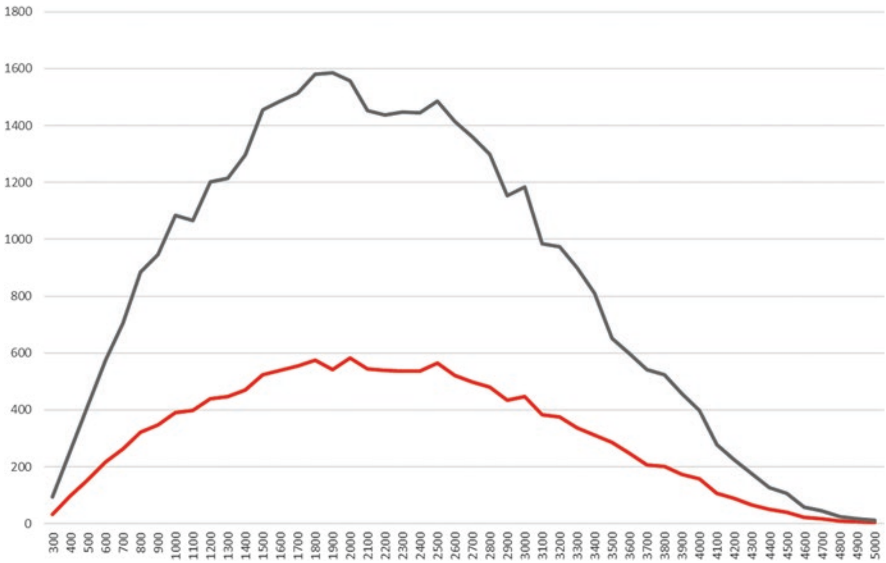

Fig. 1.10 Altitudinal distribution of endemism as the number of endemics occurring in belts of 100 m altitude (red line) shown against the background of the total plant richness (black line)

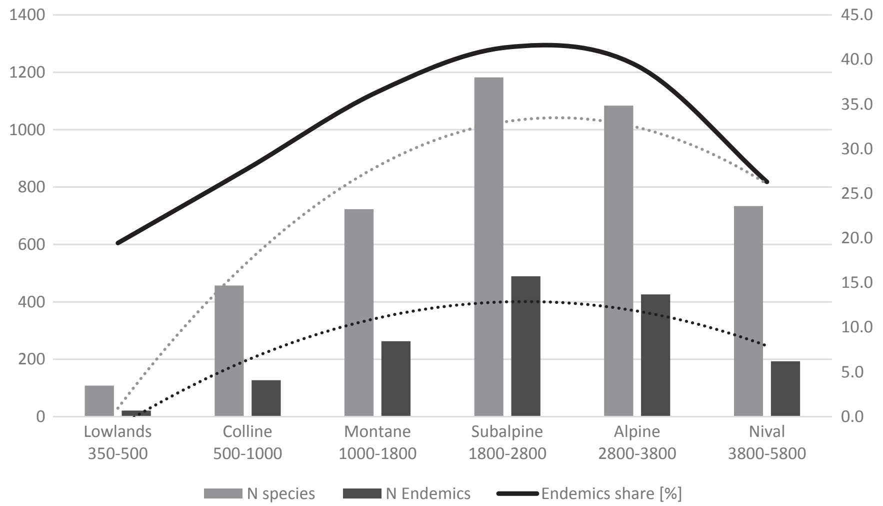

Fig. 1.11 The endemism in the Pamir-Alai in relation to altitudinal zonation and total flora richness

1.6 Major Vegetation Types

The Pamir-Alai vegetation is fairly diverse and can be generally divided into 21 major types: mesophilous deciduous forests (so called Chernolesya), riverside forests (Belolesya), river-bed forests (Thugay), xerothermophilous shrubs (Shiblyak), subalpine coniferous forests (Artschevniki), river-bed shrubs, meadows and pastures, segetal vegetation, alpine meadows and swards, steppes and so-called semi-savannas, xerothermophilous swards, xerothermophilous dwarf shrubs, desert and semi-desert vegetation, fen-spring vegetation (sazy), tall-herb vegetation, rush vegetation, aquatic vegetation, scree and sliding rock vegetation, rock vegetation (petriphyton) and salt-marsh vegetation. Within these vegetation types approximately 200 plant associations were distinguished (see below), but there is still a vast under-investigated area in the mountains as well as in lowlands. Particularly huge areas of pasturelands, rock vegetation of the nival and alpine zones and Eastern Pamir semi-deserts and cryophilous steppes need to be explored in detail. Additionally, forbs, mesic xerothermophilous shrubs and dry xeric shrubs should be assigned to a priority list of research.

1.6.1 Segetal Vegetation (400–3800 m a.s.l.)

Tajikistan is a highly agrarian country, with its rural population at more than 70%. But because of the mountainous character, only 28% of the Tajik territory (14.3 million hectares) is agricultural land (Statistical Committee 2006). The segetal vegetation is relatively rich in species. In the colline belt up to 60 species per plot were recorded. Four segetal associations, differing in altitude and soil fertility, were distinguished in crops: *Eremodauco lehmannii-Lagonychietum farcti* (the most thermophilous), *Vicietum hyrcanico-peregrinae* (colline to montane belts), *Asperugo-Cannabietum ruderalis* (colline to alpine belts) and *Lathyretum sativi* (subalpine and alpine belts; Nowak et al. 2013b). Additionally, seven associations in root crops vegetation were distinguished: *Convolvulo arvensis-Cyperetum rotundi*, *Daturo stramonii-Hibiscetum trioni*, *Setario pumilae-Sorghetum halepensi*, *Galinsogo-Setarietum*, *Equiseto arvensi-Xanthietum italici*, *Portulacetum oleracei* and *Brassico campestris-Lamietum amplexicauli* (Nowak and Nowak 2013).

1.6.2 Forests

1.6.2.1 Mesophilous Deciduous Forests (Chernolesya; 700–2400 m a.s.l.)

These plant communities are typical broad-leaved, riparian or gallery woods inhabiting mainly the lowland, colline, montane and subalpine zone on northern slopes of several mountains and in river valleys. Habitat differences resulted in the distinction of ten associations in the Pamir-Alai ranges assigned to four alliances reflecting gradients of fertility, salinity and altitude. The first group comprises typical mesophilous stands assigned to *Acero turkestanici-Juglandion regiae.* They comprise deciduous, mesophilous woods on moist habitats, on fertile and deep brown soils. The most common is a zonal forest dominated by *Juglans regia* growing on northern slopes mainly in the Hissar-Darvas ranges, preferably on northern slopes in the colline and montane belts (Nowak et al. 2017). The most frequent and diagnostic taxa for this community are *Brachypodium sylvaticum*, *Cardamine impatiens*, *Carex otrubae*, *Impatiens parviflora*, *Juglans regia*, *Millium effusum* and *Poa nemoralis*. The walnut forests are important refuges for relict plants as the valley bottoms of Hissar and Darvaz ranges were not glaciated during the Ice Age (Epple 2001). Almost within the same altitudinal belt, at slightly higher elevations and on shallower, lithomorphic soils with considerable gravel or rock ingredients, stands with *Acer turkestanicum* are developed. They are reported from nearly the whole area of Tajikistan, except Eastern Pamir. On the northern slopes of the Darvaz range, on deep, humid, slightly alkaline soils, stands dominated by white poplar were described as *Violo suavis-Populetum albae*. This association harbours a lot of tall-herb species that built their own communities in forest gaps or clearings or grow in the undergrowth of tree stands. The association occupying the most fertile and deep soils is a forest of *Platanus orientalis* (Fig. 1.12a). This association, defined as *Swido darvasicae-Platanetum orientalis* occupies the warmest, mostly wet and fertile stands in the river valleys of southern Tajikistan. It grows along rivers and around slope brooks and springs. The dense canopy is clearly dominated by *Platanus orientalis* and is supplemented by *Populus alba*. The lower tree layer consists of *Diospyros lotus* or *Celtis sinensis*. In the shrub layer the most abundant are *Rosa canina*, *Swida darvasica* and *Cotoneaster multiflorus*. The undergrowth consists of *Brachypodium sylvaticum*, *Epipactis royleana, Impatiens parviflora*, *Melissa officinalis, Poa nemoralis*, *Stellaria neglecta* and *Viola suavis* (Zapryagaeva 1976; Nowak et al. 2017).

1.6.2.2 River Carr Forests of Montane Stream Valleys (Belolesya; 1000–2200 m a.s.l.)

This woody vegetation is distinguished as the alliance *Populion afghanicae* and has its elevational centre of occurrence in the montane and subalpine belts (Nowak et al. 2017). The phytocoenoses occupy valley bottoms of streams and mountainous brooks, sometimes also on gentle slopes with water outflows. Typical species for this vegetation are *Equisetum arvense, Populus afghanica*, *Armeniaca vulgaris, Euonymus koopmanii* and *Berberis integerrima.* In the whole Pamir-Alai between 1000 and 2000 m a.s.l. in the Hissar, Darvaz, Karateginian, Vakhsh and Peter the First, stands of *Fraxinus sogdiana* occur (Zapryagaeva 1976; Chukavina 1984). The *Fraxinetum sogdianae* grows in deeply eroded, narrow river valleys close to water courses. The stands prefer fertile, relatively deep and alkaline soils with a considerable content of organic matter. Similar to Sogdian ash carr are the stands dominated by *Betula turkestanica* and *B. tianschanica*. They occupy higher locations at the bottoms of the V-shaped mountain river valleys and streams in the montane and subalpine zones with a fairly well developed soil profile.

1.6.2.3 River Carr Forests of Alpine Stream Valleys (1500–3500 m a.s.l.)

This group includes poplar and birch forest communities developing at higher montane and subalpine elevations along rivers with a high discharge or in the estuary areas of mountainous lakes in the Pamir-Alai Mountains. The highest locations are

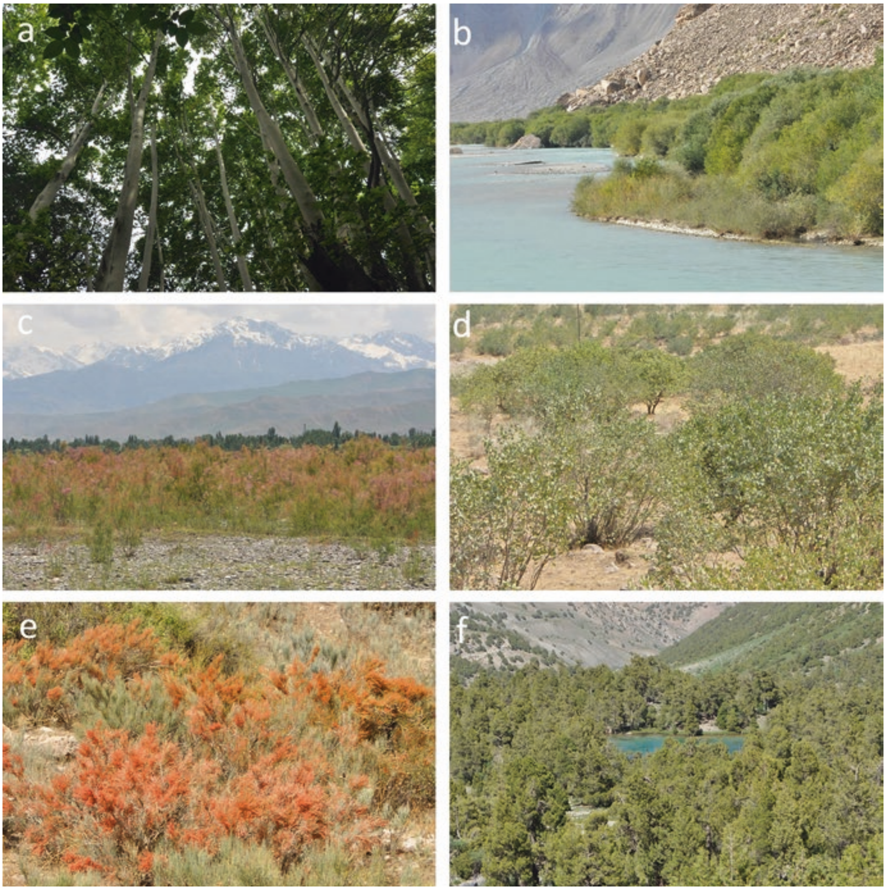

Fig. 1.12 (**a**) Stand of *Platanus orientalis* in the Panj River Valley near Qualaykhum, 2100 m a.s.l.; (**b**) *Populetum pamiricae* along the Ghunt River north of Khorogh, 3200 m a.s.l.; (**c**) Community with *Tamarix ramosissima* in the Zeravshan Valley near Sudzhina, 800 m a.s.l.; (**d**) Thermophilous shrubs with a domination of *Cercis griffithii* in the Panj River Valley near Qualaykhum, 1600 m a.s.l.; (**e**) Xeric alpine shrubs with a dominance of *Ephedra equisetina* in the surroundings of the Iskander-kul lake, 2250 m a.s.l.; (**f**) Woods of *Juniperus seravschanica* in the Seven Lake Valley, 2600 m a.s.l. (photos A. Nowak)

occupied by stands of *Populus pamirica* (3000–3500 m a.s.l., Fig. 1.12b). This is a typical subalpine forest community occurring close to the timber line. It develops on river valley floors close to the river-beds, sometimes almost on pure gravel deposits. It is found in the Eastern Pamir, and rarely in the western Pamir and the Darvaz Mts. (Zapryagaeva 1976; Nowak et al. 2015a). A wider altitudinal amplitude has the shrubby *Salicetum turanico-pycnostachyae*, that occurs closer to the river's gravel beds. The soil profile is poorly developed at such sites and the vegetation is under strong grazing pressure by ungulates. Stand looks like dense, hardly accessible thickets made up of small trees or large shrubs. The shrub layer consists mainly of *Lonicera stenantha*, *Hippophae rhamnoides* and *Rosa huntica.* From the shoreline of the Iskander-kul Lake in the Zeravshan Mts., an endemic stand of *Populus* *talassica* was reported. The *Populetum talassicae* prefers a subalpine landscape and has a number of typically alpine species that often occur in the association (e.g. *Trifolium seravschanicum*, *Pedicularis olgae* and *Gentianopsis vvedensky*; Nowak and Nobis 2013).

1.6.2.4 Gallery Forests in Lowland River Valleys (350–750 m a.s.l.)

In south-western Tajikistan, in the confluence area of the big Pamir-Alai rivers like Panj or Wakhsh, an association dominated by *Populus pruinosa* occurs on wet, marshy and frequently inundated areas with increased salinity. This association was formerly reported as a part of the so-called "thugay" vegetation – river-bed shrubs and forests. But in a recent revision of the Tajik forest communities (Nowak et al. 2017), this type of thermophilous woods were shown to have close relations to gallery associations of Mediterranean origin. It occupies low river terraces with a shallow ground water table and numerous ox-bow lakes, ditches and marshlands.

1.6.3 River-Bed Vegetation (1000–4000 m a.s.l.)

River-bed vegetation is sometimes included in "thugay" (Stanyukovich 1982). But there is considerable difference between gallery forests at ca. 500 m a.s.l. and alpine river thickests at 3500 m a.s.l. They are completely distinct in terms of species composition, climate and habitat conditions. The lowland thermophilous woods are related to the mediterranean *Nerio-Tamaricetea*, and the dense thickets of *Hipophae rhamnoides* on gravel deposits of alpine streams should be excluded from this class (Eberhardt 2004). A whole range of river-bed shrub phytocoenoses is found between 1000 and 4000 m a.s.l. and they mainly contain *Equisetum ramosissimum*, *Hippophae rhamnoides*, *Lonicera korolkovii*, *L. pamirica*, *Salix blakii*, *S. capusii* and *S. wilhelmsiana*. It is worth mentioning that the river-bed vegetation, due to its openness, contains a huge number of species from surrounding habitats, mainly screes and fields (almost 700 species). Another type of common river-bed vegetation is *Myricaria squamosa* and *M. bracteata* scrub. There are also thermophilous river-bed shrubs of *Tamarix* spp. in the south-western Pamir-Alai (*T. ramosissima*, *T. hohenackeri*, *T. arceuthoides*) as well as a *Halimodendron halodendron* community at salty places or *Vitex agnus-castus* (Fig. 1.12c). They occupy the warmest sites at altitudes of 300–1000 m a.s.l. and constitute a successional shrub stage towards the gallery forest of *Populus pruinosa*.

1.6.4 Thermophilous Orchards and Shrublands (Shiblyak; 500–1750 m a.s.l.)

This type of vegetation is known from the colline and montane belts of the Hissaro-Darvasian, Kuraminian, Zeravshanian, Karatau, Aktau and Babatag ranges, as well as the southern slopes of the western Pamir. It is related to thermophilous mantle and shiblyak communities of the eastern and south-eastern Mediterranean areas of Europe, probably also to the thermophilous scrub or small tree communities on deep soils reported from Crimea, such as e.g. *Asparago verticillati-Crataegion tauricae* or *Elytrigio nodosae-Rhuion coriariae* (Mucina et al. 2016). In the south-western Pamir-Alai, this formation is an important landscape dominant at lower and mid-elevations. Shiblyak is dominated by small trees or shrubs like *Amygdalus bucharica, Cercis griffithii*, *Ficus carica*, *Punica granatum* and *Zizyphus jujuba* (Fig. 1.12d). In the undergrowth the most frequent taxa are *Aegilops triuncialis*, *Artemisia baldschuanica*, *Bromus oxyodon*, *B. tectorum, Elytrygia trichophora*, *Hordeum bulbosum*, and many other steppe, semi-savanna and forb plants. They can thrive in shiblyak vegetation because the density of its canopy is very sparse, ranging between 10% and 20% on average.

1.6.5 Xerophilous Shrubs of the Montane and Subalpine Belts (1500–2500 m a.s.l.)

In Russian bibliography this type of vegetation is called Rosaria, as *Rosa* species often dominate the communities. In our opinion, this kind of deciduous shrub vegetation, that shows the typical seasonality of the temperate zones, should be divided into two groups: a mesophilous formation, found on well developed brown or grey soils, and dry formation, typical for arid places with a scarce and under-developed soil profile.

The first group in the Pamir-Alai is distinguished by the abundance of *Rosa divina*, *R. beggeriana*, *R. ecae, R. fedtschenkoana* and *R. maracandica*. They are accompanied by other shrub or forb taxa, such as *Amygdalus spinosissima*, *Berberis integerrima*, *Cotoneaster hissaricus*, *Restella alberti*, *Polygonum coriaria* or *Ferula jaeschkeana*. They occupy slopes of different exposition at altitudes of 1500–2500 m a.s.l. on moderately humid substrates with fairly well developed and fertile soils.

In arid habitats of dry screes or rock ledges and shelves, communities of *Ephedra* spp. form a dominant type of vegetation (Fig. 1.12e). Most prominent are phytocoenoses of *Ephedra intermedia*, *E. glauca* or *E. equisetina,* accompanied by shrubs of *Atraphaxis pyrifolia*, *A. seravshanica* and *Sageretia laetevirens*.

1.6.6 Juniper Woods and Scrub (Archevniki; 1000–3500 m a.s.l.)

These orotemperate, fairly dry and evergreen stands constitute the dominant zonal vegetation formation in the subalpine belt at altitudes of 1000–3500 m a.s.l. They built sparse and small tree stands in alpine landscapes. In the Pamir-Alai, this type of vegetation can be divided into three altitudinal vicariants. The thermophilous Juniper woods are dominated mainly by *Juniperus seravschanica* – an endemic species of Middle Asia (Fig. 1.12f). The densest and most extensive stands of seravshanian juniper were recorded in the Turkestan, Zeravshan, Hissar and Darvaz ranges in the western Pamir-Alai at the elevation of approximately 1000–2600 m a.s.l. The scrub and herbaceous layers vary greatly in canopy density and habitat conditions. Among the most frequent plants contributing to this vegetation are steppe and forb species like *Elytrigia trichophora*, *Festuca sulcata*, *Prangos pabularia*, *Dianthus baldschuanicus* and *Polygonum paronychioides*.

Cryophytic Juniper woods consist of *Juniperus turkestanica* and *J. semiglobosa* and occupy higher altitudes. In the western Pamir-Alai, they form a distinct zonal belt on northern slopes at elevations of approximately 2200–3000 m a.s.l. A series of subassociations of Turkestan Juniper woods were defined depending on differences in the composition of the undergrowth (Zapryagaeva 1976).

1.6.7 Deserts and Semi-deserts (350–5000 m a.s.l.)

1.6.7.1 Herbaceous and Dwarf-Shrub Vegetation

The desert zone in the Pamir-Alai includes the lowlands of the Ferghana Basin, the south-western parts of Tajikistan and the cold, dry plateaus of the Eastern Pamir (Stanyukovich 1982). Geographically these areas are significantly distinct and this is reflected in the vegetation types and their species composition. The common feature in the desertic vegetation of the Pamir-Alai is the seasonality with a blooming period shifted to late summer or autumn, and with a short geophytic aspect in early spring.

In the hottest areas in the Prisyrdarian and South-Tajikistanian geobotanical subregions (350–1000 m a.s.l.), the semi-desert vegetation consists of herbs and dwarf-shrubs that are drought resistant, such as *Aristida karelini*, *Calligonum elegans*, *C. calcareum*, *Convolvulus divaricatus*, *Corispermum lehmannianum*, *Dorema sabulosum*, *Kochia iranica*, *Psilurus aristatus*, *Salsola aperta*, *Schismus arabicus* and *Zygophyllum bucharicum*. This vegetation is found on gentle slopes or river terraces on sandy or gravely alkaline substrates.

The highest locations in East Pamir harbour a range of cryoxerophytic semi-deserts. They occupy gentle slopes, sand deposits and occasionally screes at 3500 to

5000 m a.s.l. The most abundant and frequent taxa in that type of sparse vegetation are *Ajania tibetica*, *Corispermum gelidum*, *Crepis flexuosa*, *Ermania crassifolia*, *Krascheninnikovia ceratoides*, *Lepidium cordatum*, *Salsola oreophila*, *Zygophyllum obliquum*, *Braya brachycarpa*, *Elymus alaicus* and *E. dasystachys* (Fig. 1.13a; Stanyukovich 1982).

1.6.7.2 *Semi-desert Shrub Vegetation* (Dzhangal; 350–750 m a.s.l.)

The so-called dzhangal is a semi-desert scrub vegetation with sclerophytic plants on sandy, desertic lands. It is dominated by species with reduced or rudimentary leaves with a bi-seasonal activity in spring and autumn. The most important species that form these communities in south-western Tajikistan and in the Ferghana Basin are *Haloxylon aphyllum*, *H. persicum*, *Calligonum griseum*, *C. prszewalskii*., *C. junceum*, *Carex physodes*, *Anisantha tectorum*, *Salsola dendroides* and *S. orientalis* (Sidorenko 1953). In some plots also *Lycium ruthenicum*, *Calligonum elatum*, *Carex physodes* and *Ammodendron karelinii* attain a high cover.

1.6.8 Salt Marshes and Shrubs (350–4500 m a.s.l.)

The salt marsh vegetation in the Pamir-Alai occupy small, distinctive areas on lake shores at high altitudes in Eastern Pamir and also in the colline and foothill belts along rivers, springs and artificial leakages. In south-western Tajikistan, the salt vegetation inhabits shallow ponds and wetlands on clayey and silty soils in valley bottoms or in the apron zone of screes and rock faces. It develops as an ephemeral spring community, but often has also a second blooming time in autumn, similar to desert plant communities. This type of vegetation is closely related to east Mediterranean salt marshes and can be included in the order *Fankenietalia pulverulentae*. The most prominent diagnostic taxa that occur in southern Tajikistan and in the Ferghana Valley are *Aeluropus littoralis*, *Bunium salsum*, *Centaurium meyeri*, *Cressa cretica*, *Crypsis schoenoides*, *Frankenia bucharica*, *Gamanthus gamocarpus*, *Halimocnemis mollissima*, *Henrardia glabriglumis*, *Psylliostachys leptostachya*, *P. myosuroides*, *Suaeda* spp., *Tetracmidion bucharicum* and *Tetradiclis tenella* (Fig. 1.13b).

As succession proceeds, these herbaceous communities develop into a shrubby vegetation with *Anabasis eriopoda*, *A. subaphylla*, *Haloxylon persicum*, *Kalidium caspicum*, *Salsola orientalis* and *Seidlitzia rosmarinus*. They occur in the same geobotanical regions, in a mosaic of semi-desertic communities, and they fringe on patches of river-bed shrublands dominated by *Tamarix* spp. Significantly distinct are the salt-marshes of high altitudes in the Eastern Pamir (3500–4500 m a.s.l.), which inhabit the shorelines of alpine ponds and lakes as well as along rivers. They

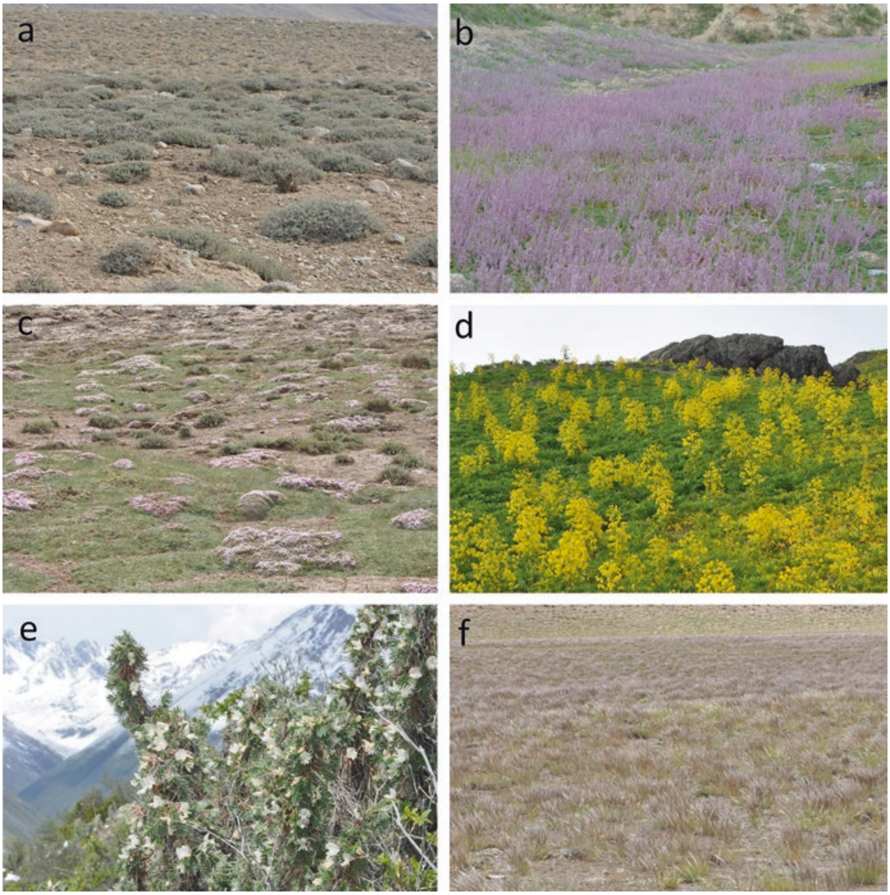

Fig. 1.13 (**a**) High altitude semi-deserts dominated by *Krasheninnikovia ceratoides* and *Oxytropis chiliophylla* in Eastern Pamir near Murghab, 4300 m a.s.l.; (**b**) Lowland salt marsh with dominance of *Psylliostachys leptostachya* near Vase in SW Tajikistan, 500 m a.s.l.; (**c**) Cushion community of *Gypsophila herniarioides* in the subnival zone of the Eastern Pamir near Murghab, 4500 m a.s.l.; (**d**) Tall-forb vegetation with *Ferula gigantea* at the Shagir-dasht Pass in the Darvaz range, 3000 m a.s.l.; (**e**) Community of *Caragana jubata* in the Alay Range, 3800 m a.s.l.; (**f**) Community of *Serratula procumbens-Stipa caucasica* subsp. *desertorum* in the Eastern Pamir-Alai near Murghab, 3800 m a.s.l. (photos A. Nowak)

are poor in species and have a sparse vegetation cover. They consist of species adapted to extremely harsh conditions, such as *Artemisia macrocephala*, *Limbarda salsoloides*, *Puccinellia gigantea*, *P. humilis*, *P. pamirica*, *Suaeda olufsenii* and *Taraxacum pamiricum*.

1.6.9 Cushion-Tragacanthic Scrub (Kolyuchepodushechniki; 1500–4500 m a.s.l.)

This type of vegetation shows strong differences along altitudinal gradient. In the arid lands of the Eastern Pamir, the cushion-tragacanthic communities inhabit gentle slopes with under-developed soils; often they appear almost as barelands, and screes or crests. They may be compared to the *Carici-Genistetalia lobelii* from the Mediterranean mountains of Sardinia or Corsica (Mucina et al. 2016). The communities comprise sclerophylous dwarf shrubs and scleromorphic, perennial cushion plants, often full of thorns. They are resistant to strong winds, and to long winters with extremely low temperatures (down to minus 50 °C) and they thrive in the short growing period, mostly on alkaline bedrocks with a very low organic matter content. They occur up to 4500 m a.s.l. (communities with *Acantholimon korolkovii*, *A. pamiricum*, *Arenaria griffithii*, *Gypsophila herniarioides*, Fig. 1.13c). At lower elevations (ca. 1600–2800 m a.s.l.) the *Onobrychis cornuta* community finds a suitable habitat.

1.6.10 Tall Forbs (With So-Called Semi-Savannas; 500–3500 m a.s.l.)

This type of thermophilous tall-herb, fringe vegetation seems to be one of the most important and distinct vegetation types in Middle Asia and the Pamir-Alai. Although plant communities dominated by Apiacae species on mesic habitats are known from other parts of the Irano-Turanian province (Klein 1988) or even from south-eastern Europe (compare the *Dictamno albi-Ferulagion galbaniferae* from the Illyrian and Balkan regions), in the montane and subalpine belts of the Pamir-Alai the so-called "umbelipherniki" (plants of Apiaceae family) have their optimum occurrence and their centre of diversity (Korovin 1961, 1962; Stanyukovich 1982). In the montane belt the fleshy and species-rich tall-forbs with *Astragalus retamocarpus*, *Asyneuma baldshuanicum*, *Cousinia leptacantha*, *Eremurus candidus*, *Inula macrophylla*, *Stubendorffia aptera* and *S. orientalis* are widely distributed. They inhabit the slopes in the shiblyak and deciduous forest zone, mainly in the Hissar, Darvaz and Peter the First ranges.

Higher belts, between 1500 and 2500 m a.s.l., offer suitable conditions for communities with *Dictamnus tadshikorum*, *Eremurus comosus*, *E. robustus*, *Exohorda albertii*, *Ferula gigantea*, *Fritillaria olgae*, *Geranium regelii*, *Ligularia thompsonii*, *Megacarpea gigantea*, *Paeonia intermedia*, *Prangos pabularia*, *Rumex paulsenianus*, *Senecio olgae* and *Vicia tenuifolia* (Fig. 1.13d). In the Eastern Pamir and the highest elevations of the western Pamir-Alai ranges, mostly above 3000 m a.s.l., the cryophytic tall-forb vegetation is dominated by *Delphinium oreophilum*, *Geranium himalayense* and *Rumex nepalensis*. There are also azonal tall herbs along river streams in the Pamir-Alai. A showy example is the community with *Heracleum lehmannianum* that creates a conspicuous vegetation in the Hissar and Zeravshan ranges. A very distinct tall forb community are the stands of *Caragana jubata* (Fig. 1.13e).

1.6.11 Steppe Vegetation (600–4200 m a.s.l.)

Steppes form one of the most prominent biomes in Middle Asia thanks to continental climate influences with warm and dry summers and severe, cold winters that cannot support tree growth. Environmental conditions and long pastoral traditions bring about the vast grassland areas in the montane, subalpine and even alpine belts (Werger and van Staalduinen 2012; Nowak et al. 2018). Steppes of the Pamir-Alai can be divided into three types depending on soil profile and altitude.

1.6.11.1 High-Altitude Arid Steppes

These sparse grassy phytocoenoses occupy the highest and driest sites, at altitudes ranging from approximately 1700 to 4200 m a.s.l. The vegetation has a patchy physiognomy, forming loose stands dominated by graminoid taxa. They occur on vast, flat areas in cryophilous semi-deserts. From the Eastern Pamir-Alai the community of *Serratula procumbens-Stipa caucasica* subsp. *desertorum* (Fig. 1.13f) (on flat sandy and gravely substrates with *Eremopyrum distans* and *Serratula procumbens*) and the association *Astragalo chomutowii-Stipetum subsessiliflorae* (with *Acantholimon hedini*, *Androsace dasyphylla, Ephedra regeliana*, *Euphorbia tranzschelii*,) were described (Nowak et al. 2018). Both steppe types are species-poor (mean species number ca. 9) with a herb cover of around 40%, occuring on sites with a low organic matter content. In the western Pamir-Alai, mainly in the Zeravshan and Turkestan Ranges, the association *Stipetum drobovii* occurs (Nowak et al. 2016a). It grows at altitudes ranging from 1350 to 2250 m a.s.l., forming a low, sparse vegetation in close contact with alpine scree phytocoenoses and semi-deserts.

1.6.11.2 Dry, Thermophilous Steppes of the Montane and Subalpine Belts

This type of steppe vegetation develops on slopes in the colline and montane belts at altitudes between 600 and 1800 m a.s.l. They can have a typical graminoid physiognomy but can also consist mainly of dwarf shrubs. On southern slops in the

Ferghana Valley and northern gentle slopes of the Alay range the association *Convolvuletum spiniferi* occurs. This patchy, dwarf-shrub steppe includes also herbaceous plants like *Artemisia persica*, *Eremurus sogdianus*, *Scabiosa olivieri, Sanguisorba alpina* or *Stipa drobovii* var. *iskanderkulica.* It grows on gravelly substrates and has a total herb cover of about 30–70%. A typical graminoid steppe is the community of *Elytrigia trichophora-Linum corymbulosum.* It is a thermophilous vegetation, growing on gentle slopes at altitudes of 1600–2500 m a.s.l., preferring substrates with a well-developed organic soil layer and a low amount of gravel debris. At the same altitudes the association *Stipo magnificae-Otostegietum olgae* grows on hillsides and escarpments with considerable inclinations of ca. 20°–50°. Its substrate is loamy, deep, often of a reddish colour and with a low content of organic matter. Next to the diagnostic species, the most prominent contributors to this association are *Aegilops triuncialis*, *Elytrigia ferganensis*, *Haplophyllum ferganensis*, *Stipa arabica, S. hohenackerana* and *Ziziphora tenuior.* In the western Pamir-Alai, on northern and western slopes of the Hissar, Zeravshan and Turkestan Mts., the association *Stipetum lipskyi* occurs at elevations of ca. 1100–1650 m a.s.l. (Fig. 1.14a). It consists of *Artemisia persica*, *Boissierra squarrosa*, *Stipa hohenackeriana, Ziziphora tenuior* and develops on slopes with a considerable amount of organic soil content with very insignificant amount of gravel debris (Nowak et al. 2016a).

1.6.11.3 Mountain Steppes of Semi-Arid Areas

This type of steppe vegetation occupies the high, flat and wide valleys of the northern Pamir-Alai. In the alpine belt of the Alay Valley the association of *Littledaleo alaicae-Stipetum trichoidis* inhabits vast terraces of rivers. It has the typical physiognomy of a 'grassy' steppe with a total plant cover of 60–90% and it is composed mainly of *Artemisia sieversiana*, *Elymus dasystachys*, *Festuca sulcata*, *Stipa arabica*, *S. glareosa*, *S. krylovii* and *Stipa turkestanica* subsp. *trichoides*. Another steppe association able to withstand the harsh environmental condition is *Helictotricho fedtschenkoi-Stipetum kirghisori.* It occupies a bit more fertile sites and reaches a higher total plant cover. Stands of the association were reported from the slightly lower altitudes of 2300 to 3500 m a.s.l. in the eastern Alay Mts.

In the western Pamir-Alai, in the high montane and alpine belts of the Zeravshan Mts., phytocoenoses of *Stipetum jagnobicae* occupy gentle slopes with firm, stable surfaces at altitudes between 1730 and 2450 m a.s.l. More similar to tall-herb vegetation is the *Stipetum margellanicae* known from the Peter I, Turkestan and Ak-tau Mts. This steppe develops on the gentle slopes of wide valleys, on stable ground fully covered with an organic soil layer. Additionally, in the Pamir-Alai a lot of steppes dominated by *Artemisia* species occur. They are considerably different, depending on altitude, geographical range and organic matter content in the soil profile.

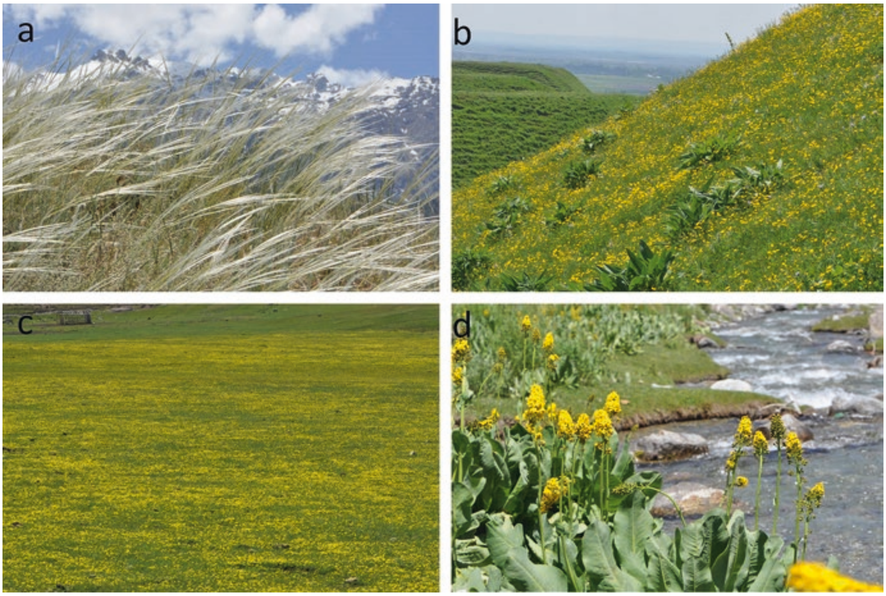

Fig. 1.14 (**a**) *Stipetum lipskyi* on northern slopes of the Zeravshan Mts. near Urmetan, 1750 m a.s.l.; (**b**) Meadow with *Koelpinia macrantha* (yellow) and *Arctium leiospermum* near Panj, 500 m a.s.l.; (**c**) Pastures with *Ranunculus alaicus* in the alpine belt of Hissar Mts., 3500 m a.s.l.; (**d**) Alpine pasture with *Ligularia heterophylla* in the Pastrud River Valley in the Zeravshan Mts., 2600 m a.s.l. (photos A. Nowak)

1.6.12 Meadows and Pastures (500–4500 m a.s.l.)

Mesophilous grassland is one of the most prominent vegetation formations in the Pamir-Alai. It stretches along all ranges and forms distinct phytocoenoses from the colline to the alpine belt. Although the Tajik grasslands need considerable more studies to uncover their diversity and distribution paterns, preliminary studies on meadow-like phytocoenoses in south-western Tajikistan reveal their extreme richness in species composition (up. to 80 species per 100 square meter plot). This is due to the large species pool available and to their extensive management with a mixed pastoral and mowing scheme.

1.6.12.1 Colline and Lowland Meadows

These are found mainly in the south-western Pamir-Alai and on the northern slopes of the Ferghana Valley. These meadows have high total plant cover values of plants (ca. 80–90%) and have their blooming peak fairly early in spring (April; Fig. 1.14b). After blooming the plant cover of these meadows almost disappears during very hot summer, and in autumn they are grazed and are almost bare ground in some years. The most prominent species are *Aegilops squarrosa*, *Astragalus retamocarpus*, *Carex pachystylis*, *Hordeum bulbosum*, *Lolium persicum*, *Plantago lanceolata*, *Trachynia distachya* and *Vulpia persica*. In patches *Medicago* species dominate (e.g. *Medicago denticulata*, *M. rigidula*). The species richness of these communities are truely high with approximately 40 species per 25 m^2 on average. On the northern and north-eastern slopes of the Ferghana Valley, the species richness of the meadows is somewhat bit smaller. The dominants are largely the same, but the species composition reveals the dryer and more continental conditions with frequent species such as *Carex turkestanica*, *Festuca valesiaca*, *Galium pamiroalaicum*, *Hyalea pulchella* and *Potentilla asiae-mediae*.

1.6.12.2 Alpine Swards and Pastures

The alpine belt is located between approximately 2500 and 4000 m a.s.l. depending on whether or not the mountain range offers suitable conditions for grasslands development: the amount of precipitation should be sufficiently high (ca. 600–1000 mm per year). These alpine meadows and pastures occur as a complex patchy mosaic and depend on microhabitat patterns and temporary changes in management conducted by local people (Afanasjev 1956; Sidorenko 1971). These alpine swards consist of *Achillea bucharica*, *Aconitum rotundifolium*, *Aster serpentimontanus*, *Gagea jaeschkei*, *Lagotis ikonnikovii*, *Linum olgae*, *Lloydia serotina*, *Pedicularis sarawschanica*, *Polygala hybrida*, *Pulsatilla campanella* and *Tulipa turkestanica*. A very distinct community is formed by *Potentilla flabellata* and *P. gellida* in the Hissar-Darvaz Mts. They are sporadically mown or grazed. As far as life spectrum and species composition is considered, some of these stands of vegetation resemble the species-rich alpine swards of southern Europe (*Onobrychido-Seslerietalia*) that are rarely mown and extensively grazed. The typical alpine pastures in the Pamir-Alai are dominated by *Adonis turkestanicus*, *Alopecurus mucronatus*, *Cirsium acaule*, *Crepis multicaulis*, *Geum kokanicum*, *Inula rhizocephala*, *Lagotis korolkowii*, *Poa alpina*, *Polygonum viviparum* and several *Taraxacum* species. They are grazed in summer with different intensity depending on the distance from human settlements and altitude (Fig. 1.14c, d). At high altitudes there are also species-poor mats dominated by *Kobresia capillifolia*, *K. humilis*, *K. persica*, *K. stenocarpa* and *K. pamiroalaica*. These are wind-exposed, short grasslands on base-rich substrates in the subnival and alpine belts of the Pamir-Alai (Fig. 1.15a).

1.6.13 Fens and Springs (So-Called Sazy*)*

1.6.13.1 Fen Communities

The mountainous fens of the Pamir-Alai are moderately rich in species and dominated by sedges with an addition of grasses and dicots, e.g. of the genera *Dactylorhiza*, *Euphrasia*, *Gentiana* and *Primula*. The most widespread fen association in the Pamir-Alai is *Eleocharido quinqueflorae-Primuletum iljinski* found in

Fig. 1.15 (**a**) Overgrazed pastures in the northern Alay foothills, 1100 m a.s.l.; (**b**) *Eleocharido quinqueflorae-Primuletum iljinski* in the Funn Mts. in Saytog, 2100 m a.s.l.; (**c**) *Angelicetum ternatae* on screes in the Gorna Matcha Valley in the Zeravshan Mts., 1850 m a.s.l.; (**d**) *Feruletum koso-polianskyi* on screes near Ayni in the Zeravshan Mts, 2000 m a.s.l. (photos A. Nowak)

the alpine and subalpine belts of the western Pamir-Alai. The association has been recorded at altitudes from 1500 to 3100 m a.s.l. Diagnostic species are *Eleocharis quinqueflora*, *Parnassia laxmanii* and *Primula iljinskii.* Mosses are not particularly abundant, having the average cover of ca. 15% (Nowak et al. 2016b; Fig. 1.15b).

From much higher elevations in the alpine belt (ca. 2500 to 3200 m a.s.l.) species-poor stands of *Allium fedtschenkoanum* have been reported. The most frequent and abundant species in this community are *Blysmus compressus*, *Carex orbicularis* subsp. *hissaro-darvazica*, *Philonotis calcarea*, *Pedicularis peduncularis*, *Phleum alpinum* and *Trifolium repens*. In the Eastern Pamir-Alai, the widest distributed fen type is a low mat of *Carex pseudophoetida*. It occupies the highest elevations between 2500 and 4200 m a.s.l. and consists of several frequent taxa as *Cerastium pusillum*, *Juncus brachytepalus*, *Leontopodium ochroleucum*, *Potentilla pamiro-alaica* and *P. gelida.* The only shrubby fen association known from the Pamir-Alai, comparable to stands with *Salix lapponum* in Europe, is *Salicetum schugnanicae*. It occurs in the alpine belt of the western Pamir-Alai at altitudes between 2500 and 2900 m a.s.l. The Eastern Pamir also supports a range of communities that still need final classification. Examples are communities with *Allium atrosanguineum*, *Trollium dshungaricum*, *Primula turkestanica*, *Pedicularis rhinanthoides*, *Viola altaica*, *Carex pseudofoetida, Saxifraga hirculus* and *Oxytropis lehmanniana.*

Additionally, shrubby fens of *Salix coesia* and *Aconitum leucostomum-Caragana aurantiaca* are found.

1.6.13.2 Spring Communities

In the montane to alpine belts, the most frequent spring community that occurs in close contact with tall-forbs is *Codonopsideto clematidi-Cortusetum turkestanicae.* It was reported from relatively high elevations, at altitudes ranging from 2100 to 3400 m. It forms a flush vegetation on side water outflows, sometime even on stony scree with cobbles. Much richer in mosses is the association *Epilobio tianschanici-Bryetum schleicheri.* It occurs exclusively in crenic, alkaline waters, sometimes going down along the upper section of brooks and rivulets. The stands are characterised by a moderate herb cover of about 60% (Nowak et al. 2016b). *Clementsietum semenovii* is a kind of verge community along brooks and small rivulets in the alpine belt. Other spring vegetation in the Eastern Pamir-Alai that was identified recently includes communities of *Oxygraphis glacialis* and *Trollius liliacinus-Schultzia crinita.*

1.6.13.3 Littoral and Aquatic Vegetation (350–4300 m a.s.l.)

The Pamir-Alai mountains are not particularly suitable for littoral communities. But since human activity created a lot of artificial dams, reservoirs and paddy fields in the valley bottoms, littoral vegetation, although being not broadly distributed, is fairly rich in terms of the number of plant communities. During the last decade about 30 plant communities were identified in the foothills of the Pamir-Alai, mainly within the Syr-Daria, Panj, Zeravshan, Kafirnigan, Khanaka and Surkhandaria river valleys. Seven littoral plant associations were reported as unique for this area: *Caricetum songaricae*, *Eleocharitetum argyrolepis*, *Eleocharitetum mitracarpae*, *Juncetum brachytepali*, *Mento asiaticae-Nasturtietum microphyllae*, *Rorippo palustris-Alismatetum graminei*, *Scirpetum hippolytii* and *Sparganietum stoloniferi* (Nowak et al. 2014a).

There is no comprehensive study on the aquatic communities of the Pamir-Alai. From the alpine belt of the Zeravshan Mts. the association *Stuckenia amblyphylla* was described (Nowak and Nobis 2012). In the Eastern Pamir a community of *Stuckenia pamirica* was found in the Alichur River. Additionally, from rice paddy fields a number of aquatic communities were reported. Within the class *Potametea* the *Najadetum graminae*, *Parvo-Potamo-Zannichellietum pedicellatae*, *Potametum denso-nodosi, Potametum pusilli*, *Zannichellietum palustris* and were reported. From the class *Lemnetea* the small buoyant vegetation *Ceratophyllo-Azolletum filiculoidis* and *Lemno minoris-Salvinion natantis* were reported (Nowak et al. 2013a).

1.6.14 Chasmophytic Vegetation (500–5600 m a.s.l.)

With more than 1500 plant species, the vegetation of rocks and screes is the most diverse in the Pamir-Alai. It is also the most unique type of vegetation as approximately 70% of all endemic species are characteristic for this type of vegetation (Nowak et al. 2011). The richness observed depends on habitat heterogeneity, which is especially affected by the long altitudinal gradient, variable geological substrates and the extremely diversified orography and relief of the Pamir-Alai Mts.

1.6.14.1 Vegetation of Solid Rock Faces and Fissures

The phytocoenoses found in tiny fissures and on solid rock faces at higher altitudes (alpine and subnival) may inhabit different geological substrates, such as limestone, dolomite, marble, granite, syenite, schist and gneiss. Sometimes such vegetation also develops on rock ledges, in coarse cracks and on friable rocks. Recently, several associations have been distinguished in this habitat, e.g. *Achoriphragmetum darvazici*, *Achoriphragmetum turkestanici*, *Andrachnetum fedtschenkoi*, *Asperuletum fedtschenkoi*, *Campanuletum lehmannianae*, *Eritrichietum turkestanici*, *Minuartio litwinowii-Phaeonychietum surculosi*, *Sergietum regelii*, *Scutellarietum megalodontae*, *Scutellarietum orbicularis*, *Scutellarietum rubromaculatae*, *Silenetum kuhistanicae*, *Silenetum samarcandensis* and *Violetum majchurensis* (Nowak et al. 2014b). In the montane and colline belts another eight associations have been distinguished: *Campanuletum albertii*, *Dionysietum involucratae*, *Nanorrhinetum ramosissimi*, *Scutellarietum baldshuanicae*, *Scutellarietum hissaricae*, *Scutellarietum schugnanicae*, *Scutellarietum zaprjagaevii*, *Tylospermetum lignosae* and the community of *Scutellaria adenostegia* (Nowak et al. 2014b).

1.6.14.2 Vegetation of Rock Clefts and Ledges

Rock ledges and coarse crevices contain a considerable amount of soil sediment, and thus have a relatively high nutrient content. This respect this habitat differs from the more arid, tiny fissures and solid faces. Recently, seven chasmophytic associations have been distinguished from this habitat: *Achoriphragmetum pinnatifidi*, *Asperulo albiflorae-Stipetum zeravshanicae*, *Inuletum glaucae*, *Paraquilegietum anemonoidis*, *Pentanemetum albertoregeliae*, *Rhinactinidietum popovii* and *Saussureaetum ovatae* (Nowak et al. 2014c). On rock ledges and shelves also support a chasmophytic dwarf-shrub vegetation with associations such as *Pentaphylloidetum parvifoliae, Rhamnetum coriaceae, Spiraeetum baldschuanicae* (western Pamir-Alai) and *Pentaphylloidetum dryadanthoidis* (Eastern Pamir-Alai). Additionally, a community of *Ephedra glauca* and a community of *Rhamnus minuta* were found.

1.6.14.3 Fern-Dominated Communities

On permanently moist and often shaded overhangings and in deep crevices, fern vegetation dominates, e.g. the recently described *Cryptogrammetum stelleri* and *Soncho transcaspici-Adiantetum capilli-veneris*. In the western Pamir-Alai, on dry rocks, other fern-dominated communities occur: *Asplenio-Ceterachetum officinarum*, *Asplenio-Cystopteridetum fragilis*, *Asplenietum trichomano-rutae-murariae* and *Cheilanthetum persicae* (Nowak et al. 2015b).

1.6.14.4 Scree Vegetation

From the high montane and alpine belts in the Pamir-Alai, on gravel, pebble, cobble and rocky block slides and screes, nine associations were described: *Anaphallidetum zeravschanicae*, *Angelicetum ternatae* (Fig. 1.15c), *Feruletum foetidissimae*, *Feruletum koso-polianskyi* (Fig. 1.15d), *Feruletum sumbuli*, *Feruletum tenuisectae*, *Hedysaretum flavescentis*, *Stellarietum turkestanicae* and *Tetrataenietum olgae,* and one subassociation: *Feruletum foetidissimae mediasietosum macrophyllae* (Nowak et al. 2016c).

Fairly rich and diverse is also the scree vegetation of the montane and colline zones in the Pamir-Alai. Eight phytocoenoses have been described: *Cousinietum corymbosae*, *Eremostachyetum tadschikistanicae*, *Cousinietum refractae*, *Caccinietum dubiae*, *Eremuretum sogdiani*, *Feruletum kuhistanicae*, *Zygophylletum atriplicoidis* and *Corydalidetum kashgaricae.*

The classification of chasmophytic vegetation needs further studies. Only from the Eastern-Pamir a number of communities were described, e.g. *Allium tianschanicum*, *Corydalis gortschakovii*, *Eritrichium subjaquemonti*, *Inula schmalhausenii*, *Parrya schugnanica*, *Potentilla malacotricha* and *Waldheimia glabra*.

1.6.15 Subnival Vegetation (So-Called Pustosha and Cryophyton; 4000–5600 m a.s.l.)

The cryophytic vegetation of the harshest environments occurs up to the highest summits of the Eastern Pamir, up to 5600 m a.s.l. (e.g. *Braya oxycarpa* or *Nepeta longibracteata*). In that zone the environmental conditions are largely unsuitable for vegetation. But more than 250 vascular plants species were recorded from the subnival belt that ranges between 4400 and 5600 m a.s.l. These harsh habitats are determined not only by extremely wide temperature amplitudes, with the lowest minimum temperature in winter down to −60 °C, but also by the very strong solar radiation, and particularly the UV-B radiation, that can be more than 100% more intensive than in the valleys (see Leuschner and Ellenberg 2017). Moreover, the daily frosts even in summer, the thin soils and low nutrient availability, combined with solifluction, long and deep snow covers, slabs, avalanches, and strong winds make this area one of the most unfavourable habitats for the plant life.

The most distinct vegetation types of the highest summits in the Pamir-Alai are snow-bed mats and patchy alpine swards of various types. No detailed classification from calcicole to calcifuge vegetation types is available for the Pamir, but the most important components of this vegetation are *Astragalus heterodontus*, *Dracocephalum paulseni*, *Leontopodium fedtschenkoanum*, *L. nanum*, *Oxytropis humifusa*, *O. immersa*, *O. leucocyanea*, *O. michelsonii*, *O. savellanica*, *Saussurea caprifolia*, *Scrophularia incisa* and *Smelovskia calycina*. They occur on slopes or mountain tops with some organic matter at the surface, a fairly humid soil profile and a snow cover that lasts for at least a few months.

More arid places with no or a very short snow cover support gravelly or even scree substrate communities of chinophobous habitats. They are species-poor and have a short blooming period, and, in fact, the entire vegetation season lasts only from late June to early September. The most prominent species of this community are *Acantholimon diapensioides*, *Astragalus alitschuri*, *Oxytropis incanescens*, *O. trichosphaera*, *O. vermicularis*, *Chorispora songorica*, *Saussurea kuschakeviczii* and *Sisymbriopsis mollipila*. There are also typical snow-bed and moraine vegetation types. They develop on unstable, often destroyed sites next to glacier fringes, or on sites with a northern exposition and with a snow cover lasting for almost whole year. They are extremely species-poor with 2–5 taxa per plot. The most frequent contributors of this vegetation are *Saussurea glacialis, S. gnaphalodes*, *Desideria pamirica* and *Oreoblastus himalayensis*. Under rock faces in wide rock ledges or in crevices with some soil content, rudimental subnival communities of rupiculous habitats are found. They consist of plants like *Nepeta longibracteata*, *Euphorbia polytimetica*, *Acantholimon tianschanicum*, *Corydalis tenella*, *Erigeron brachyspermus*, *Parrya pamirica* or *Sibbaldia tetrandra*.

1.7 Conservation

The Pamir-Alai territory is regarded as one of the most sensitive areas in the world to climate change and biodiversity loss (Giam et al. 2010). But still only two of its species are listed as globally endangered (*Swida darvasica* and *Malus sieversii*). Additionally, Middle Asian mountainous temperate forests and steppes are regarded as a vulnerable ecoregion (Olson and Dinerstein 1998). But there is no solid information as to how many vascular plant species, especially endemics, are threatened or legally protected in the Tajikistan part of the Pamir-Alai. The Red-list of the country indicates 209 vascular plant species as threatened, including 27 trees and shrubs (Narzikulov 1988). Sixteen plant species have already disappeared from the territory of Tajikistan (Safarov 2003). However, the conservation status of species was based on uncertain criteria and not according to the IUCN recommendations. The number of taxa assessed as threatened is surprisingly low, considering that the threats from urbanization, agriculture and climate change in the area are most powerful in the Central Asia. The mountains of the Pamir-Alai are particularly sensitive to climate change due to the low adaptive capacity of its ecosystems; they already have been affected by glacier melting and increase of the mean temperature (Makhmadaliev et al. 2003). Considering only the three mostly threatened habitats (Nowak et al. 2011), i.e. riverside forests, broad-leaved forests and alpine Juniper forests, the number of potentially threatened taxa is more than 750. This shows the remarkable deficiency in flora conservation. Also the gallery forests are under considerable threat due to clear cuttings and unconstrained use by local people. Only the Tigrovaya Balka National Park effectively protects the stands of *Populus pruinosa* and related habitats. Tajikistan's natural heritage is under severe threat from climate change, habitat fragmentation and degradation. Around 50% of its forests have disappeared in the past 100 years, causing massive soil erosion and increased risk of landslides. Several types of riverside forests, e.g. stands of *Fraxinus sogdiana*, *Populus pruinosa* and *Platanus orientalis,* almost entirely vanished. Uncontrolled collecting of medicinal plants also poses a significant threat to many locally distributed species with small population sizes. During the past years the government of Tajikistan started several hydroelectric investments and road construction. As the population of the country still increases, the unsustainable use of the country's natural resources remains an increasing risk factor as a third of the population lives below the poverty line.

In the Pamir-Alai, large protected areas have been established in recent decades which cover approximately 22% of the country's territory (Safarov 2003). Additionally, a number of programs and strategies have been developed to enhance biodiversity conservation and management of protected areas. However, in practice, they are insufficiently managed.

The most important areas, representing category I in the IUCN classification of conservation areas, are strict nature reserves, so-called zakazniki. They are assigned with staff and headquarters that are committed to conservation responsibilities within the area. In Tajikistan four Strict Reserves were established. The Tigrovaya Balka NR is located in the south-western foothills of the Pamir-Alai, in the confluence area of the Amu-daria and Vakhsh rivers. It is devoted to protect riparian habitats of the subtropical climatic zone, the former habitat of the Caspian Tiger. The second nature reserve was created in 1956 in the Hissar Mts and is called the Romit NR. The aim of the conservation efforts here is the preservation of mid-altitude mountain ecosystems with an extremely rich flora and fauna. The third reserve is the Dashtidjum NR designed for the protection of one of the most precious and unique biocoenoses in Middle Asia, containing spectacular broad-leaved forests, river-bed thickets and, on slopes, tall-herbs and semi-savanna vegetation. The proportion of endemic species here is the highest in all of the Pamir-Alai. The last reserve is the Zorkul NR located in the Eastern Pamir around the quake lake. The area includes well-sustained steppe, semi-desert and high-altitude pastures and meadows. The Zorkul depression with its lakes, wetlands and surrounding mountains, offers suitable habitats for birds. In 2001 this protected area was added to the Ramsar list of wetlands. At present, it is also on the proposal list for future world heritage nominations (Diment et al. 2012). This area was designated as early as 1972 as a nature sanctuary (*zakaznik*). In the year 2000 it was enlarged to an area of 877 km^2 and upgraded to a strict nature reserve (*zapovednik*, IUCN Category I).

In order to increase the effectiveness of conservation in the Pamir-Alai we need urgent action plans that specify specific priorities for the hotspots of plant diversity. The designation as a microhotspot within the global hotspot of 'Mountains of Central Asia' is necessary, particularly for the most threatened ecosystems like forests and grasslands. It will be necessary to improve the connectivity of the ecological network and enhance the adaptive capacity of the most sensitive areas by ensuring a balance between traditional management practices and the economic growth of the local communities. To achieve this, a thorough inventory of current species distributions and their dynamics, and analyses of population sizes and ecological responses are indispensable.

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Chapter 2
The Hindu Kush/Afghanistan

Siegmar-W. Breckle and M. Daud Rafiqpoor

Abstract Afghanistan is a mountainous country in C Asia with connections to S Asia. The main mountain ranges are the Hindu Kush with several partly isolated ranges, which diverge from NE to the W and SW. Deep valleys, basins and very high mountains form a complex mosaic of sites with contrasting climatic conditions. The Hindu Kush has significantly higher elevational belts than the Alps, the Caucasus, and the Iranian mountains. Thus, the ecological conditions are very diverse and are the reason for a high biodiversity and very diverse vegetation cover. The climate is high continental with hot summers and cold winters. Most regions are rather dry or even arid, having precipitation only during fall, winter or spring. However, the SE facing parts of the Hindu Kush in Nuristan, Nangarhar and Paktia (Safed Koh) receive additional summer-rains by monsoonal influence. Phytogeographically, those regions with their Himalayan influence had dense forests, whereas most other parts of the Hindu Kush have predominantly Irano-Turanian species with open woods, steppes or semi-deserts often with thorny cushion plants. The family Asteraceae has the most genera and species, and the genus *Astragalus* has the highest number of species. The upper elevational belts are home to some Siberian and boreal floristic elements. The most recent estimations of species numbers for Afghanistan are about 5000 species and 25% endemism.

Abbreviations

C	Central
E	East
K	Kelvin (Δ°C)
N	North

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S	South
W	West
ITCZ	inner tropical convergence zone
NP	National Park
PET	Potential Evapotranspiration
P	Precipitation

2.1 Introduction

About half of Afghanistan is at altitudes of over 2000 m a.s.l. The highest point of the country lies in the main peak of the E Hindu Kush (Nowshaq, 7485 m a.s.l.) on the Afghan-Pakistan border, Tirich Mir being the highest peak of the Hindu Kush (7708 m a.s.l., in Chitral, Pakistan). Afghanistan has also a part of the Pamir plateau (Wakhan area) in the province of Badakhshan (Frankenberg et al. 1983).

The main high mountain range of Afghanistan is the Hindu Kush, the greater part of the E Hindu Kush is glaciated. Because of the altitudinal decrease from E to W, the W Hindu Kush harbours only a few glaciers. But here are many snow patches in the glacial cirques, primarily on N-facing slopes. In contrast, the E Hindu Kush sends downwards long glaciers to the valleys from the nival belt. In the glacial cirques of the W Hindu Kush (and also in Kohe Baba), active rock glaciers emerge from the accumulated snow patches in combination with frost debris and moraine material.

Further to the W, the Hindu Kush gradually declines and changes into the mountains of C Afghanistan with its main block Kohe Baba (its summit Shah Fuladi is at 5050 m a.s.l.). The country's C mountain has the form of a fan (Fig. 2.1) with its handle at the Salang-pass. It corresponds with the Late Cimmerian terrane mosaic which is subdivided by a fan-shaped bundle of E- to NE-trending faults into a series of blocks wedging out towards the NE. These are, from NW to SE: the Farah flysch basin; the Waras–Panjaw ophiolitic suture zone; the Helmand and Arghandab zones of the Helmand continental block; and the Kandahar Basin in the Spin Boldak area, truncated by the Chaman Fault System against the Himalayan realm (Breckle and Rafiqpoor 2010; Siehl 2017). This mountain range, with a steady decrease in altitude to W and SW, forms a spreading range with the main heights between 2500 and 4500 m a.s.l. The mountain block of C Afghanistan has the general feature of a huge, old, flat surface ("peneplain") with some higher summits giving the impression of smoothly rounded divides in which numerous wide and narrow V-shaped valleys (Schekari, Khenjan, Salang, Panjsher, Ghorband, Helmand, Hari Rud, and Arghandab) have been incised. Separate from the mountainous region of C Afghanistan to the W and NW, the Ferozkoh and the massifs of Paropamesus and Tirbande Turkistan rise to moderate heights between 2500 and 3500 m a.s.l.

In the nival belt of the Afghan high mountains the recent glaciation encompasses all the areas above the climatic snow line. In the E Hindu Kush the glaciated landscape extends from 4800 m a.s.l. upwards. In the W Hindu Kush on the other hand only the areas over 5100/5200 m a.s.l. are recently glaciated (Rathjens 1978). The

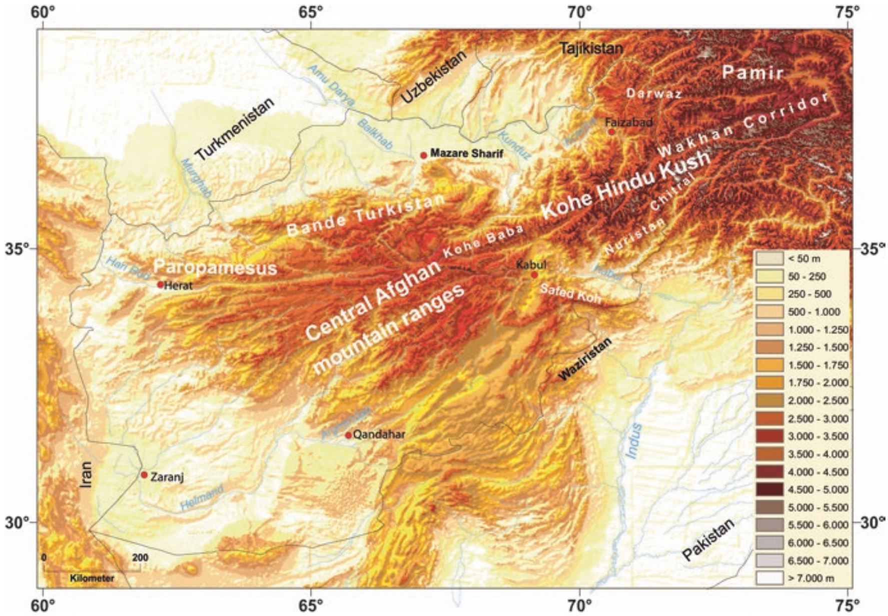

Fig. 2.1 Geography and main mountain systems of Hindu Kush and other high mountains in Afghanistan

nival belt which partly covers the summit regions of Hindu Kush, especially on N-facing slopes, is mainly characterized by an ice cover sending downwards up to 10 km long valley glaciers (Rathjens 1972). Whilst the recent glaciation is concentrated in the E Hindu Kush, in the W Hindu Kush and also in parts of the Afghan C mountains and in Kohe Baba there are only some snow patches in the former glacial cirques, particularly on N-facing slopes above 4800 m a.s.l. Only a few of these snow patches survive the extreme daily solar radiation in summer, forming penitent fields. The glaciated high mountain regions of the Hindu Kush and Kohe Baba receive their main rainfall in winter (Rafiqpoor 1979; Rathjens 1980).

Depending on the mountain exposure, in the Hindu Kush and Kohe Baba, as well as in the other mountainous regions of C Afghanistan, a very broad subnival and alpine altitudinal belt is located below the snow line and reaches downwards to 3300–3400 m a.s.l. This belt is at least 1400–1500 m wide (Rathjens 1978), and is characterized by forms and processes of recent solifluction. In the subnival altitudinal belt of the Hindu Kush and Kohe Baba, block glaciers are widespread and are mainly common in the humid and cool N exposures.

Here we present a synthetic view on the highly diverse vegetation and flora of the Hindu Kush mountains and underline the geological and climatological precondition. Its flora and vegetation are the result of a long history and evolution.

2.2 Geology

Laying in the W end of the Himalayan Orogenic Belt, the geology of Afghanistan is very complex (see Geolog. Map in Rafiqpoor and Breckle 2010) comprising of a complex assemblage of tectonic and stratigraphical differentiated crustal blocks separated by great fault zones (Kaever 1972; Wolfart and Wittekindt 1980; Quraischi 2014; Siehl 2017).

According to Quraischi (2014) and Siehl (2017) there are three main tectono-stratigraphic units in Afghanistan:

- The N Afghanistan-Tajik Platform, to which the Bande Turkestan and Feroz Koh belong. It was part of the Asian continental landmass and was affected by the upper Paleozoic Hercynian (Varician) orogeny.
- Areas S of the Harirod-C Badakhshan fault system (the Afgh. C mountain and the main part of Hindu Kush) up to the N and W of the Chaman and Konar faults were once part of Gondwana and accreted to the S margin of Eurasia during the Mesosoic Kimmerian orogeny.
- The mountain ranges to the S and E of the Chaman and Konar faults with the Suleiman mountains and the Kohe Baba are part of the Alpidic-Himalayan orogenic segment originating from the collision of the Indian and Eurasian Plates.

According to their geologic history, each of these units incorporate different rock types from sedimentary up to high metamorphic and intrusive rocks.

The pedological conditions in Afghanistan are much more complicated than soil maps can indicate. In the treatment of soil regions in Afghanistan, where necessary, also the bedrocks, topo-climate and vegetation in their three-dimensional arrangement should be taken into consideration. The extreme contrasts in soil quality in Afghanistan are a result of the varied topography, the petrological basis, the climatic differentiation in its hypsometric arrangement and the vegetation cover (Salem and Hole 1969, 1973).

The high altitudes of the Hindu Kush and the mountainous region of C Afghanistan are characterized by weak soil formation. Developed on frost debris, they are very young soils and still without any clear differentiation in the soil profile. In the zone of frost debris at the upper periglacial altitudinal belt of the Hindu Kush – and partly also of the mountainous region of C Afghanistan – directly below the recent snow line, large amounts of frost debris accumulate at the foot of the steep rock walls. From these debris masses, in combination with moraine material and snow rests, rock glaciers arose as periglacial mesoforms predominantly in the cirques of the N-facing slopes. In the subnival altitudinal belt of the Hindu Kush and in the Afghan C mountainous region, as well as in Ferozkoh, thin layers of raw soils of the cold mountain climates are developed between the snow line (4800–5100 m a.s.l.) and the lower limit of the alpine belt (3300–3400 m a.s.l.), predominantly on N expositions.

The very diverse geological and pedological conditions cause together with other non-organic factors (climate, hydrology, geomorphology) a very high ‘geodiversity’ as basis for a high degree of biodiversity of the country (Breckle and Rafiqpoor 2019).

2.3 Climate

The climate of the Hindu Kush is high continental with cold winters and hot summers (Flohn 1969). The altitudinal belts of climate and vegetation in the Afghan mountains are in accord with the accentuated topography of Afghanistan. The altitudinal belts of climate in general are characterized by the vertical temperature and precipitation gradients. In vertical direction, there is a temperature range of almost 22 K between the hot desert climate (e.g., Zaranj: 250 m a.s.l., annual mean 21.8 °C) and the main ridge of the Hindu Kush (e.g., Salang pass: 3366 m a.s.l., mean annual temperature − 0.3 °C). This is equivalent to about 0.74 K/100 m, which corresponds to a nearly dry adiabatic temperature gradient.

In all parts of Afghanistan except the very SE, the temperatures in winter are below 0 °C and frost is a common feature (Fig. 2.2). The interior mountain valleys exhibit absolute extremes of −50 °C. Only the basin of Jalalabad has very rare frosts and here subtropical and even tropical fruits can be grown. This is the very basis of the Hindu Kush on the SE side (see below also profile Fig. 2.23). The foothills on the N side exhibit temperature extremes in January of about −20 °C to −25 °C.

Precipitation also exhibits a dramatic difference between the desertic lowlands and the almost year-round cold parts of the high mountains of the Hindu Kush. The combination of this accentuated hypso-metrical change of temperature and precipitation is the basis for a rather broad pattern of various climatic types within the

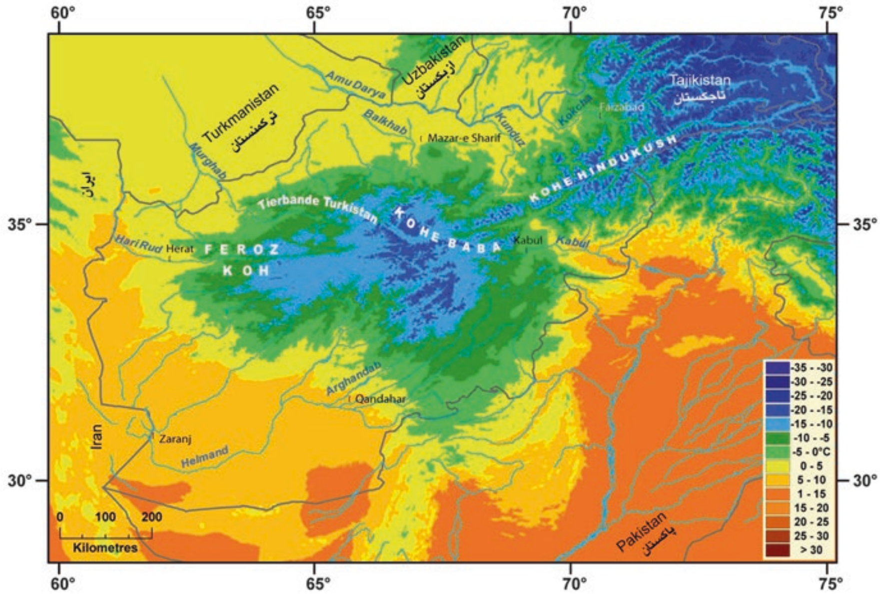

Fig. 2.2 Mean temperatures of January in Afghanistan and adjacent regions (After Breckle and Rafiqpoor 2010)

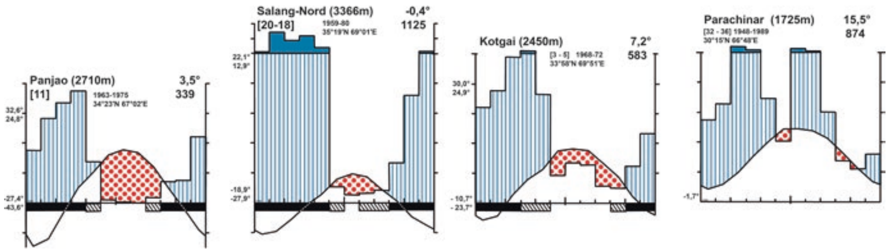

Fig. 2.3 Ecological climatic diagrams of Hindu Kush area

country and specifically within the various altitudinal belts which show a typical asymmetry of the altitudinal belts of vegetation.

The Hindu Kush lies in the sub-tropical dry winter-rain zone of the Old World. The cyclones which hike from the Atlantic Ocean eastwards and deploy on their pathway rainfall from the European Mediterranean via Turkey, the E Mediterranean and Iran and affect the high mountains of Afghanistan. Finally, in the W Himalaya they completely lose their energy. The cyclo-genesis over the Hindu Kush is more pronounced in spring; from this the rain-exposed mountain flanks in N and C Afghanistan benefit. The maximum rainfall is therefore, at most meteorological stations, in March and April (Rafiqpoor and Breckle 2010). In summer, the E parts of Afghanistan come under the influence of the tropical summer monsoon circulation (Sivall 1977; Rafiqpoor 1979; Breckle and Rafiqpoor 2019).

Regarding the distribution patterns of rainfall, three main landscape units of the Hindu Kush can be defined. They differ from each other depending on their general topography:

1. The high mountains of the Hindu Kush (over 4500 m a.s.l.) with more than 700 mm mean annual rainfall (Fig. 2.3b, Salang area).
2. The mountainous region of C Afghanistan including Kohe Baba, Ferozkoh and Tirbande Turkistan (4500–1250 m a.s.l.) with 700–200 mm mean annual rainfall (Fig. 2.3a, Panjao).
3. A narrow strip at the E part of the Hindu Kush and the Safed Koh comes under the influence of the Indian summer monsoon where a secondary maximum of rainfall occurs. This region has 500 to more than 1000 mm mean annual precipitation (Fig. 2.3c,d, Kotgai, Parachinar). In this so-called "summer rain-strip", the basins of Jalalabad and Laghman receive yearly <500 mm rainfall.

On the high plateaus of the country's C mountain region between 200 and 300 mm of precipitation (Fig. 2.3a: Panjao) are recorded, in the wind protected basins and large valleys, something less. Due to their exposure against the rain-bearing winterly winds, the N slopes of the Hindu Kush, Parapamesos and Tirbande Turkistan and Kohe Baba receive much more moisture than their S slopes lying in the rain shadows. The station Salang-Nord (3366 m a.s.l., 1125–1027 mm)

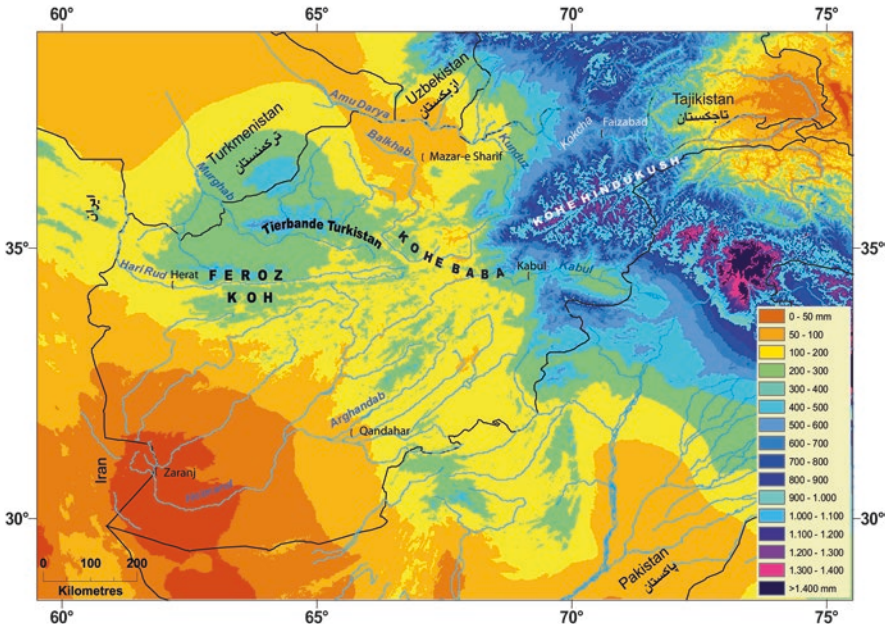

Fig. 2.4 Annual precipitation in Hindu Kush and Afghanistan (After Breckle and Rafiqpoor 2010)

(Fig. 2.3b) represents rainfall conditions in the high Afghan mountains. The annual rainfall in Afghanistan is shown in Fig. 2.4.

The inter-montane basins of E Afghanistan, such as the basins of Jalalabad, Kabul, and Kohistan (Roostai 2018), have annual rainfalls of between 250 and 400 mm. They are crossed by large rivers (Ghorband, Salang, Panjer, Kabul, Logar, and Tagab) with huge amounts of water and high loads of erosion.

2.4 Flora and Phytogeography

The most comprehensive source of information on the flora of the Hindu Kush is the monumental multi (100!)-authored Flora Iranica (Fl. Ir.) edited by Rechinger (1963–2015). It includes almost all accessible collections from the area and is now nearly completed with 181 fascicles of plant families published. However, understandably, the older volumes are outdated. The Flora of Pakistan has in a similar way covered almost all plant families and 217 fascicles (now all on-line) have been published; it started in 1970. Additionally, many research papers on the flora and vegetation of various parts and floristic lists from several expeditions have been published, e.g., on the Hindu Kush (Kitamura 1960, 1964; Gilbert 1968), on the Wakhan corridor (Podlech and Anders 1977), the Bande Amir area (Dieterle 1973).

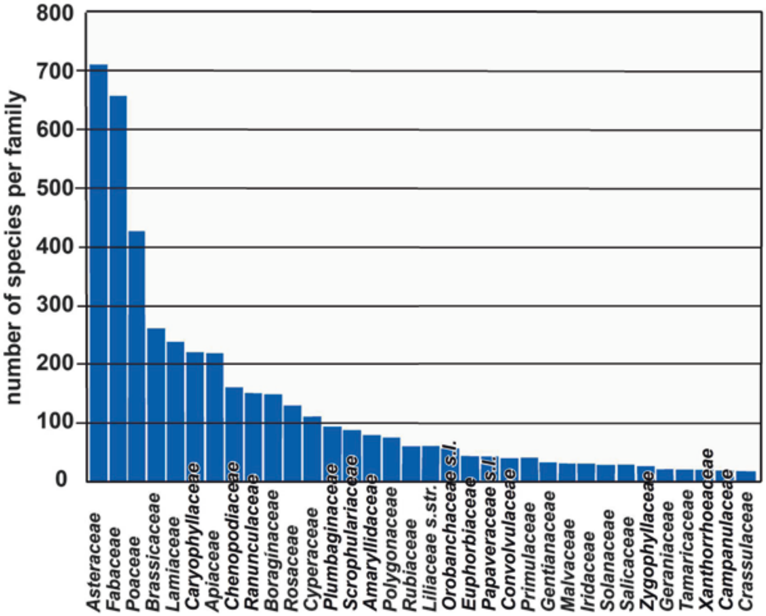

Fig. 2.5 Number of species in the large families of vascular plants in Afghan Hindu Kush (After Breckle et al. 2013)

More recently a checklist of the Afghan flora was published (Breckle et al. 2013) as a follow-up to the Field Guide "Flora and Vegetation" with 2000 coloured photographs of about 1200 species (Breckle and Rafiqpoor 2010). Answering the question, how many plant species do we have in Afghanistan or in the various mountain parts of the country is now easier as a result of this checklist (Breckle et al. 2013). In it, c. 5000 species of vascular plants are recognized. The following figures give some statistical data as a quantitative survey according to species, genera and families. Figure 2.5 indicates the number of species in the larger plant families. It clearly shows that the seven largest plant families account for more than half of all Afghan species. Figure 2.6 gives the number of genera in the larger plant families. Again, the seven largest families have more than half of all genera. But the sequence of families differs: Leguminosae (Fabaceae) are only on fifth place now, Gramineae (Poaceae) move to third place. Figure 2.7 indicates the number of species within the larger genera of Afghanistan. There are 12 genera with more than 40 species each, by far the largest being *Astragalus* with c. 320 species but *Cousinia* with 147 is also substantial. Whether *Oxytropis* really merits third rank is questionable: many species are only known from single gatherings and with better material may turn out to be synonyms. Somewhat similar is the situation with *Taraxacum.* Other species-rich genera are *Acantholimon, Allium* and *Silene*. With *Artemisia*, very common in many vegetation types, the taxonomic situation is very complex and urgently would need a detailed study.

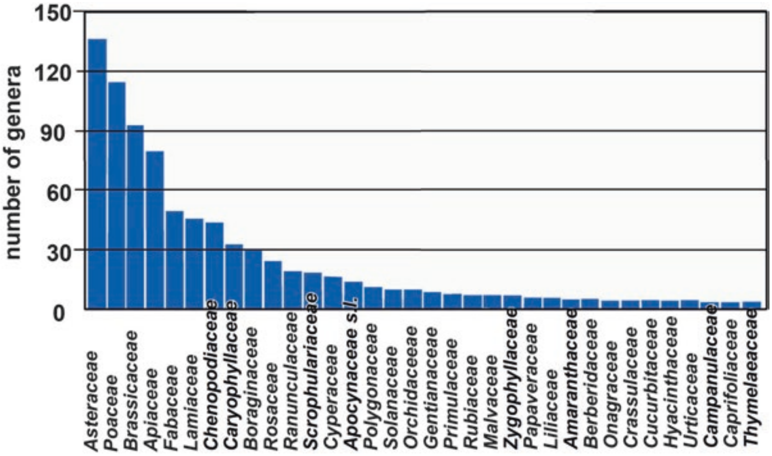

Fig. 2.6 Number of genera in the large families of vascular plants in Afghan Hindu Kush (After Breckle et al. 2013)

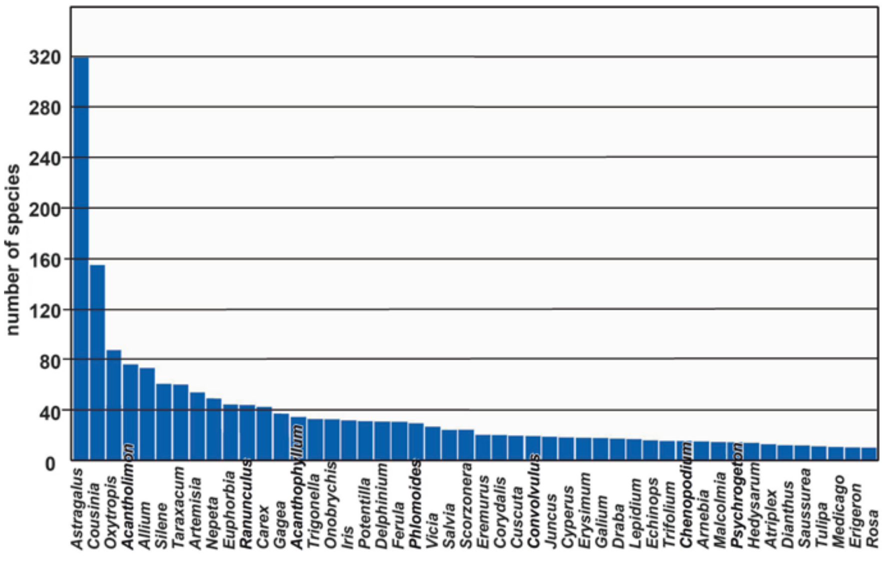

Fig. 2.7 Number of species in the large genera of vascular plants in Afghan Hindu Kush (After Breckle et al. 2013)

Table 2.1 gives a summary of the main statistics of the Afghan flora. In brackets, we give estimated numbers for the Hindu Kush. From the total number of taxa in Afghanistan with c. 5000 species, there might be about 3600 species restricted to the Hindu Kush mountain area and the degree of endemism is 24% considering that their distribution is restricted to Afghanistan and closely connected mountains

Table 2.1 Number of families, genera, species, taxa and endemics in the Afghanistan flora (percentage in round brackets), estimated figures for the Hindu Kush mountain area [in square brackets]

Taxon group	Number of families	Number of genera	Number of species	Number of taxa	Number of endemics and sub-endemics (%)
Pteridophytes	12 [11]	26 [16]	50	60 [39]	0 [0]
Gymnosperms	4 [4]	8 [7]	24	24 [17]	2 (8%) [2 (11%)]
Monocotyledons	28 [21]	198 [157]	822	846 [665]	78 (9.0%) [52 (7.8%)]
Dicotyledons	106 [93]	863 [648]	3945	4130 [2935]	1138 (27.8%) [675 (23.0%)]
Total (Vascular Plants)	**150 [129]**	**1095 [828]**	**4841**	**5060 [3655]**	**1218 (24.1%) [729 (19.9%)]**
Marchantiophyta (Hepaticae)	12	16	24	24	
Bryophyta (Musci)	28	87	228	244	
Anthocerotaceae (Hornworts)	1	1	1	1	
Total (Bryophytes)	**41**	**104**	**253**	**269**	**?**
Lichenophyta				**262**	

(Chitral). These figures depend on the delimitation of the mountain area. Regarding only species of the Hindu Kush mountain area, endemism is somewhat less with 20% (Table 2.1).

The number of vascular plant species is distinctly high, though overall Afghanistan is a rather arid country with extensive deserts and semi-deserts. But this is mainly because of the high geo-diversity of the mountain ranges and the diversity of habitats. Groombridge (1992) gave an estimate of 3500 species of vascular plants and 30–35% endemism, and suggested that an additional c. 5–10% of species might be found in future. With the new data from Breckle et al. (2013), about 5000 taxa are known from the whole country and about 3600 from the mountain regions of the Hindu Kush.

The link between species numbers and altitude is shown in Fig. 2.8. It clearly demonstrates the trend of decreasing species numbers with increasing altitude, which is a very general rule for almost all mountains (Körner 1999; Breckle 1981; Lauer et al. 2001; Agakhanjanz and Breckle 2002).

Though the bryophyte flora (Kürschner et al. 2020) is less studied and is in an arid country like Afghanistan not really covering large areas, available data show that it is typical to have the highest number of bryophyte species recorded from middle altitudes (Fig. 2.9). This is not only due to the fact that collecting there may have been most intensive, but we also may assume that at middle elevations there is

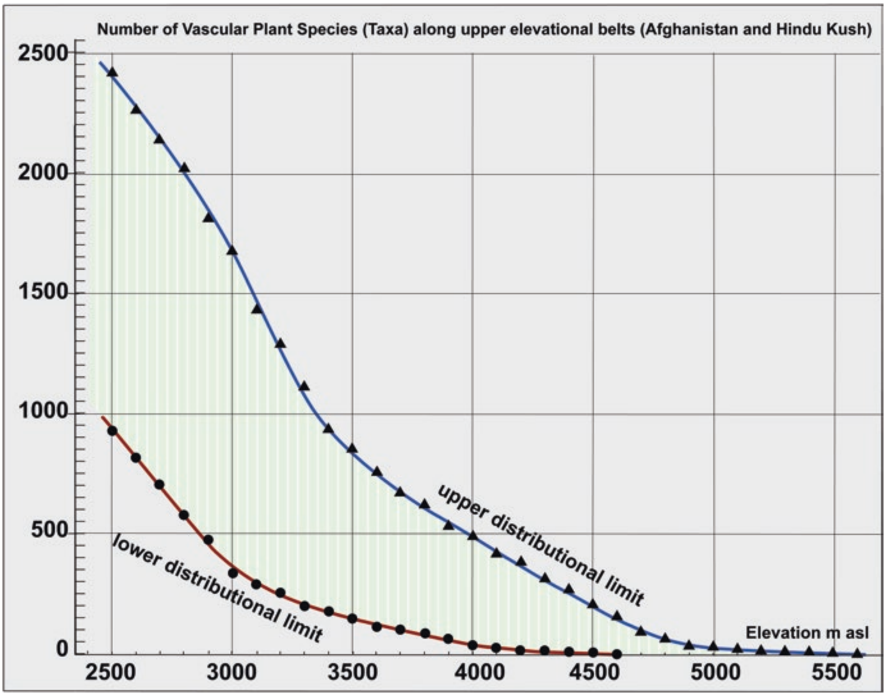

Fig. 2.8 Species numbers of vascular plants in relation to altitude of the Afghan mountains with lower and upper limits (Derived from Breckle and Rafiqpoor 2010)

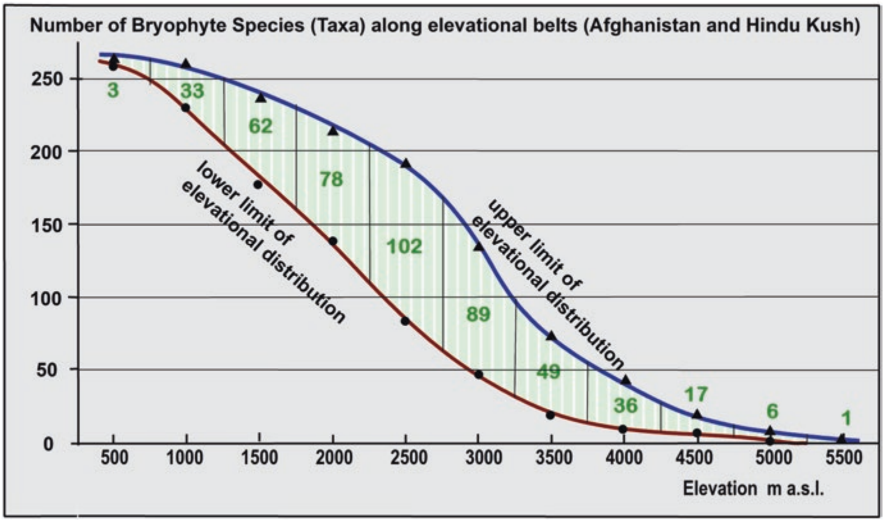

Fig. 2.9 Species numbers of bryophytes in relation to altitude of the Afghan mountains with lower and upper limits (Derived from Kürschner et al. 2020)

a maximum diversity of bryophytes. But certainly, as the overall range of many Afghan plant species is as yet not known, our knowledge is still rather limited.

Diverse ecological conditions, ranging from hot deserts and humid subtropical regions to high alpine regions, have favoured the establishment of a complex and varied flora and vegetation. However, the composition of the flora and the vegetation structure are also greatly influenced by a long history of over-exploitation. This has led not only to the almost complete loss of forests and woods but also to widespread degradation of formerly rich woodland and semi-desert ecosystems. Grazing by sheep and especially goats, as well as cutting down of trees and uprooting of shrubs, even dwarf shrubs, have not only greatly reduced the coverage of the vegetation, but also have changed its composition and floristic diversity.

With regard to the plant geographical aspects and distribution patterns of plant species (chorotypes), most parts of Afghanistan and its mountains belong to two very different phytogeographical regions: the Irano-Turanian floristic region with c. 92% of the country's surface, and the Sino-Japanese (Himalayan) floristic region with c. 7%. In both of them, the temperature conditions are rather similar, but they are sharply separated by the amount and seasonal distribution of rainfalI. Two smaller parts of the country belong to other floristic regions or show at least strong admixtures of species from adjacent regions. Species of the Saharo-Sindian region intrude into the lower altitudes of S- and E-Afghanistan. But only in the hot and dry Jalalabad basin they are so numerous and dominant that the area should be included in that phytogeographical region; this area comprises just the subtropical SE exposed foothills of the Hindu Kush.

In the upper belts of the high mountain areas, the number of C-Asian elements increases. The eastern part of the Wakhan is often considered as the SW extension of the C-Asian floristic region. That region extends eastwards along the Karakorum and N of the Himalayas to C- and NE-China, and northwards to S-Siberia.

Every elevational belt has its own phytogeographical characteristics. In the lowlands, Saharo-Sindian plants may prevail, in the lower mountains Irano-Turanian elements, in the eastern parts Himalayan species, in the higher mountain belts more C-Asian and Eurasian species, and in the alpine and nival belt some boreal and even arctic elements occur. Within these chorotypes, any particular species has acquired an individual distributional area according to its particular ecological requirements, evolutionary age, and widely differing dispersal abilities. The topography has greatly contributed to the high number of endemic species, particularly among mountain plants of the montane belt with less effective modes of dispersal. However, though the overwhelming majority of plant species belong to one or the other chorotype, there are rather many that are distributed in more than one phytogeographical region. For instance, many annuals that are adapted to summer drought occur in both the Mediterranean and the Irano-Turanian region. Other species were able to reach suitable habitats even if those areas are geographically widely separated from each other. This applies in particular to plant species of high mountain areas. Below we give just a few examples of the various chorotypes, mainly of the more conspicuous plants.

In parallel with the tremendous diversity of habitats in the Irano-Turanian floristic region, from different types of lowland semi-deserts up to montane woodlands and alpine meadows, the distribution pattern varies considerably. Most large genera, as e.g., *Astragalus, Cousinia, Acanthophyllum, Acantholimon, Allium, Eremurus* and *Eremostachys,* as well as smaller ones like *Ephedra,* occur in all elevational belts, but with different constituent species. Examples of typical Irano-Turanian genera that radiated into most diverse ecosystems are shown in the isoflor-maps. The isoflor-maps of *Eremurus*, *Eremostachys* and *Acantholimon* indicate, with their high species-numbers, the relevant centres of evolution (Hedge and Wendelbo 1970a). The unusually high species diversity in, e.g., *Astragalus, Cousinia, Acantholimon, Acanthophyllum, Allium*, *Eremostachys, Eremurus* and *Dionysia* is attributable to the fact that, due to genetic isolation, in the same altitudinal belt ecologically corresponding species have evolved in different mountain systems.

With its Himalayan subregion, the Sino-Japanese region extends into E-Afghanistan. Like the Irano-Turanian area, it also includes altitudinal belts with a large variety of ecological niches. Though species diversity per square kilometer certainly is much higher than in the Irano-Turanian area, the species number of the total area is smaller, simply as a result of the limited surface. In outline, the geographical distribution of the species belonging to that chorotype in Afghanistan is comparatively uniform because in the respective parts of the country the different altitudinal belts are particularly close to each other. However, their eastern extensions vary greatly and most are restricted to the Himalayas or even to the W-Himalaya. A large number of mesophytic and moderately xerophytic trees, shrubs and perennials belong here, as, e.g., *Cedrus deodara* (Himalayan cedar), the pines *Pinus gerardiana* (Fig. 2.10) and *P. wallichiana*, the oaks *Quercus baloot*, *Q. dilatata* and *Q. semecarpifolia*, the shrubs *Indigofera gerardiana* (Fabaceae), *Plectranthus rugosus* (Lamiaceae) and *Syringa emodi* (Oleaceae), the grasses *Stipa brandisii* and *Piptatherum munroi*. Not surprisingly, only rather few species of that floristic element are endemic or subendemic in E-Afghanistan, such as *Gymnospermium sylvaticum* (Podophyllaceae), *Pertya aitchisonii* and *Saussurea afghana* (both Asteraceae) in the most mesophytic evergreen broad-leaved oak forests, *Rhododendron afghanicum* as undergrowth in the upper coniferous forests, and *R. collettianum* (Fig. 2.19d) in the subalpine juniper scrub. These isolated endemics indicate that the Himalayan forests did not recently invade the area. Fossilized leaves, needles and cones of Himalayan trees growing today only further east, such as the thermophilous pine *Pinus roxburghii,* and many other fossil leaves from a rather humid vegetation, have been found in marl sediments at the Latahband pass east of Kabul. They indicate that in the relatively recent past, probably in the Early Pleistocene, they grew appreciably further west, indicating a higher monsoonal activity and a warmer climate (Breckle 1967).

The Saharo-Sindian floristic region and the corresponding chorotype are much less homogeneous than the others. Though the climatic conditions in the belt from the W-Sahara to the southern foothills of the Hindu Kush in N-Pakistan, which are characterized by high aridity, very hot summers and rather mild but not frost-free winters, are very similar, the distribution pattern of the plant species differs

Fig. 2.10 Slopes with dry conifer forests of *Pinus gerardiana*, Nuristan, E Afghanistan (photo SWB)

considerably, due to the very long distances covered by this belt and the varying climatic history in the individual parts of the area. Only in the lowland area around Jalalabad in Nangarhar province and, less significantly, around Khost in Paktya province, many Saharo-Sindian species occur that require more favourable winter temperatures and somewhat higher rainfall: e.g. the deciduous thorny shrubs and small trees *Acacia modesta* (Mimosaceae), *Zizyphus nummularia* and *Z. oxyphylla* (Rhamnaceae) and the evergreen shrubs *Calotropis procera*, *Periploca aphylla* and *Rhazya stricta* (all three in Apocynaceae). Another southern element is represented by mostly sclerophytic trees and shrubs that have their centre of distribution in an area stretching from the driest parts of the westernmost Himalayas southwards along the foothills of the Suleiman Range, through the lower mountains of Pakistani Baluchistan to the higher ranges along the eastern and southern margin of the Arabian peninsula, like *Reptonia buxifolia* (Sapotaceae), the palm *Nannorrhops ritchieana*, *Gymnosporia royleana* (Celastraceae) and *Dodonaea viscosa* (Sapindaceae). The typical decrease in the number of species with increasing elevation is shown comparably in Fig. 2.11 for the Hindu Kush, the Caucasus and the Alps.

The alpine and nival belts are more or less continuously present in the eastern section of the Afghan Hindu Kush and become more scattered towards the west, with an outlier in the Kohe Baba massif in C-Afghanistan. There, floristic elements

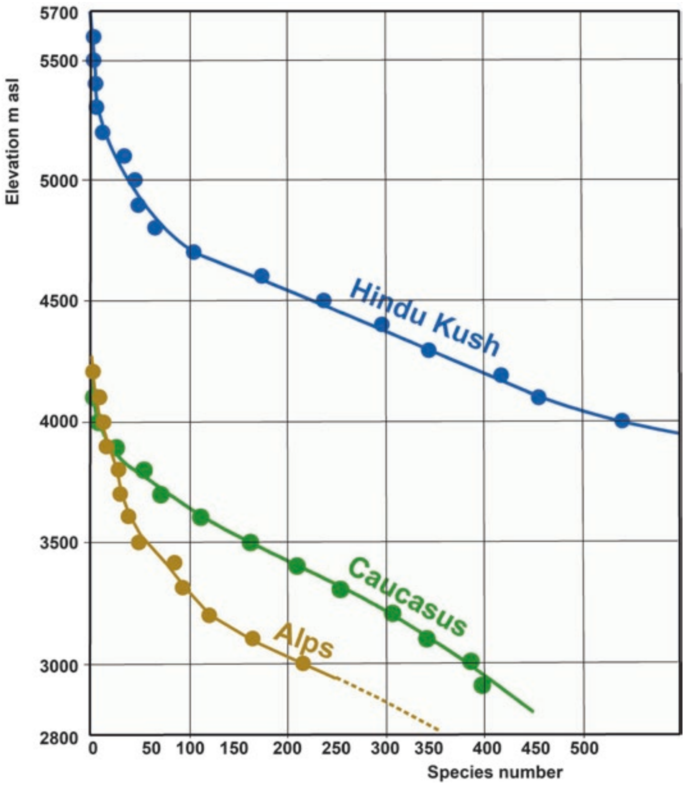

Fig. 2.11 Floristic drainage in mountains: Species numbers of vascular plants in relation to altitude of the Hindu Kush, Caucasus and Alps (After Breckle et al. 2018)

of the C-Asian, the Himalayan and the high Irano-Turanian mountains occur partly side by side and together with species that have wider distributional ranges. The number of widespread species of the Hindu Kush which are common with the Alps, the Caucasus mountains and/or the Himalayas is indicated in Fig. 2.12.

The high alpine and nival flora had been checked by Breckle (1988) according to their chorological character along elevational belts. It turned out that endemism is sharply decreasing, which is in contrast to some other mountains. The highest percentage of species is recorded, however, from several C Asian Mountains and the Himalayas (Fig. 2.13). The alpine belt is especially rich in species with a rather wide distribution, such as Euro-Siberian or even boreal and arctic (Breckle 1974, 1988; Breckle and Rafiqpoor 2011). We can distinguish the following groups:

(a) Cosmopolitan (or almost so) high mountain species, e.g., *Luzula spadicea, Oxyria digyna, Polygonum viviparum, Phleum alpinum* and *Androsace* species
(b) Circum-boreal mountain species partly extending into the Arctic, e.g., *Cerastium cerastoides, Cystopteris fragilis* incl. *C. dickieana, Lloydia serotina*

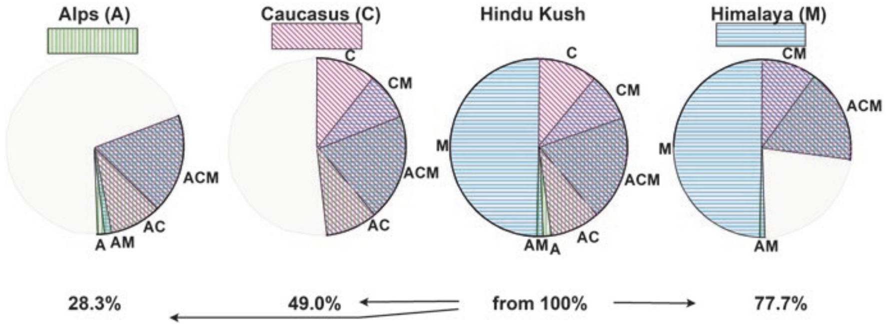

Fig. 2.12 Percentage numbers of widespread species of the Hindu Kush common in Caucasus (C, red), the Alps (A, green) and the Himalayas (M, blue) (After Breckle et al. 2018)

Altitudinal Range : / Chorological group:	cosmopolit. (worldwide in Mtns.)	Northern Hemisphere Mtns., Arctic	Central- and Middle Asian Mtns.	C-, Middle Asian Mtns. , Himalaya	Himalayan	endemic
> 5400 m NN	-	10	20	40	30	-
5200 - 5400 m	5	15	15	45	20	-
5000 - 5200 m	6	16	14	38	24	2
4800 - 5000 m	4	14	14	36	28	4
4500 - 4800 m	3	10	14	32	28	13
4000 - 4500 m	2	10	11	28	27	22

Fig. 2.13 Percentage of chorological groups from the alpine-nival flora of the Afghan Hindu Kush above 4000 m a.s.l. (After Breckle 1988)

(c) Species restricted to some Asiatic and North American mountains and in parts of the Arctic, e.g., *Epilobium latifolium*, *Smelowskia calycina*, *Koenigia islandica*

(d) Central Asian high mountain species occurring in most C Asian mountain systems, on the Tibetan plateau, the Trans-Himalaya and Himalaya, such as *Delphinium brunonianum* and *Sibbaldia cuneata*, but not in the Himalaya as e.g., *Chorispora macropoda* and *Primula algida*

(e) Species restricted to the Afghan mountains, the Pamirs, the Karakorum and the W Himalaya, such as *Anaphalis nubigena, Juncus membranaceus*, *Lamium rhomboideum, Primula macrophylla* and *Rheum tibeticum*
(f) Species endemic to the Hindu Kush and some Iranian mountains (Zagros, Alburs, and partly extending into the Caucasus) are among others, such as *Gentiana umbellata, Polygonum serpyllaceum* and *P. thymifolium* (Breckle et al. 2018)
(g) Species endemic to the Pamir-Alay and the Hindu Kush, such as *Didymophysa fedtschenkoana*, *Polygonum myrtillifolium, Polygonum chitralicum, Waldheimia tridactylites* and some *Nepeta*-species
(h) Narrow endemics of the Hindu Kush and parts of the Wakhan, or even restricted to one of the Afghan mountains, e.g., *Aconitum rotundifolium, Corydalis metallica, Gentiana longicarpa, Gynophorea (Erysimum) weileri, Potentilla coelestis, P. collettiana* and *Rhododendron afghanicum (*subalpine)

In the upper elevational belts, as in boreal and arctic regions, the predominant life-form is hemicryptophyte (Fig. 2.14). Only below 4000 m a.s.l. chamaephytes become more prominent. Annuals and geophytes are rare.

For further references on the still tentative plant geographical subdivision of the area and floristic elements see among others Hedge and Wendelbo (1978, Afghanistan), Browicz (1997, Iran and the wider area), Breckle (2004, high mountain flora), Cox and Moore (2005, worldwide) and Agakhanjanz and Breckle (1995 floristic history).

Live form :	Phanerophytes	Nano-Phanerophytes	Chamaephytes	Hemicryptophytes	Biennial Species	Annuals (Therophytes)	Geophytes	Parasitic species	Hydrophytes
Altitudinal Range: > 5400 m NN	-	-	10	70	10	-	10	-	-
5200 - 5400 m	-	-	16	74	5	-	5	-	-
5000 - 5200 m	-	-	12	71	8	6	4	-	-
4800 - 5000 m	-	-	12	72	6	5	4	-	-
4500 - 4800 m	-	1,6	11,7	69,2	4,0	6,5	6,5	-	0,4
4000 - 4500 m	0,1	2,8	17,1	61,2	2,3	9,1	7,2	0,1	0,1

Fig. 2.14 Live form spectra of the alpine-nival flora of the Afghan Hindu Kush above 4000 m a.s.l. (After Breckle 1988)

2.5 Endemism

An endemic taxon is defined as one which is only found in a distinct area or location and nowhere else in the world. The definition requires that the area in which the species is endemic be defined: such as a "site endemic" (e.g. just on one hill), a "national endemic" (e.g. found only within the border of the state of Afghanistan), a "geographical range endemic" (e.g. found in the Hindu Kush region, which may however cover also parts on Pakistan territory: "subendemic").

The percentage of endemism for the whole country is about 25%; for the mountain region it is less, about 20%. This may be due to the fact, that endemism always is defined for a specific area. But the Hindu Kush ranges are connected with the Pamirs and the Karakoram in the east, thus, a rather high portion of species exhibits a wider distribution in adjacent mountains.

Quite a number of species from the montane belts are endemics: their occurrence is restricted to the Afghan mountains though some might just penetrate into adjacent mountain areas of Pakistan or Tajikistan. Only a limited number of these endemics occur all over the country in their typical altitudinal zone, such as *Salvia rhytidea*; most are restricted to smaller areas.

In some plant families, but not in the grasses, the percentage of Afghan endemic species is rather high (Hedge and Wendelbo 1970a; Breckle et al. 2013). Many of the endemics are very isolated, at least morphologically, such as *Pseudodraba* (*Drab*a) *hystrix, Pyramidium griffithianum, Halarchon vesiculosus* and *Salvia pterocalyx*. Iran and Turkey have larger totals of flowering plants than Afghanistan, but the Afghan endemics are, in general, taxonomically more isolated. For example, Turkey has very many more species of *Salvia* than does Afghanistan, and many more endemics, but the majority of them have clear allies in that country. In contrast, Afghanistan has relatively few endemics of *Salvia,* and it is hard to pinpoint taxonomical allies of those endemics. Furthermore, there are endemics at specific and generic level that can, objectively, be classified as "isolated" or "narrow". *Draba* and *Salvia* are certainly very distinct in this respect.

The thorny cushions (*Acantholimon, Acanthophyllum, Onobrychis* etc.) also exhibit a rather high degree of endemism in the Afghan mountains. Some examples of rates of endemism in plant families and genera are given in Table 2.2. In some of the Afghan plant families, the ratio of endemics is rather high. In some other families, many species are more widespread. Some high alpine genera as e.g. *Draba* exhibit only very low rates of endemism, while others are very specialized and have small distributional areas, e.g. *Dionysia*.

Some endemic genera are listed by Sales and Hedge (2013). These are in Apiaceae: *Gongylotaxis, Kandaharia, Mastigosciadium, Pinacantha, Pyramidoptera* and *Registaniella;* in Asteraceae: *Chamaepus* and *Tiarocarpus;* in Brassicaceae: *Cyphocardamum, Pseudodraba* and *Veselskya*; in Caryophyllaceae: *Kabulianthe, Ochotonophila, Pentastemonodiscus* and *Scleranthopsis;* in Chenopodiaceae*: Halarchon;* in Papaveraceae*: Cryptocapnos* and in Plumbaginacae: *Bamiania* and *Bukiniczia.* They do not include a few genera that are subendemic,

Table 2.2 Plant families and genera in Afghanistan with high endemism ratios

Plant family/resp. genus	Country endemics (Afghanistan) %	Subendemics (Afghanistan and closely related adjacent regions) (%)	Total (%)
Acantholimon	75.0	17.1	92.1
Dionysia	91.7	0	91.7
Plumbaginaceae	66.7	12.9	79.6
Cousinia	67.5	10.4	77.9
Oxytropis	51.7	13.8	65.6
Onobrychis	45.4	18.2	63.6
Astragalus	48.8	4.7	53.5
Iridaceae	40.0	5.7	45.7
Nepeta	28.8	15.3	44.1
Lamiaceae	29.3	13.4	42.7
Boraginaceae	26.5	13.6	40.1
Primulaceae	34.9	4.6	39.6
Apiaceae	28.3	9.1	37.4
Amaryllidaceae (incl. *Allium*)	27.6	9.2	36.8
Caryophyllaceae	24.9	8.3	33.2
Ranunculaceae	22.1	3.4	25.5
Brassicaceae	14.6	8.3	22.9
Draba	5.9	0	5.9

After Breckle et al. (2013)

such as *Kurramiana* (Gentianaceae), *Calyptrosciadium* and *Scrithacola* (Apiaceae) and *Polychrysum* (Asteraceae). However, this certainly is not a definitive list of endemic genera, because our taxonomic knowledge is still proceeding.

Sales and Hedge (2013) gave also a broader overview of generic endemism throughout SW Asia; 161 genera were listed as endemic. In that publication SW Asia was defined to include, in addition to the countries normally included in that area, the Caucasus and parts of C Asia (Pamir-Alay and Tian Shan). Three families, Apiaceae, Asteraceae and Brassicaceae, had by far the greatest number of endemic genera, between them accounting for over 120 genera. The grass and legume families had very few. The paper emphasized the major importance of SW Asia as a global hotspot, especially the Afghanistan/C Asiatic part of it. It also considered a few of the larger non-endemic genera in Afghanistan with respect to their ranges in adjacent countries. Surprisingly, the distributions of individual species differed markedly. In, for example, *Acantholimon, Acanthophyllum, Allium* and *Nepeta* there were remarkably few species that were common to wider areas, such as Afghanistan, Takijistan, Iran or Turkey. *Acantholimon* has 76 species in Afghanistan and none of them occur also in Turkey. This fact emphasises the importance, when discussing endemism, of considering it from a broader geographical viewpoint and not just per country.

There are two subcategories of endemism – palaeo-endemism and neo-endemism. A palaeo-endemic species is thought to have been widespread formerly but is now restricted to a smaller area and is morphologically rather isolated. A neo-endemism is a relatively young species that has recently arisen and become reproductively isolated, or one of hybrid origin and now classified as a separate species; such species occur in smaller areas. Many of the Afghan endemic species can be designated as neo-endemics (Hedge and Wendelbo 1970a), especially in genera which are still actively evolving new species, as in *Astragalus, Acantholimon, Eremostachys, Oxytropis, Taraxacum* etc. In contrast, four genera that are good candidates for classification as palaeo-endemics are *Halarchon* (Chenopodiaceae), *Pseudodraba* (Brassicaceae), *Pyramidoptera* (Apiaceae) and *Veselskya* (Brassicaceae). At least morphologically, they are clearly isolated from other genera, but whether future molecular research will support this designation remains to be seen.

2.6 Major Vegetation Types

The most extensive study dealing with the whole country and incorporating earlier results is that by Freitag (1971a, b). With regard to the high mountain vegetation, it was supplemented by papers of Breckle (1971a, b, 1973, 1974, 1975), Breckle and Frey (1974). Here we present an updated account that includes some so far unpublished information. During recent decades Afghanistan's flora and vegetation have been much studied, though mainly before the Soviet military intervention and subsequent civil wars (Breckle et al. 2017, 2018).

Except for some weeks from spring to early summer, outside of the irrigated areas which cover about 5% of the country's surface and the few forest areas, the plant cover of Afghanistan has a poor visual appearance and looks rather uniform. For most of the year, when seen from a distance, plant life appears to be almost completely absent, and the monotonous grey or brown colours of the landscapes seem to be caused by the barren soil or rock surfaces. This is caused by the strongly seasonal and predominantly semiarid climate in combination with the long-lasting destructive influence of man on the plant cover.

The survey of the broadly defined vegetation types given here focuses on two aspects: the 'Potential Natural Vegetation' (Fig. 2.15) as it would exist without the influence of man in natural habitats; and the 'actual vegetation' as it is today as a result of man's destructive impacts. The country-wide survey by Freitag (1971a, b) resulted in two maps of the potential natural vegetation: (1) a country-wide map that was largely adapted by Nedjalkov (1983a, b), and slightly modified by Breckle (2007); (2) a detailed map showing the much more diversified easternmost part of the mountainous country in higher resolution both with regard to scale and vegetation types (in Freitag 1971a).

Other authors mainly dealt with the actual vegetation (Pelt 1967). Gilli (1969, 1971) studied the vegetation, mainly around Kabul; Nedjalkov (1983a, b) described some vegetation types from the forest region in Kunar province in E-Afghanistan, while much earlier Neubauer (1954a) and Volk (1954) gave a survey on the vegetation and studied the forests (Neubauer 1954b) in Nuristan and Rathjens also in

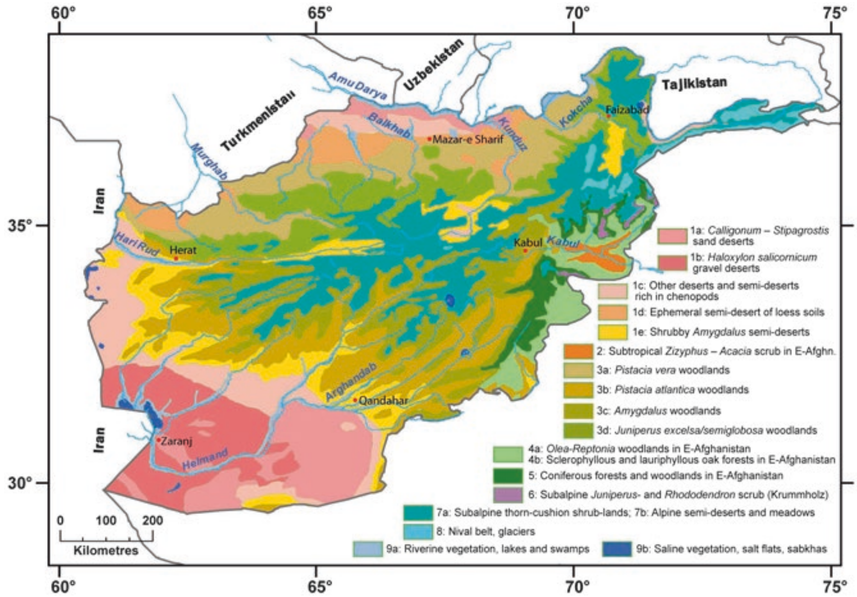

Fig. 2.15 Potential natural vegetation of Afghanistan (After Freitag 1971, Breckle and Rafiqpoor 2010)

Paktia (Rathjens 1974). The ecological conditions of forests were reviewed by Afghanzada (1970). Mountain vegetation and the flora of the C-Hindu Kush were studied by Frey and Probst (1978, 1982); Pavlov and Gubanov (1983) and some others.

For classifying the vegetation cover the potential natural vegetation is chosen here. It indicates the vegetal resources of the various parts of the country as determined by climate and soil. Furthermore, it shows to what extent the vegetation could be restored by application of careful and conscious practices of land use, though sometimes, or often, only in the long run. It applies to "normal habitats" which are defined as being flat to moderately sloping, not receiving additional water-supply.

The most important sources for information about the composition, structure and geographical distribution of the natural vegetation gained decades ago were:

- the few remnants of little disturbed vegetation all over the country but preferably those in remote and inaccessible areas;
- some intentionally protected small plots (e.g., pistachio and pine woodlands); the surroundings of tombs and shrines ("ziarat");
- and some rare, written documents.

Natural vegetation cover is often replaced by substitute plant communities caused by human activities. In fact, the vegetation of the country is much more diversified, due to its mountainous character. The common rocky sites have their peculiar plant communities, as do scree-covered slopes or naturally eroding slopes in weak marly sediments. Caused by their geographic or topographic isolation, these communities, made up of highly specialized plant species, are particularly rich in narrow-ranged endemics. They cannot be dealt with in this survey. The main zonal vegetation categories on standard ecological sites are shown in the map (Fig. 2.15) under No. 1 to No. 8.

Those with the predominant influence of one ecological factor, namely additional water supply or high salinity (river valleys, lakes, swamps and saline flats), are summarized in the map in Fig. 2.15 under category No. 9. They represent azonal vegetation types, since here the zonal climate is less decisive than the predominant ecological factor (water, salt, gypsum, heavy metals, etc.) causing peculiar habitats.

Vegetation types occurring in the Afghan mountains are described below mainly after Freitag et al. (2010).

2.6.1 Shrubby or Sub-shrubby Chenopod Deserts and Semi-deserts (Fig. 2.15: 1c)

A number of rather different plant communities with predominance or high percentages of chenopodiaceous shrubs and sub-shrubs occur at lower altitudes of S-Afghanistan as well as along the W and N periphery where rainfall scarcely exceeds 150–200 mm. But they also dominate in drier basins and valleys of the C- and E-Afghanistan mountains where locally rocks rich in gypsum reach the surface, as in the Bamyan (Fig. 2.16a) and Ajar valleys, parts of the Ghorband valley and in the lower Gomal valley. Important species are, among others, shrubby or sub-shrubby chenopods as *Halothamnus subaphyllus, Salsola arbuscula, S. montana, S. gemmascens*, locally *S. maracandica, Seidlitzia rosmarinus*, several species of *Artemisia,* in particular *A. oliveriana* and *A. sieberi*, and the shrubs *Cousinia deserti, Ephedra sarcocarpa, E. strobilacea, Zygophyllum atriplicoides* and *Z. eurypterum,* and. Depending on soil structure, in spring-time ephemerals and hemicryptophytes can contribute considerably to the diversity of these open communities.

On loess-covered foothills in the N the grass-cover is significant with several heavily grazed species (*Festuca, Poa*), mainly characterized by *Carex stenophylla,* giving a steppe-like appearance.

2.6.2 Shrubby **Amygdalus** *Semi-deserts (Fig. 2.15: 1e)*

Close to the foothill areas of S- and W-Afghanistan as well as in drier interior valleys of the Hari Rud, Kokcha, Surkhab etc., where rainfall varies between c. 150 and 250 mm, different but closely related spiny *Amygdalus* species (*A. eburnea, A. erioclada*) that usually grow up to 0.5–1.5 m are the most significant plants in open

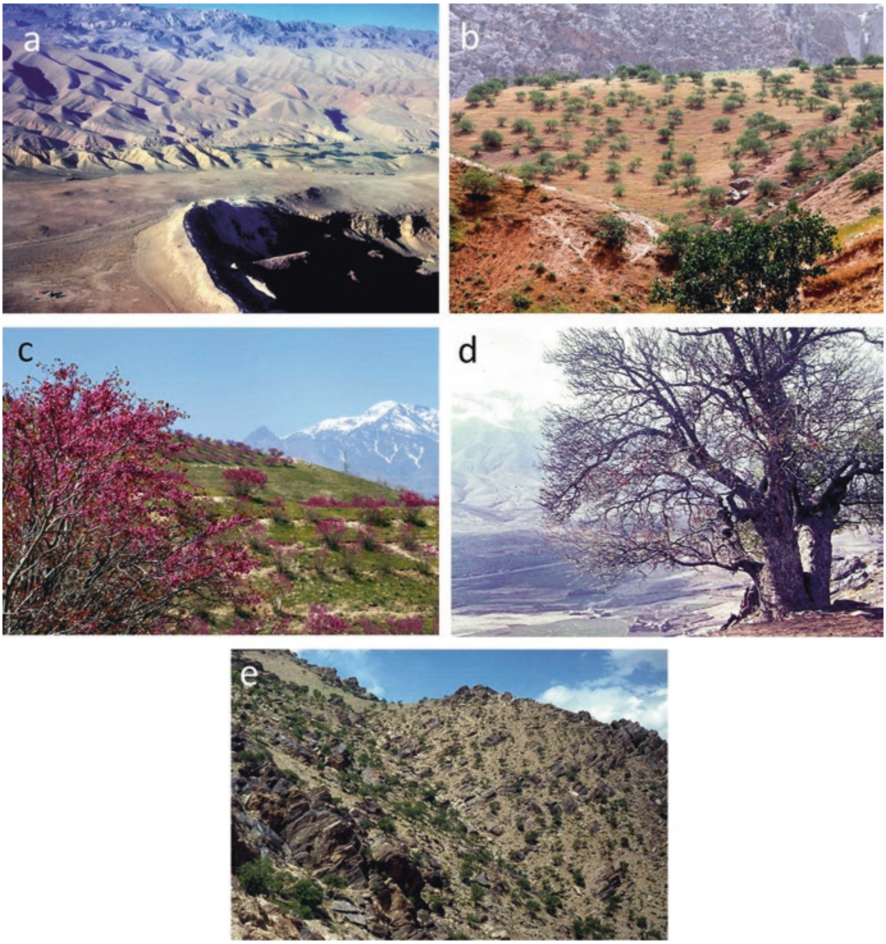

Fig. 2.16 (**a**) Dragon valley, SW of Bamyan, is an inner-mountain valley, which is very dry and characterized by a local chenopod desert with *Salsola maracandica, Anabasis* and *Arthrophytum* species, 2800 m a.s.l. (photo SWB); (**b**) Open stands of *Pistacia vera*, strongly grazed, N parts of Marmul-Mtns., 650 m a.s.l., N Afghanistan (photo M Keusgen); (**c**) *Cercis griffithii* (Caesalpiniaceae), is one of the conspicuous shrubs, sometimes forming small trees, which may have covered in former centuries all lower montane slopes of N Hindu Kush and mountain slopes from Tajikstan to E Iran (photo M Keusgen); (**d**) Old large *Pistacia cabulica (P. atlantica)* trees, Khorogh Koh, at Ziarat W of Kabul, indicating the good potential of tree stands on slopes around Kabul (photo SWB); (**e**) Open woodland with *Amygdalus kuramica*, Qarabagh, Wardak, C Afghanistan (photo H Freitag)

semi-desert shrub-lands. They are accompanied by a high number of other low shrubs like *Ephedra intermedia*, dwarf shrubs of *Acanthophyllum, Diaphanoptera* (in W)*, Acantholimon, Cousinia* and *Artemisia*, perennial grasses like *Stipa hohenackeriana,* many hemicryptophytes and numerous annuals and geophytes.

Overgrazing effects are usually less conspicuous here because, by their spiny morphology, most woody plants are well protected both against grazing animals and fuel-collecting villagers. Sometimes the density of sub-shrubs has even increased, in particular in the case of the widespread *Cousinia stocksii* community in S- and W-Afghanistan.

2.6.3 Subtropical **Zizyphus – Acacia** *Scrub (Fig. 2.15: 2)*

The semi-desert scrub and dry thorn savannah of the distinctly semi-arid (c. 150–300 mm) and hot Jalalabad basin shows strong subtropical influence by the spiny deciduous shrubs and small trees of *Zizyphus nummularia* and *Acacia modesta*, mixed with such evergreen unpalatable shrubs as *Periploca aphylla, Rhazya stricta, Calotropis procera*, *Ephedra ciliata*, and *Withania coagulans* (Solanaceae). In the comparatively densely populated region, these strongly armed or unpalatable species most likely have gained a higher coverage at the cost of perennial grasses like *Chrysopogon aucheri, Hyparrhenia hirta, Tetrapogon villosus* and *Stipagrostis* spp. Most other species of the herbaceous layer are likewise unpalatable, as the annuals *Stipa capensis* (Poaceae) and *Cleome viscosa* (Capparidaceae), the perennials *Aerva javanica* (Amaranthaceae) and the tiny desertic *Salvia* species as *Salvia aegyptiaca, S. santolinifolia* and *S. trichocalycina,* and also *Farsetia edgeworthii, Convolvulus spinosus* and even *Haloxylon salicornicum* may be found. This scrub community represents, at the SE side, the lowest dry belt of the mountains. Slightly higher *Pistacia khinjuk, Periploca aphylla, Ephedra intermedia* and *Cerasus verrucosa* may be part of an open formation with many dwarf shubs and geophytes, as well as the succulent *Caralluma aucheriana*.

2.6.4 **Pistacia vera** *Communities (Fig. 2.15: 3a)*

The foothills, lower and medium altitudes (c. 600–1500 m a.s.l.) in N-Afghanistan, where rainfall fluctuates between c. 300 and 500 mm, are the areas of several woodland types dominated by the deciduous *Pistacia vera* (Fig. 2.16b). It coincides with the upper part of the broad loess belt, and on these soils the communities show their most typical structure. Size and coverage of the trees that have flat crowns and often several stems vary from shrub-like 2–3 m up to 6 (10) m, according to the water supply and grazing intensity. In higher altitudes, on northern slopes or on other more mesic habitats, the coverage can reach up to 40% and other deciduous trees might appear like *Amygdalus bucharica, Celtis caucasica, Cercis griffithii* (Fig. 2.16c)*, Acer semenowii, Fraxinus xanthoxyloides* and the woody liana *Ephedra foliata*. On loess soils, the herbaceous layer is meadow-like and made up of a multitude of perennial and annual grasses, together with large-leaved composites like

Codonocephalum grande and *Cousinia umbrosa*; also Lamiaceae such as *Phlomis bucharica* and *Salvia pterocalyx* occur.

The first geophytes appear at the end of March: *Anemone bucharica, Corydalis aitchisonii* and *Eranthis longestipitata*; later are such showy *Eremurus* species as *E. bucharica, E. olgae* and *E. regelii*, together with *Bellevalia atroviolacea, Bongardia chrysogonum* and *Ungernia trisphaera*. Several smaller woodland areas were protected for centuries by the village people in order to safeguard their pistachio nut-collecting as a considerable source of income. However, during recent decades their area and/or the density of trees have greatly decreased. Removal of trees at first led to higher productivity of the most valuable herb layer but overgrazing favoured less palatable species, in particular wormwoods like *Artemisia prasina, A. diffusa* and *A. oliveriana*. From large areas at higher altitudes, natural vegetation has disappeared because of rain-fed agriculture (lalmi).

2.6.5 **Pistacia atlantica** *Communities (Fig. 2.15: 3b)*

In W-, S- and E-Afghanistan, at altitudes from c. 1000–2000 m a.s.l. and mean precipitation of c. 250–450 mm, the natural vegetation is represented by *Pistacia atlantica* communities. *P. atlantica* is a robust, long-lived tree (Fig. 2.16d) with a thick trunk and a rounded or somewhat flattened crown. Size and coverage of trees as well as the associated species depend strongly on site conditions and on the geographical location. Additional tree species such as *Cercis griffithii* (Fig. 2.16c)*, Fraxinus xanthoxyloides* and *Ficus johannis* occur here and there. Because of the predominating skeletal soils, shrubs and subshrubs, like *Amygdalus spinosissima, Cerasus bifrons, Astragalus* spp. (in particular *A. koshubensis*) and *Artemisia* spp. are often common at the expense of perennial and annual herbs. Some of the common perennial hemicryptophytes are the grasses *Stipa arabica* and *Piptatherum vicarium*, as well as *Salvia leriifolia,* sometimes *Adonis turkestanicum* (Fig. 2.17a).

Among geophytes, the showy *Fritillaria imperialis* (Fig. 2.17b), *Eremurus stenophyllus* (Fig. 2.17c)*,* and *Tulipa* spp. are particularly conspicuous, besides *Anemone biflora, A. petiolulosa, A. tschernjaewii, Corydalis afghanica, Iris stocksii, I. cabulica,* various *Allium* species (Fig. 2.17d) and *Arum korolkowii*. Degradation mainly resulted in open low shrublands dominated by spiny *Astragalus* or by unpalatable *Artemisia* species with an increasing coverage of small, prostrate annuals.

2.6.6 **Amygdalus** *Communities (Fig. 2.15: 3c)*

From c. 2000–2800 m a.s.l., in areas with higher precipitation, longer-lasting snow cover and more moderate summer temperatures, the *Pistacia atlantica* woodlands are gradually replaced by the communities of *Amygdalus kuramica* (Fig. 2.16e) (E-Afgh) and *A. browiczii* (= *A. zabulica)* (SE- to W- Afgh). They reach up to the

Fig. 2.17 (**a**) *Adonis turkestanicum* (Ranunculaceae), a large flowering, perennial *Adonis* of shady slopes and good soils, here near Yarwan, Badakhshan, 2870 m a.s.l. (photo M Keusgen); (**b**) *Fritillaria imperialis* (Liliaceae), a very showy geophyte of montane and subalpine rocky slopes in Iran and Afghanistan (photo I Hedge and P Wendelbo); (**c**) *Eremurus stenophyllus* (Xanthorrhoeaceae), one of the most widespread steppe-lilies of the area, on montane slopes in all Afghan mountain regions (photo I Hedge and P Wendelbo); (**d**) *Allium mirum* (Alliaceae), an endemic geophyte to Afghan mountains with two large leaves and a short stalked huge inflorescence, here from Panshir Valley, 1950 m a.s.l. (photo M Keusgen)

tree line. The trees are bushy, with rounded crowns, and rarely exceed 3–5 m. Other tree species are usually absent but the loose shrub layer includes many species of *Rosa, Colutea, Cerasus, Cotoneaster, Rhamnus, Berberis, Sageretia thea* subsp. *thea, Spiraea, Ephedra* etc. Common herbaceous perennials are, among many others, *Salvia bucharica* and *S. rhytidea, Eremurus aitchisonii* and *E. korshinskyi* (Fig. 2.18a), *Rheum ribes*, large *Ferula jaeschkeana* (Fig. 2.18b) and many *Cousinia* spp. These communities reach up to the timber line, which however, is often obscured by the removal of trees. Overgrazing has often favoured the expansion of thorny cushion subshrubs. In areas where all the cushions and sub-shrubs are removed as brushwood, a final stage of degradation results in an open *Leucopoa karatavica* grassland with low productivity and poor in species.

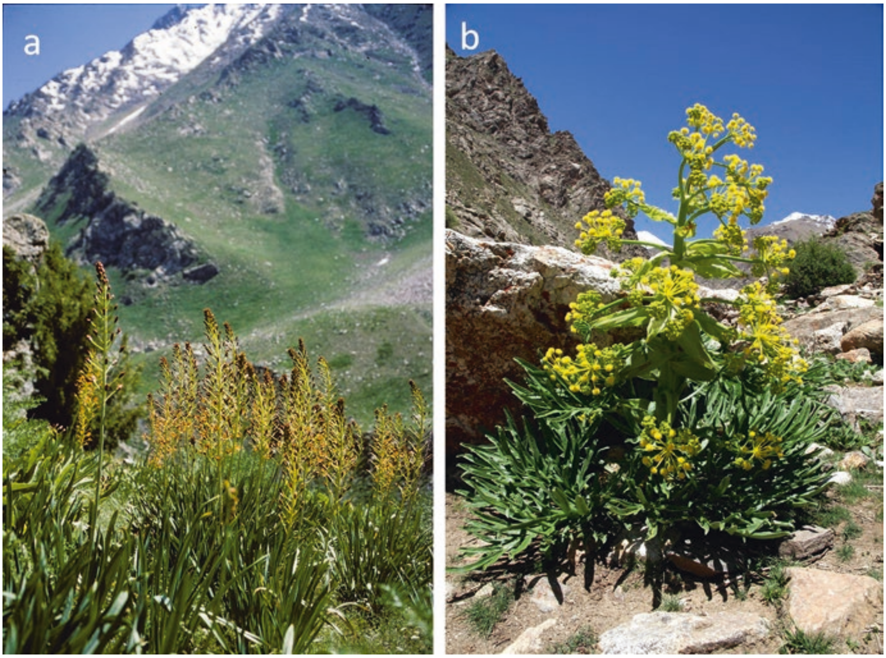

Fig. 2.18 (**a**) *Eremurus korshinskyi* (Xanthorrhoeaceae), another large geophytic steppe, one of many species in Hindu Kush (photo I Hedge and P Wendelbo); (**b**) *Ferula jaeschkeana* (Apiaceae), a huge hapaxanthic herb, related to the old medicinal plant species *F. assa-foetida*, common on montane slopes of Hindu Kush, Parandi Valley, Panshir (photo M Keusgen)

2.6.7 Juniperus excelsa/semiglobosa *Communities (Fig. 2.15: 3d)*

In N-Afghanistan, above c. 1400 m a.s.l. the deciduous *Pistacia vera* woodlands grade into evergreen *Juniperus excelsa* communities (Fig. 2.19a) that form a belt up to the tree line at 2900 m a.s.l. (W-Afgh) to c. 3200 m a.s.l. (NE-Afgh). In altitude, they correspond to the *Amygdalus* communities. They re-occur at higher altitudes in E-Afghanistan, in particular in Paktya, where they replace the *Cedrus* forests in drier areas from c. 2800–3500 m a.s.l. However, due to the different precipitation regimes in both regions, the structure of the shrub-layer and the herbaceous layers varies considerably. In N-Afghanistan, the precipitation is much higher, with approximately 450–1000 mm, most of it as snow; the winter rains are often prolonged until June, but the summer is dry as everywhere in the Irano-Turanian region. These conditions allow a rich shrub, dwarf shrub and herbaceous vegetation to develop, with each layer depending on the others, as long as the slopes are not too steep and unstable.

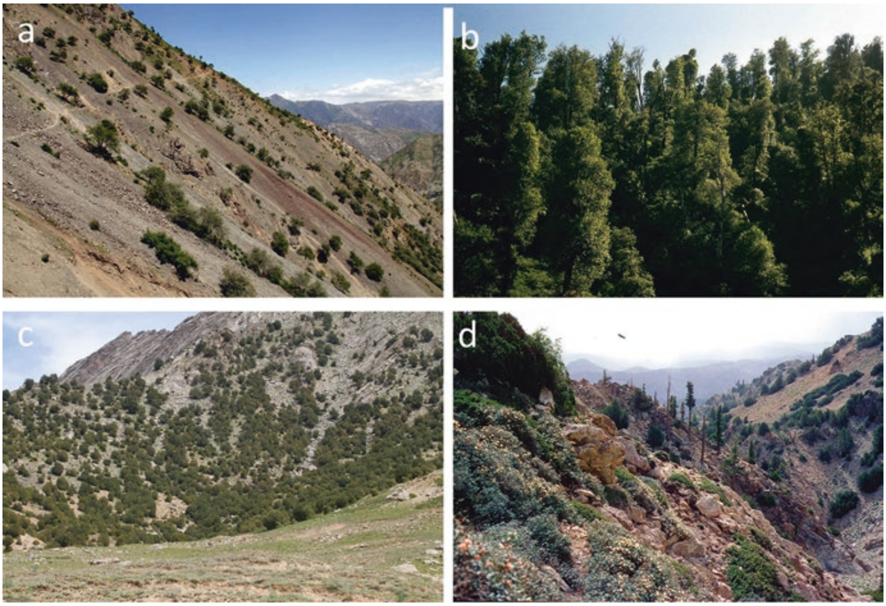

Fig. 2.19 (**a**) Open tree stands of *Juniperus* (*J. semiglobosa, J. seravschanica*) on mountain slopes W of Shingan, 2025 m a.s.l., NE Afghanistan (photo M Keusgen); (**b**) Evergreen oak forest with *Quercus baloot*, Panshir Valley, E Afghanistan (photo M Keusgen); (**c**) Dense high montane *Quercus dilatata* forest at Darah Nur (2100 m a.s.l.), Nangahar prov., E Afghanistan (photo H Freitag); (**d**) Dense Krummholz vegetation under monsoon influenced summer climate with *Rhododendron collettianum* shrubs above Paiwar Kotal (3200 m a.s.l.) with highest climbing trees at tree line (*Cedrus, Picea, Juniperus*), Safed Koh, E Afghanistan (photo I Hedge and P Wendelbo)

Cutting of trees for charcoal production or natural die-back favours the shrubs, and when they are cleared, on deeper soils the herbaceous layer might expand into veritable meadows which are locally harvested for hay. Under optimal conditions, the trees might grow up to 12 m and together with the rich shrub layer the coverage can go up to c. 80%.

In NE- and E-Afghanistan, the common *Juniperus excelsa* is usually accompanied by *J. semiglobosa*. The latter often outnumbers the former species in the subalpine belt. Common shrubs are *Lonicera nummulariifolia* (often as a small tree), *Ephedra equisetina*, different species of *Rosa, Berberis, Colutea, Prunus, Cerasus* and *Cotoneaster*. The shaded ground is loosely covered by thin-leaved, delicate annuals such as *Alliaria petiolata, Geranium rotundifolium, Impatiens parviflora, Lepyrodiclis holosteoides* and *Parietaria lusitanica*. Prominent geophytes are, e.g., *Eremurus furseorum, E. spectabilis* and *Allium*-species like *A. rosenbachianum, Iris microglossa, I. fosteriana,* and many *Gagea* species.

Important hemi-cryptophytic plants are, among others, *Prangos pabularia* and *Codonocephalum grande*. On loess soils, after clearing the trees and shrubs, the latter two species greatly expand in meadows formed by floristically rich and productive substitute communities. In contrast, on slopes covered with scree all layers are much reduced, and deciduous trees like *Celtis caucasica, Fraxinus xanthoxyloides, Acer turkestanicum* and *Amygdalus kuramica* (Fig. 2.16e) widely replace the junipers, while tall hapaxanthic *Ferula* species (Fig. 2.18b) become dominant in the herbaceous layer, together with *Rheum ribes*.

The *Juniperus* communities in E-Afghanistan receive less winter rain but sometimes additional summer rain. Common shrubs are *Ephedra major* subsp. *procera, Ephedra gerardiana* and *Ribes orientale*. The herbaceous layer is dominated by more xerophytic species, like the perennial grasses *Stipa turkestanica, Piptatherum baluchistanicum, Psathyrostachys caduca, Poa* spp., and species of *Cousinia, Ferula* and *Artemisia*. After the destruction of trees, *Artemisia glanduligera* often occupies large areas with thorn-cushion species invading from the subalpsubalpine belt.

2.6.8 *Evergreen Broad-Leaved* Reptonia/Olea *Woodland in E-Afghanistan (Fig. 2.15: 4a)*

Around the basins of Khost and Jalalabad, in areas from about 800–1300 m a.s.l. and rainfall from c. 300–500 mm, the *Reptonia buxifolia-Olea ferruginea* community forms structurally rich woodlands of widely differing coverage. Addional sclerophytic tree and shrub species are *Nannorrhops ritchieana, Gymnosporia royleana, Sageretia thea* subsp. *brandrethiana, Ephedra pachyclada* and *Dodonaea viscosa* which grow together with deciduous trees and shrubs as *Pistacia khinjuk, Acacia modesta*, and *Ebenus stellatus*. A particularly striking feature of these woodlands is the high coverage of perennial, subtropical tussock grasses like *Tetrapogon villosus, Dichanthium annulatum, Cymbopogon parkeri, Hyparrhenia hirta, Heteropogon contortus* and *Aristida cyanantha*; they greatly increase in coverage after destruction of the woody component. Most of them start sprouting with the onset of the summer rains and can give the landscape the aspect of a lush tropical savannah between July and September, whereas in the same period in interior Afghanistan, because of the climatic dryness, most plant life activity has completely ceased. This may partly also result from the fact, that a number of those grasses are C4-grasses with very high photosynthetic capacities at high temperatures.

2.6.9 *Sclerophyllous and Lauriphyllous Oak Forests in E-Afghanistan (Fig. 2.15: 4b)*

The *Quercus baloot* communities occur adjacent to the former in altitudes from 1300–2100 m a.s.l. and rainfall from c. 350–600 mm. Depending on water supply and soil conditions, they might form forests, with the individual trees up to 15 m high (Fig. 2.19b), or shrubby woodlands, but most of the latter are caused by intensive cutting of twigs for feeding domestic animals during winter (Breckle and Kull

1971), and by selective felling of whole trees as *Quercus baloot* yields very valuable fire wood (Freitag 1982). Accompanying woody species are the trees *Amygdalus kuramica* and *Pistacia khinjuk*, the lianas *Lonicera griffithii* and *Rosa brunonii*, and the shrubs *Daphne mucronata* (, *Plectranthus rugosus, Perovskia atriplicifolia* and *Salvia cabulica*. These forests and woodlands have disappeared from large areas, and their place is taken by shrub communities of *Perovskia atriplicifolia* and *Sophora griffithii*, or, when even more degraded, by different *Artemisia* (e.g., *Artemisia kurramensis*) communities. The westernmost remnants of *Quercus baloot* forests have survived in the Panjshir valley to the N of Kabul, and a few tall trees were observed at Top Dara above the Kohe Daman basin near Charikar. Historical records of *Q. baloot* also exist from the Latahband pass, some 25 km E of Kabul (Breckle and Kull 1971). It might well be that those forests covered most of this area centuries ago.

In the semi-humid to humid areas of Nuristan and around the Safed Koh, from c. 1900 m a.s.l. upwards, with higher amounts of summer rain, *Q. baloot* is replaced, at first by the mesophytic *Q. dilatata* (Fig. 2.19c) and higher up, about 2900 m a.s.l., by *Q. semecarpifolia* which forms dense forests of 8–20 (25) m in height. Common associates of these true Himalayan forests are, e.g., the deciduous trees *Juglans regia, Celtis caucasia, Acer turkestanicum, Diospyros lotus, Pyrus pashia*, the woody climbers *Rosa brunonii* and *Lonicera griffithii*, and shrub species like *Corylopsis jacquemontiana, Indigofera gerardiana, Cotoneaster rosea, C. aitchisonii* and *Rubus niveus*. In higher altitudes, *Taxus contorta, Viburnum cotinifolium* and *Abelia triflora* have been observed. The luxuriant herbaceous layer includes other mesophytic Himalayan species, like *Strobilanthes urticifolius, Nepeta erecta, Polygonum amplexicaule, Rumex dentatus, Salvia nubicola*, the grasses *Brachypodium sylvaticum, Piptatherum munroi* and *Piptatherum aequiglume*, several annual species of *Impatiens* and even hygrophilous tall ferns like *Dryopteris ramosa, Dryopteris stewartii, Diplazium tomentosum, Dreparia (Athyrium) allantodioides* and *Pteris cretica*. Lianas are *Rosa brunonis, Hedera helix* and *Clematis*. Under less humid conditions, the evergreen oaks form mixed stands with the tall *Pinus wallichiana*.

2.6.10 Temperate Coniferous Forests and Woodlands in E-Afghanistan (Fig. 2.15: 5)

Woodlands and forests of different Himalayan conifers gradually replace the broad-leaved evergreen forests when mean precipitation is too low, or when the growth period becomes too short at higher altitudes. This also explains the occurrence of broad transitional zones. In altitudes from 2100–2500 m a.s.l., *Pinus gerardiana* woodlands (Fig. 2.10) alternate with the *Quercus baloot* communities. The trees are usually 5–12 m tall and might cover 15–70% of the ground. Locally these woodlands are protected (similar to the *Pistacia vera* woodlands) for "nut" collecting.

The seeds are important in the internal and external trade. Due to strong root competition, intact plant communities are rather poor floristically, but in natural openings and after logging a rather rich shrub layer might be found with *Sophora griffithii, Amygdalus spinosissima, Caragana ulicina, Berberis calliobotrys, Daphne mucronata, Cotoneaster afghanicus, Rosa ecae* and other Rosaceae.

Higher up, from 2500–3100 m a.s.l. in mountain systems that receive c. 450–600 mm mean precipitation, mainly in winter, *Cedrus deodara* communities take the place of *Pinus gerardiana* woodlands in between the more xerophytic *Juniperus* woodlands (Fig. 2.19a) and the mesophytic, mixed *Quercus-Pinus wallichiana* forest communities. On steeper slopes, the *Cedrus deodara* communities occur as woodlands, but under optimum conditions, the usually mono-specific tree layer may be 25–35 m tall and reach coverage of 80%. The thin shrub layer is more or less restricted to clearings and usually consists of *Lonicera quinquelocularis, Berberis calliobotrys, Cotoneaster* spp. and *Ribes orientale*. The herbaceous layer is also open and varies much according to water supply and shade. Usually, it includes a prominent grassy component, with *Carex cardiolepis, Piptatherum angustifolium* and *Poa aitchisonii*. As *Cedrus deodara* provides the most valued timber wood in Afghanistan and adjacent Pakistan, the forests have been exploited or over-exploited for decades and are almost completely destroyed in most of the area. They are replaced by stable but poor *Artemisia* communities with prevailing *A. bicolor* and/or *A. glanduligera*.

At the same altitude but with a much higher summer rainfall, usually above the broad-leaved evergreen oak forests, in a few more humid parts of Nuristan and on the upper slopes of the Safed Koh, mixed *Abies-Picea* forests are distributed. They consist of *Abies pindrow* (upper montane), *A. spectabilis* (subalpsubalpine) and *Picea smithiana;* they are 15–30 m high and often include individual trees of *Quercus semecarpifolia* and *Pinus wallichiana*. Due to the shade in intact communities, the shrub and herbaceous layers are poorly developed. They contain a number of mesophytic species like *Pertya aitchisonii, Salvia nubicola, Nepeta pinetorum, Saussurea afghana, Rumex nepalense, Lilium polyphyllum* and *Cicerbita aitchisoniana*. On unstable slopes and in small valleys close to the tree-line the conifers are locally replaced by a *Betula jacquemontii* community.

2.6.11 Subalpine **Juniperus-** *and* **Rhododendron** *Scrub (Krummholz, Elfinwood) (Fig. 2.15: 6)*

In the wettest parts of Nuristan, from the timberline at 3200–3300 m a.s.l. up to c. 4000 m a.s.l., *Abies spectabilis, Picea* and *Quercus semecarpifolia* are replaced by a dense 1 m high *Juniperus squamata* community (Schickhoff 2005). Sub-ordinate components of this dense Krummholz thicket (Fig. 2.19d) are *Rosa macrophylla, Ribes alpestre, R. villosum, Rubus irritans, Lonicera webbiana* and *Rhododendron collettianum* (Fig. 2.19d). The herbaceous layer is similar to that of the subalpine *Abies* forest.

On lower sites at the Safed Koh and in the upper Laghman area, just below the treeline, in the upper montane and subalpine belt, the very rare *Rhododendron afghanicum* occurred, but is most probably now extinct at this site in Afghanistan (Breckle 1972; Hedge and Wendelbo 1970b; Larsen 2009; Muhammad et al. 2017).

Where summer rain is somewhat less abundant and *Abies* is replaced by *Picea* at the timberline, as in most parts of Nuristan and around the Safed Koh, the *Juniperus communis* subsp. *nana* community takes the place of the former. It is only 40–60 cm high and has a patchy structure, with the clearings covered by thorn-cushions like *Cousinia kuramensis, Cicer macracanthum, Onobrychis spinosissima* and numerous hemicryptophytes related to or identical with those of the cushion shrub communities.

2.6.12 Subalpine Thorn-Cushion Shrublands (Fig. 2.15: 7a)

Plant communities dominated by thorn cushion plants (Fig. 2.20) represent a broad upper vegetation belt in higher mountain systems of Afghanistan where summer rain is absent and where the soil water supply completely depends on moisture from melted snow. It is part of a vast tragacanthic belt from Spanish (Sierra Nevada) and Moroccan mountains (Atlas) until the Himalaya. These very peculiar shrublands extend from the timberline located at c. 2800–2900 m a.s.l. in the W parts and 3300–3500 m a.s.l. in the NE and E parts up to 3800 to 4000 m a.s.l. and play an important role as summer pastures. Most predominant species belong to spiny species of *Cousinia, Astragalus* (Fig. 2.20a,c)*, Acantholimon* (Fig. 2.20a)*, Onobrychis* (Fig. 2.20b)*, Acanthophyllum* and *Cicer*, but species composition varies between the different mountain systems, and the proportion of endemics is particularly high. Here the evolution of many of those tragacanthic species has taken place. Other common dwarf shrubs are *Artemisia* spp., *Ephedra gerardiana, Rhamnus prostrata*, and *Krascheninnikovia ceratoides*. The herb layer includes many palatable grasses, as e.g., *Piptatherum laterale, Poa araratica, Koeleria* spp. and *Festuca* spp. Together with many legumes, such as species of *Astragalus, Oxytropis* and *Trigonella.* It provides important grazing resources, together with *Platytaenia lasiocarpa, Trigonella koelzi, Rindera neubauerei, Winklera silaifolia* etc. One of the most striking plants is the steppe lily *Eremurus kaufmannii*. Most likely, the often strong grazing pressure has resulted in a marked increase in thorn-cushion plants and in the tufted grass *Leucopoa karatavica* beyond their original occurrence.

2.6.13 Alpine Semi-deserts, Steppes and Meadows (Fig. 2.15: 7b)

The borderline between subalpine and the alpine vegetation is not readily discernible, except in the wetter parts of E-Afghanistan where it is marked by the upper border of the juniper scrub. In most areas, the thorn-cushion plants of the subalpine

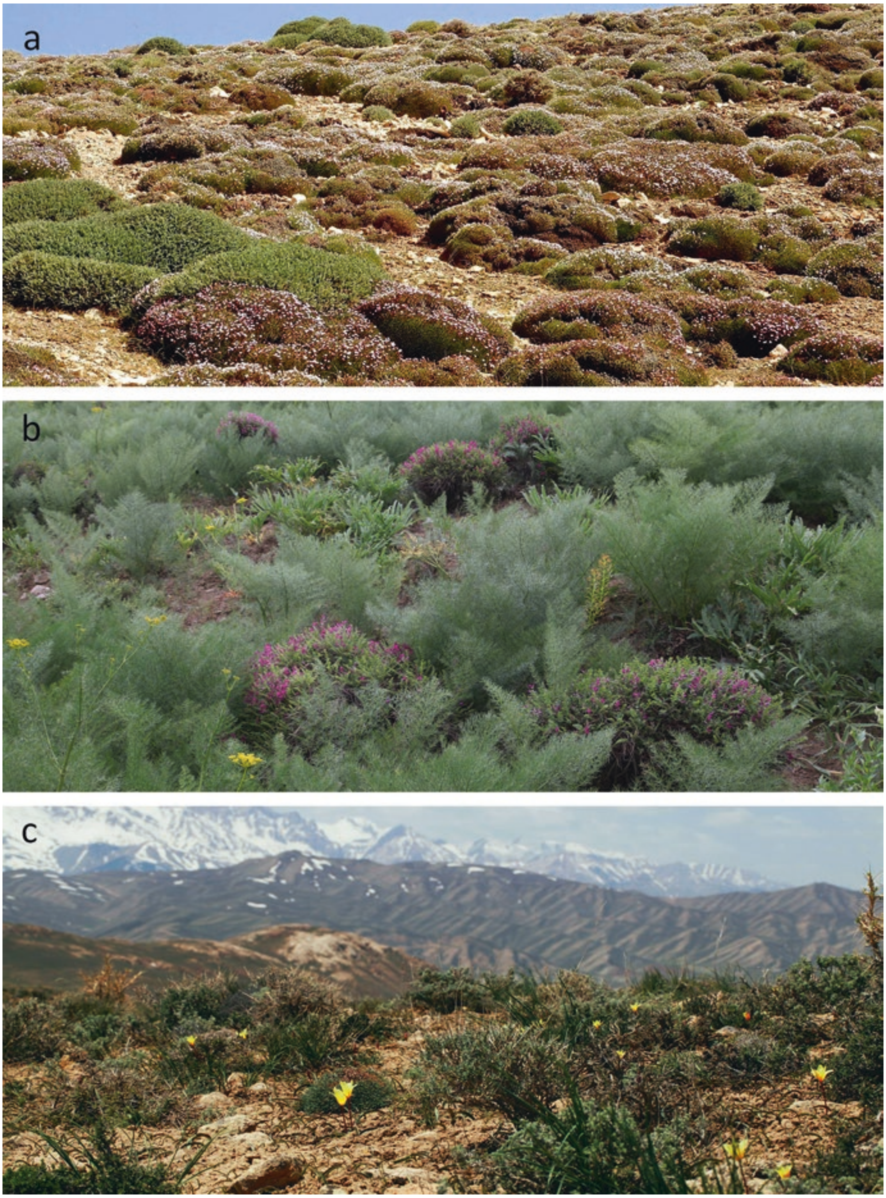

Fig. 2.20 (**a**) Thorn-cushion shrub-land at Dashte Nawor (3300 m a.s.l.) with *Acantholimon* and other tragacanthic species (photo H Freitag); (**b**) *Onobrychis cornuta* (Fabaceae), a typical tragacanthic cushion shrub, widely distributed in the Flora Iranica region, here with many giant herbs, like *Prangos pabularia* (photo M Keusgen); (**c**) Open subalpine sub-shrub vegetation with many *Artemisia* species, with *Kraschennenikovia, Astragalus* and *Acantholimon* and many geophytes, being summer grazing patches of nomads (photo M Keusgen)

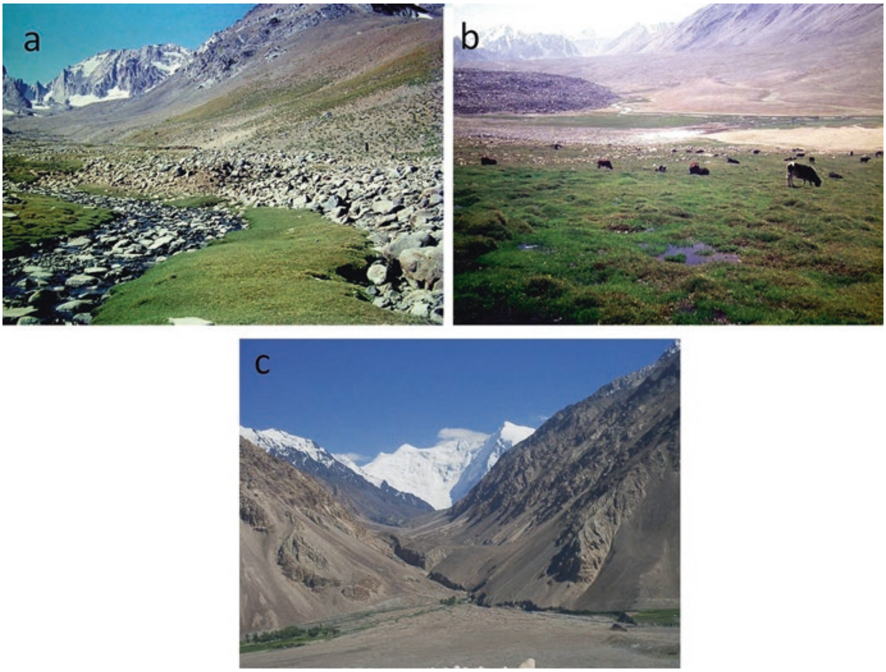

Fig. 2.21 (**a**) Vegetation mosaic at a small creek with snow melt water with patches of *Kobresia* meadows and open scree vegetation, 4200 m a.s.l., Fuladi Valley, Kohe Baba (photo SWB); (**b**) Yaks grazing on high alpine pastures and snow patches near Wazit pass, Wakhan, 4400 m a.s.l. (photo SWB); (**c**) The E Hindu Kush range with Noshaq (7480 m a.s.l.), seen from Tajik side, indicating all higher elevational belts and specialized irrigation systems in Abe Panj Valley of E Afghanistan (photo M Wennemann)

belt are step-wise replaced by smaller-sized species of the same genera, and also the species composition of the herbaceous layer changes gradually. Genuine alpine meadows dominated by grasses and a greater variety of herbs are restricted to the C- and E-Hindu Kush and the Pamirs because these areas receive more summer rainfall (Huss 1978; Breckle 2004). Consequently, they are heavily used for summer pasture during the short summer (2 months), usually by nomad (koochi) people. Elsewhere, even on deeper soils, the vegetation is rather open, except for wet sites along creek borders (Fig. 2.21a), head-waters and swamps (Fig. 2.21b) below melting snow fields; there alpine meadows exist. Because of the steep topography, delayed soil formation, and the locally long-lasting snow cover, even small areas might show a high diversity of plant communities. Vast stretches look almost devoid of vegetation as they consist of rocks, blocks and scree. The total number of species occurring in the upper belts (above 3900 m a.s.l.) in the Hindu Kush and Afghan mountains is about 542 vascular plant species from 188 genera (Breckle et al. 2018), see also Figs. 2.8 and 2.11.

2.6.14 Nival Belt (Fig. 2.15: 8)

Approaching the snow line at c. 4800–5000 m a.s.l. (N exposed slopes) to 5400 m a.s.l. (S exposed), everywhere the coverage and numbers of species decrease significantly. In the nival belt single plants survive amidst bare rock and on scree slopes (Fig. 2.21c). However, on S-facing rocky slopes in the Hindu Kush even dwarf woody plants like *Juniperus semiglobosa* and *Lonicera microphylla* can be found above 5000 m a.s.l., as well as the fern *Cystopteris dickieana* (Breckle 1974, 1988). There are almost 40 species recorded from above 5000 m a.s.l. (Breckle 1974, 2017, 2019; Breckle et al. 2017, 2018), see Table 2.3 and Fig. 2.8. The highest altitudinal record of a vascular plant in Afghanistan is the beautiful *Primula macrophylla* in the C-Hindu Kush at 5600 m a.s.l. *Sibbaldia cuneata* is also known from about 5500 m a.s.l. Several other Brassicaeae also reach high alpine to subnival elevations, like *Solmslaubachia flabellata*, and *S. surculosum* or *Draba*. Mosses and lichens occur on all rocky substrates – even up to the highest peaks. Among the bryophytes, 6 species are recorded from 4750 m a.s.l. and above, with *Didymodon luridus* at 5630 m a.s.l. being the highest recorded. A coherent nival belt occurs only in the higher parts of the Pamirs, the Hindu Kush and the Kohe Baba range.

The typical decrease in number of species (Figs. 2.8 and 2.11) with increasing altitude for various mountains in SW and C-Asia was shown by Breckle (1974) and by Noroozi et al. (2008) (see also Körner 1999). The average snow line in the W-Hindu Kush is at c. 4900–5200 m a.s.l., in Wakhan between 5000 and 5300 m a.s.l. (see also Grötzbach and Rathjens 1969; Rathjens 1972, 1978; Breckle and Frey 1976a, b); in some parts, as in the Salang region, it is below 4800 m a.s.l. The eternal snow and cover of glaciers in summer often shows the typical "Penitentes" formation resulting from the high solar radiation sometimes with reddish snow-algae (*Chlamydomonas nivalis*).

Briefly, we have to mention the **azonal vegetation** (Figs. 2.9a,b and 2.15) with special soil conditions or additional water supply along creeks, ponds and lakes. The delimitation is often quite distinct as can be seen in meadows fed by snow melt water (Fig. 2.21a,b).

2.6.15 Vegetation Profiles

In the C-Afghan mountains, the altitudinal zonation of the vegetation along a profile between Zaranj and Amu Darya via Kohe Baba (Fig. 2.22), shows a relatively simple structure (Breckle et al. 2013). The lowlands of Sistan and the Registan in the S and SW-Afghanistan harbour *Calligonum-Stipagrostis-, Haloxylon salicornica-* and Chenopodiaceae-semi-deserts. With 10–12 thermal vegetation months and very sparse rainfall (<100 mm), the climate is extremely harsh. This vegetation formation includes all areas below 950 m a.s.l. In the foothill areas between 950 and 1200 m a.s.l., a narrow belt of a semi-desert formation of *Amygdalus* shrubs exists.

Table 2.3 The highest plant species in the Afghan mountains (Hindu Kush) from 4800 m a.s.l. upwards; the nival flora (after Breckle et al. 2018)

Family	Species	Max (m)
Pottiaceae (Bryo.)	*Didymodon luridus* Hornsch.	5630
Primulaceae	*Primula macrophylla* D. Don var. *macrophylla*	5600
Asteraceae	*Allardia (Waldheimia) tridactylites* (Kar.&Kir.) Sch.-Bip. ssp *tridactylites*	5400
Rosaceae	*Sibbaldia cuneata* Kunze	5400
Saxifragaceae	*Saxifraga hirculus* L. ssp *alpina* (Engler) Podl.	5400
Asteraceae	*Saussurea glacialis* Herder	5300
Saxifragaceae	*Saxifraga komarovii* Los.	5300
Apiaceae	*Aulacospermum stylosum* (C.B.Clarke) Rech.f. & H.Riedl	5200
Asteraceae	*Psychrogeton andryaloides* (DC.) Novopokr. var *denudans* (Botsch.) Grierson	5200
Asteraceae	*Saussurea gnaphalodes* (Royle) Sch.-Bip.	5200
Brassicaceae	*Solmslaubachia flabellata* (E.Regel) Al-Shehbaz	5200
Lamiaceae	*Nepeta pamirense* Franch.	5200
Ranunculaceae	*Delphinium brunonianum* Royle	5200
Woodsiaceae (Pter.)	*Cystopteris fragilis* Bernh. ssp *dickieana* (Sim.) Hook.f.	5100
Cyperaceae	*Carex pseudofoetida* Kük. In Ostend. ssp *afghanica* Kukkonen	5100
Asteraceae	*Leontopodium ochroleucum* Beauv.	5100
Boraginaceae	*Eritrichium canum* (Benth.) Kitam.	5100
Brassicaceae	*Chorispora macropoda* Trautv.	5100
Brassicaceae	*Draba altaica* (C.A.Mey.) Bunge	5100
Brassicaceae	*Smelowskia calycina* (Willd.) C.A.Mey.	5100
Brassicaceae	*Solmslaubachia surculosa* (N.Busch) D.German & Al-Shahbaz	5100
Caryophyllaceae	*Silene himalayensis* (Rohrb.) Majundar ssp. *himalayensis*	5100
Grimmiaceae (Bryo.)	*Coscinodon cribrosus* (Hedw.) Spruce	5100
Lamiaceae	*Nepeta glutinosa* Benth.	5100
Lamiaceae	*Nepeta paulsenii* Briq.	5100
Lamiaceae	*Thymus linearis* Benth. ssp *linearis*	5100
Poaceae	*Alopecurus himalaicus* Hook.f.	5100
Polygonaceae	*Rheum tibeticum* Maxim.	5100
Rosaceae	*Pentaphylloides dryadanthoides* (Juz.) Sojak	5100
Rosaceae	*Potentilla desertorum* Bunge	5100
Brassicaceae	*Draba korshinskyi* (O.Fedtsch.) Pohle	5060
Cyperaceae	*Carex nivalis* Boott.	5050
Brassicaceae	*Allardia tridactylites* (Kar.&Kir.) Sch.-Bip. ssp *glabra* (Decne.) Podl.	5050
Apiaceae	*Ligusticum afghanicum* Rech.f.	5000
Asteraceae	*Psychrogeton olgae* (Regel & Schmalh.) Nevski	5000
Brassicaceae	*Solmslaubachia linearis* (N.Busch) Al-Shehbaz	5000
Caryophyllaceae	*Cerastium cerastioides* (L.) Britton	5000

(continued)

Table 2.3 (continued)

Family	Species	Max (m)
Encalyptaceae (Bryo.)	*Encalypta vulgaris* Hedw.	5000
Fabaceae	*Astragalus melanostachys* Benth. (§ *Brachycarpus* Boriss.)	5000
Fabaceae	*Oxytropis platonychia* Bunge	5000
Grimmiaceae (Bryo.)	*Grimmia laevigata* (Brid.) Brid.	5000
Primulaceae	*Androsace villosa* L. (*s.l.*)	5000
Ranunculaceae	*Ranunculus shaftoanus* (Aitch. & Hemsl.) Boiss.	5000
Rosaceae	*Potentilla gelida* C.A.Mey.	5000
Salicaceae	*Salix karelinii* Turcz.	5000
Saxifragaceae	*Saxifraga sibirica* L.	5000
Asteraceae	*Spathipappus griffithii* (C.B.Clarke) Tzvelev	4950
Asteraceae	*Ajania tibetica* (Hook.f. & Thoms.) Tzvelev	4900
Bryaceae (Bryo.)	*Bryum dichotomum* Hedw.	4900
Ditrichaceae (Bryo.)	*Distichium inclinatum* (Hedw.) Bruch & Schimp.	4900
Poaceae	*Koeleria litvinowii* Domin	4900
Poaceae	*Trisetum clarkei* (J.D.Hook.) R.R.Stewart	4900
Fabaceae	*Astragalus chargusanus* Freyn (§ Caprini DC.)	4900
Onagraceae	*Chamerion angustifolium* (L.) Holub	4900
Polygonaceae	*Oxyria digyna* (L.) Hill	4900
Poaceae	*Koeleria litvinowii* Domin	4900
Poaceae	*Trisetum clarkei* (J.D.Hook.) R.R.Stewart	4900
Apiaceae	*Semenovia radiata* (Rech.f. & H.Riedl) Alava	4800
Asteraceae	*Artemisia leucotricha* Ladygina	4800
Asteraceae	*Aster flaccidus* Bunge	4800
Asteraceae	*Erigeron petroiketes* Rech.f.	4800
Asteraceae	*Leontopodium nanum* (Hook.f.& Thoms.)Hand.-Mzt.	4800
Asteraceae	*Senecio korshinskyi* Krasch.	4800
Boraginaceae	*Pseudomertensia primuloides* (Dcne.)Riedl	4800
Brassicaceae	*Christolea crassifolia* Cambess.	4800
Brassicaceae	*Crucihimalaya crassifolia* (Hook.f.& Thoms.) Al-Shebaz et al.	4800
Brassicaceae	*Didymophysa fedtschenkoana* E.Regel	4800
Brassicaceae	*Erysimum erosum* O.E.Schulz	4800
Campanulaceae	*Campanula cashmeriana* Royle	4800
Crassulaceae	*Rhodiola recticaulis* Boriss.	4800
Cyperaceae	*Kobresia royleana* (Nees)Boeck.	4800
Gentianaceae	*Aliopsis pygmaea* (Regel & Schmalh.) Omer & Qaiser	4800
Juncaceae	*Luzula spicata* (L.) Don ssp. *mongolica* Novikov	4800
Parnassiaceae	*Parnassia palustris* L.	4800
Plumbaginaceae	*Acantholimon diapensioides* Boiss.	4800
Poaceae	*Festuca pamirica* Tzvelev	4800
Primulaceae	*Primula capitellata* Boiss.	4800

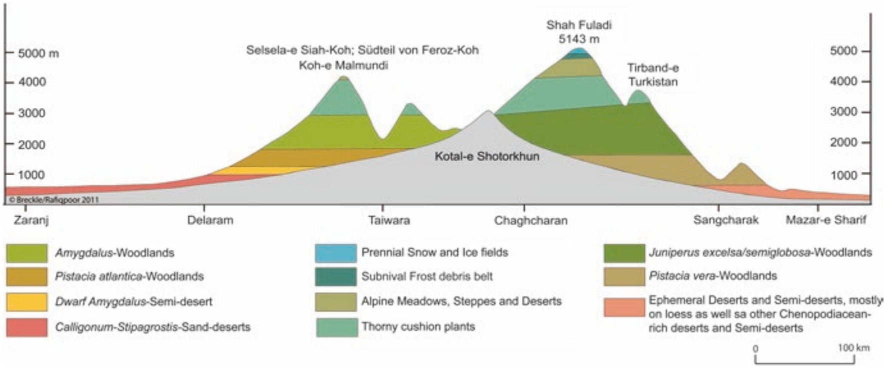

Fig. 2.22 Profile of vegetation belts along the western parts of Afghan Hindu Kush (After Breckle and Rafiqpoor 2010)

This formation is very typical only for W-, SW- and parts of E-Afghanistan. Along the major valleys (Hari Rud, Khash Rud, Helmand) this formation extends far into the mountain body. The *Amygdalus*-shrubs grow for 7–9 thermal vegetation months and in fairly arid conditions (P = 150–250 mm). Dominant shrubs are *Amygdalus cf. eburnea* in the W and the above-mentioned valleys, and *Amygdalus cf. erioclada* in the E area.

At heights of 1200–1600 m a.s.l., the altitudinal belt of the deciduous trees and open *Pistacia atlantica*-woodlands occurs in the form of a wide semi-circle between Herat and Kabul (mostly *P. atlantica* subsp. *cabulica*; at lower level in the E *P. khinjuk*).

Cercis griffithii, found on the edge of the Hari Rud valley and in the vicinity of Kabul (Fig. 2.16c), also belongs to this altitudinal belt. The climate is, with a thermal vegetation period of 7–9 months, rather warm and rainfall increases up to about 250–350 mm. Between 1600/1800 and 2900 m a.s.l., the altitudinal belt of the *Amygdalus*-woodlands (Fig. 2.16e) follows with c. 5–6 thermal vegetation months and under rather semi-humid conditions (P = 400–500 mm).

Their distribution area of the *Amygdalus*-woodlands penetrates along the Ghorband-, Salang- and Panjir valleys in the Hindu Kush mountains. Dominant species are *Amygdalus browiczii* (in W), A. *kuramica* (E, SE) and *Pistacia atlantica* (E, Fig. 2.16d). In the upper parts of this altitudinal belt, with increasing rainfall and a further shortening of the thermal growing season, isolated trees may occur on the SW slopes of the C-Afghan mountains at about 2900 m a.s.l., at the potential timberline – which hardly ever is visible. This formation gradually leads to the formation of the typical thorn-cushion plants, a belt between about 2900–3600 (4000) m a.s.l. Here, with a markedly short thermal growing season and even semi-humid conditions, *Onobrychis, Acantholimon, Artemisia, Ephedra* and various species of *Astragalus* dominate. The altitudinal belt of the alpine vegetation, found roughly between 4000 and 4500 m a.s.l., is a mosaic of semi-deserts and steppe with meadow patches. Above 4500 m a.s.l. with a very short thermal vegetation period and under relatively humid conditions, the narrow subnival belt is situated. The all year-round cold-humid subnival belt with frost debris extends in the C-Afghan mountains from c. 4500 m a.s.l. almost up to the summit regions of the Kohe Baba. The very narrow nival belt is concentrated only at the summit regions of the Kohe Baba (Shah Foladi: 5050 m a.s.l.), where, only on the main N facing slopes, small glaciers and snow patches persist in summer. In the Afghan mountains, the availability of moisture in the altitudinal belts above the timberline is not a consequence of high rainfall but results from the year-round low temperature which restricts the potential evapotranspiration (PET).

As indicated above, the altitudinal vegetation belts are in accordance with the asymmetric arrangement of climatic altitudinal zones (Breckle and Rafiqpoor 2019). Coming from the nival and subnival belts, we arrive, on the NE slopes of the mountains at about 4000 m a.s.l., in the altitudinal belt with the upper-most thorn-cushion shrubs. This zone is confined from the top as well as from bottom. Their altitudinal limits lie, compared to the SW side of the mountain, about 100–300 m higher. The altitudinal belt of the relatively uniform *Juniperus excelsa* open forest on the N slope of the mountain extends c. 1700–1800 m in amplitude. A corresponding counterpart of these forests is absent on the SW side of the mountain as well as in many intra-montane basins and valleys. A drier formation of *Amygdalus* woodland replaces it (see above). The reason for this is probably the slight increase in rainfall at the N-side of the mountain (c. 500–1200 mm depending on the region and exposition, Freitag 1971a) and a reduced average solar radiation as a result of the so-called crest-asymmetry (Klaer 1974, 1977), a special feature of the high mountains of the winter rain sub-tropics.

The *Juniperus excelsa*-open forests change downwards at about 1600 m a.s.l. into the altitudinal belt of the *Pistacia vera*-community (Fig. 2.16b), specific to the northern slopes of the C Afghan mountains. A shrubby *Amygdalus* formation of the lower elevations is not developed here, because the somewhat more favourable moisture supply is sufficient for the growth of *Pistacia*-woodlands. Below 600 m a.s.l., the climate for the growth of a *Pistacia vera*-community is obviously too dry. From here to the N, the ephemeral semi-deserts of the loess zone start, often rich in Chenopodiaceae, and they extend up to the Amu Darya.

Different and quite complicated (see Breckle and Frey 1974) is the altitudinal zonation of the climate and vegetation on the E side of the Hindu Kush and the Safed Koh, where the influence of the Indian summer monsoon is apparent. In Fig. 2.23 the slightly complicated altitudinal belts of vegetation along a profile between Jalalabad and the Amu Darya is schematically depicted.

In the semi-arid C part of the Jalalabad basin (P = <150–300 mm), under a long to very long thermal growing season, a dry quasi-tropical vegetation of *Zizyphus-Acacia*-community with grasses is developed. This community covers the entire basin, as well as its surrounding mountains in an altitudinal belt between 500 and 800 m a.s.l. Next up in the E, especially in Paktya province, also an area with a long thermal vegetation period but with subhumid conditions, between 800 and 1300 m a.s.l., an altitudinal belt of a sclerophyllous vegetation type with *Reptonia buxifolia* is found, which in its upper section is mixed with *Olea ferruginea*. In the

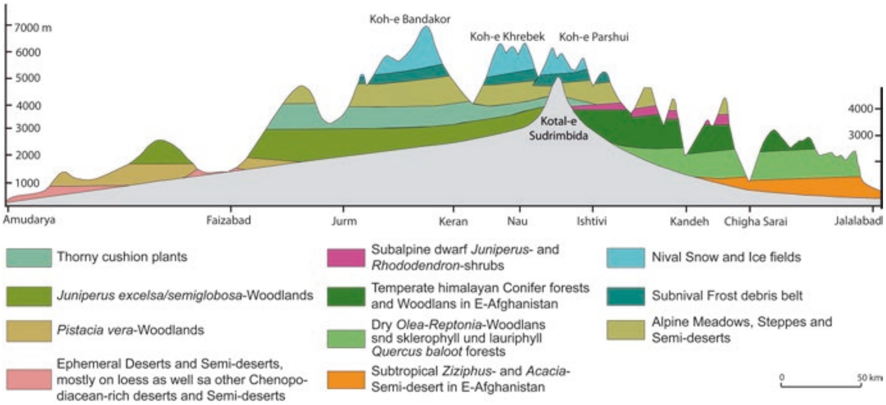

Fig. 2.23 Profile of vegetation belts along the eastern parts of Afghan Hindu Kush (After Breckle and Rafiqpoor 2010)

drier parts of this vegetation belt in the W a plant community of *Pistacia khinjuk* and *Salvia cabulica* is developed between 800 and 1100 m a.s.l. This altitudinal belt changes upwards, with a fairly sharp border, into the typical community of *Quercus baloot* (Fig. 2.19b) growing under a relatively long thermal growing season and sub-humid conditions. Its altitudinal distribution ends at around 2100 m a.s.l. and alters, with decreasing precipitation, towards the W into an *Amygdalus* woodland in the regions W of Kabul. The last stands of *Quercus baloot* to the west are found in Charikar, Tangi Gharu and the Lataband pass east of Kabul (Freitag 1971a; Breckle 2007). In the moist parts of the E slopes, above the altitudinal belt of *Q. baloot* with 5–6 thermal vegetation months and in fairly humid conditions, we find dense forests of *Q. dilatata* (Fig. 2.19c). In drier sites further W and in the inner valleys, the *Quercus baloot*-forests are replaced upwards by *Pinus gerardiana* forests. *Quercus dilatata* and *P. gerardiana* forests merge at about 2400 m a.s.l., depending on the moisture supply, either into the *Quercus semecarpifolia* forests (further E) or to the *Cedrus deodara* forests (further W). The two latter forest types whose growth climates possess a wide hygrothermal amplitude (3–6 thermal and 7–12 hygric vegetation months), lead at about 2900 m a.s.l. into the *Pinus-Abies* forests of the cool moist upper-montane belt (2900–3300 m a.s.l.). Under semihumid conditions, and by an always intermediate to short thermal growing season, *Juniperus* forms the upper timberline both on the E side of the C-Hindu Kush, as well as on Safed Koh. The *Juniperus* forest of the E forms a narrow altitudinal belt between 3300 and 3500 m a.s.l. This formation changes upward under the decrease in temperature to thorn-cushion plant formations, which occupy, under the short to very short thermal growing season, an altitudinal range between 3500 and 4000 m a.s.l. on the W side of the mountain.

On the humid E side of the mountains (and in Afghanistan only there) at the foot of this altitudinal level, i.e. in the vicinity of the tree line, a narrow belt of Krummholz formations with shrubby *Juniperus* and/or *Rhododendron* (Fig. 2.19d) is developed.

The centre of the altitudinal belt of alpine mats lies between 4100 and 4600 m a.s.l. Above 4600 m a.s.l. begins the subnival frost debris belt with a very short thermal growing season. The latter changes roughly above 5100–5200 m a.s.l. into the vegetation-free nival belt with permanent snow and glaciers and only isolated sites suitable for plant growth.

Even in the C-Hindu Kush, all ecological altitudinal limits on both sides of the mountains have an asymmetric structure. On the N side of the mountain the snow line is at c. 4800–5000 m a.s.l., on the S side some hundred m higher. Other ecological altitudinal limits lie, in contrast to the humid SE side of the mountain, at least 200–400 m lower. Also along this profile the arrangement of the vegetation belts on the N flank of the Hindu Kush is simpler than on its SE side. On the N flank of the mountain, below the potential timberline there, three distinct altitudinal belts are developed on top of each other. The altitudinal belt of thorn cushion sub-shrubs is followed lower down by the altitudinal belt of the *Juniperus*-open forests (Fig. 2.19a), then by the *Pistacia vera*-community which changes at about 800–600 m a.s.l. into the "steppe" and semi-deserts of the loess zone in the N.

2.7 Conservation

The Year 2010 was declared the International UN-Year of Biodiversity. SW-Asia is a major area for the wild progenitors of crop plants. For millennia this has been known, as demonstrated by the list of economic plants mentioned in the Holy Quran, as well as in the Bible (Musselman 2007; Barthlott et al. 2016; Barthlott 2018; Barthlott and Rafiqpoor 2018). More than 80 plant species are mentioned in the Bible or Quran. Afghanistan shares a great deal of this natural heritage of fruits, grains, grasses, trees, flowers, and fragrances. A more stable political situation in the future would greatly help Afghanistan to develop a sound and sustainable agricultural system, as well as a system of natural protection areas including National Parks and/or Biosphere reserves to conserve the country's high biodiversity and mountainous vegetation patterns. There have been several attempts to establish a regime of nature conservation but the long war against the Soviet Union and the subsequent civil war situation did not yet allow these goals to be achieved.

The various natural vegetation formations of the Hindu Kush represent a rich pattern. Land-use (agriculture, grazing, browsing, fuel collecting, mining, roads and settlements) changes the natural plant cover to a great extent (Eswaran et al. 2001; Grötzbach 1982). The rich landscape and ecosystem patterns need to be conserved by a system of nature conservation areas. This was already proposed by Petocz and several co-workers (Petocz and Skogland 1974; Petocz and Larsson 1977; Petocz et al. 1978; Shank and Larsson 1977; Shank et al. 1977). Here we give a short description of the proposed protected areas for the long term, being aware that this goal may be reached only in the distant future, and probably rather modified according to the realistic possibilities of a future Afghan nature conservation agency.

The system of protected areas should represent most of the typical landscapes and vegetation formations of the country, which then also are the basis for game reserves and wildlife conservation areas. However, we have to be aware that Afghanistan is a country in which man and his domestic animals have exercised an intensive and strong ecological impact for millennia. Given the semi-desert climate with sufficient rainfall, it may well have been that most parts of the country may have once been covered by trees (Freitag 1971a, b) prior to human settlements.

Two areas in Afghanistan are especially critical for biodiversity preservation: the „Wakhan Corridor" has some of the last relatively pristine wild life habitats and wild life populations left in Afghanistan, while the „Hazarajat Plateau" has some of the most important existing and potentially protected areas in Afghanistan.

The Great Pamir extends over about 5500 km^2 of the Wakhan (Fig. 2.21b), separated from the E Hindu Kush range with its extremyly high peaks (Noshaq area up to 7400 m a.s.l.) (Fig. 2.21c) by the Abe Panj Valley, part of the upper Amu Darya river system. A considerable part of the western Great Pamir was once included in the so-called "Great Pamir Wildlife Reserve" encompassing about 679 km^2. Although designated a reserve, it has never been legally established, and between 1968 and 1977 functioned as a hunting reserve for foreigners, managed by the Afghan Tourist Organization. Before that, part of the area was protected being a royal hunting reserve of the former king Muhammad Zahir Shah.

In a 2004 survey of wildlife in the Wakhan, it was recommended that the eastern tip of the Little Pamir should be designated as a strictly protected area (about 250 km^2). This area is at present not used by herders, and thus the habitat is in excellent condition and does not conflict with human use patterns. There is also no barrier between it and the proposed Shaymak Reserve in Tajikistan, enabling Marco Polo sheep to move freely back and forth.

The eastern tip of the „Waghjir Valley" (about 300 km^2), is at present uninhabited and used only for yak grazing in winter. There Marco Polo sheep cross the Yuli Pass between China and Afghanistan in winter and the presence of snow leopards and species such as wolf, brown bear and Asian ibex was assessed. It was also recommended that this area should be designated as a reserve with yak grazing allowed to continue but other activities prohibited.

In the Hazarajat Plateau region, Bande Amir is often described as one of the great wonders of the world. Consisting of six crystal blue lakes separated by a series of natural, white travertine dams in a unique step-like system, and surrounded by spectacular red limestone cliffs. It was identified as a National Park in 1973.

Some future areas which deserve a protection status encompass the Ajar- Valley or gorge, the granite massif of Salang, as well as the Kohe Baba summit (Shah Fuladi 5050 m a.s.l.). They show on their north-facing slopes signs of the last glacial maximum in the form of well-developed side and end moraines and recent active geomorphological processes, and merit protection in addition to their high mountain flora.

Some of the necessary next steps concerning nature conservation and sustainable management of vegetation and wildlife, which were identified by WCS1, need to be:

Table 2.4 List of proposed protected areas of Afghanistan (based on various sources and our own experience). Existing designated Reserves are underlined. The total area of all proposed reserves would cover about 42,360 km^2, equivalent to about 6.5% of total land area of Afghanistan [NP = National Park]

Reserves	Afghan Province, Area	Altitude (m a.s.l.)	Approx. size (km^2)	Vegetation type acc. to Fig. 2.15	Main characteristics
Ajar Valley	Bay	2000–3800	400	1e, 3c, 7	Wildlife Reserve
Great Pamir	Bak, Wakh	4000–6000	679.38	7, 8	Wildlife Reserve, rich flora and vegetation
Dashte Nawor	Gha	3200–4800	700 NP 75 (lake)	7, 9a, 9b	Wildlife Reserve, Wetland, waterfowl sanctuary
Abe Istada	Gha	1950–2100	270	9b, 3b	Wildlife Reserve, Wetland, waterfowl sanctuary
Bande Amir	Bay	2900–3832	410 (NP)	7, 9a	Wildlife Reserve, Wetland, NP Unique natural Monument
Western Nuristan	Kun, Lag, Bak	1100–6300	5200	4b, 5, 2, 4a, 6, 7, 8	Monsoonal influenced forests types, up to high mountain belts, rich unique flora, wildlife
Hamune Puzak	Nim	475	>350	1b, 9a, 9b	Wildlife Reserve, Wetland
Imam Sahib and Darqad	KDZ, Tak	350–470	400	1a, 1d, 9a	Wildlife Reserve, Wetland, Tugai Forests of Amu Darya
Northwestern Badakhshan, Darwaz	Bak	2500–4400	800	3a, 3a, 7	Semi-humid woodlands and mountains, unique flora
Little Pamir including Lake Zorkol, Lake Chaqmatin	Bak, Wakh [Taj, Pak, China]	4000–5900	2000	8, 7	Transboundary Reserve, Wildlife Reserve, Wetland
Waghjir Valley Pamir	Bak, [Pak, China]	3800–5500	300	8, 7	Transboundary Reserve, Wildlife Reserve, Wetland
Registan Desert	KDH	900–1100	18,000	1a, 1c, 1e	Arid sand-desert area, desert wildlife
North Salang	Bal	1600–3600	350	3d	Open *Juniperus* woodlands
Lake Hashmat Khan	KBL	1793	1.91	9a, 9b	Wildlife Reserve, Wetland, Waterfowl sanctuary
Taiwara, Kohe Malmond	Gho, Far	2000–4200	800	3b, 3c	Unique flora and vegetation, Limestone massifs, Geo-Heritage

(continued)

Table 2.4 (continued)

Reserves	Afghan Province, Area	Altitude (m a.s.l.)	Approx. size (km^2)	Vegetation type acc. to Fig. 2.15	Main characteristics
Paghman	KBL, Paw	1800–4000	200	3c	Open *Cercis* woodlands and high mountains
Mir Samir	Kap	3500–6800	450	8, 7	Arid high mountain, glaciation
Safed Koh	Pay, [Pak]	2600–4700	250	4, 5, 6, 7, 8	Humid high mountain, rich and unique forests and Krummholz
Gulran Reserve	Her, Bag	250–1000	10,000	1d, 3a	Wildlife Reserve, *Pistacia vera*- woodlands
Moqor-Chaman Lineament, from Moqor to Spinboldak	Zab, [Pak]	1300–2500	400	3b, 3c	Marked Tectonic Lineament
Salang Granite area at the summit of Kotale Salang	Paw, Bal	1600–3700	200	3c, 3d, 7	Granit, recent glacial and periglacial activity, rich alpine vegetation
Shah Fuladi, the summit range of Kohe Baba	Bay	2000–5500	200	7, 8	Old glacial and recent peri-glacial activity, rich alpine vegetation

- Perform wildlife surveys, socio-economic surveys, and rangeland assessments at each existing or potential protected area site.
- Develop and enact Wakhan protected area initiatives, including updating the "Great Pamir" Wildlife Reserve management plan and officially designating the "Little Pamir" Protected Area and Waghjir Protected Area.
- Develop and enact Hazarajat protected area initiatives, including updating the Band-e Amir National Park management plan and officially designating the Ajar Valley Wildlife Sanctuary.
- Further develop a Trans-boundary Peace Park Initiative between Afghanistan, Pakistan, Tajikistan, and China.
- Review policies and legislation affecting wild-life, wild lands, and protected areas.
- Develop a plan for forest and wildlife assessments for Nuristan, Kunar, Paktika, Khost, and Paktia.

Keeping the above-listed needs in mind, Table 2.4 gives a list of proposed protected areas with some of their characteristics. The existing or at least declared Reserve Areas only correspond to about 0.3% of the total land area of Afghanistan. For a sound national conservation system, it has to be enlarged significantly (Farhadi 2008; Shank 2006) within all projects of the national development strategy.

These designated reserves are not only for wildlife conservation and waterfowl sanctuaries, but also include proposed reserves for unique landscapes, geomorphology and vegetation types, especially woodlands and forests.

2.8 Final Remarks

The Afghan mountains including Hindu Kush are rich in plant species. The continental and arid conditions are the reason for broad vegetation belts and a very high snow-line. The E and SE exposed mountain ridges attract summer rains and thus exhibit distinct forest belts with closed forests and a Himalayan-influenced rich flora. However, centuries of grazing by settlers as well as by nomads, hunting, and more intensified agriculture by modernized irrigation systems have caused and continue to cause a decline in biodiversity and a change of vegetation cover to desertified semi-deserts in many mountain regions.

In general, our knowledge on flora and vegetation of the Hindu Kush is fairly good. There are still important priorities: a more accurate knowledge of the number of species and their distribution particularly in the mountain regions. There has been much research on plants and vegetation for a rather long time, often jointly by foreign scientists with Afghan counterparts. But the last war and decades of civil wars made field work difficult or impossible. Hopefully, in future, in Afghanistan peace and better living conditions may prevail.

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Chapter 3
The Khorassan-Kopet Dagh Mountains

Farshid Memariani

Abstract The Khorassan-Kopet Dagh Mountains are mainly east-west oriented ranges in the northeastern Iran. The climate of the area is continental and distinctly drier than the nearby mountain ranges. A total of 2576 species or infraspecific taxa belonging to 702 genera and 112 families are recorded from these mountains. It is known as a separate floristic province and is a transitional zone between the different phytogeographical units of the Irano-Turanian region. Near to 65% of the species are Irano-Turanian elements, and the level of endemism is about 14%. In spite of the uniform and dry climate of the Khorassan-Kopet Dagh, the heterogeneous topography supported the diverse vegetation types in the region. The major vegetation types of these mountains are Hyrcanian montane forests, Juniper woodlands, *Pistacia* woodlands, mesophilic shrublands, montane steppe shrublands, subalpine thorn-cushion communities, *Stipa-Artemisia* steppes, chasmophytic vegetation, edaphic vegetation, halophytic vegetation, psammophyte vegetation, wetlands, and ruderal vegetation. In recent decades, extensive urbanization and industrialization caused dramatic degradation in the natural ecosystems and the biodiversity of the Khorassan-Kopet Dagh. Almost all populations of endemic taxa outside the protected areas are severely threatened and need to be protected.

Abbreviations

ES	Euro-Siberian
IT	Irano-Turanian
M	Mediterranean
SS	Saharo-Sindian
KK	Khorassan-Kopet Dagh

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3.1 Introduction

The mountainous area of the Khorassan-Kopet Dagh (KK) is located mainly in northeastern Iran and partly extending into the neighboring parts of southern Turkmenistan. The KK area lies between 34°20′ and 39°13′ N latitude and 55°05′ and 61°20′ E longitude, and has a surface area of *ca.* 165,000 km^2. It is delimited sharply in the north and northwest by the Kara-Kum desert; in the east by the Iran-Turkmenistan border along the Tajan River and western Badghyz and partly by the Iran-Afghanistan border along the Harir-Rud River and the western extension of the Paropamisus Range; and in the south and southwest by the central Iranian deserts. To the west, the area is connected partly to the Gorgan plain and Turkman-Sahra salt desert, and partly to the eastern extension of the Alborz mountain range and the Hyrcanian forests of the ES region. There are several east-west oriented mountain ranges in the area (Fig. 3.1). The Kopet Dagh range is located in the northernmost part of the area and stretches from the northwest in Turkmenistan to the southeast in Iran, traversed by the Tajan River forming the Iran-Turkmenistan border. Chapan-dag (2889 m a.s.l.) and Shakh-Shakh Mountain (2912 m a.s.l.) are the highest peaks of the central Kopet Dagh in Turkmenistan (Kamakhina 1994; Rustamov 2012). The Iranian part of the Kopet Dagh range, its central and eastern areas, includes the high peaks Hezar-Masjed (3106 m a.s.l.) and Allaho-Akbar (2676 m a.s.l.). The northern ranges of Khorassan run parallel to the Kopet Dagh and are constituted mainly by the mountains Binalood (3301 m a.s.l., the highest peak in the KK), Shah-Jahan (3062 m a.s.l.), Salook (2956 m a.s.l.), Ghorkhod (2771 m a.s.l.) and Aladagh (2763 m a.s.l.). The Sabzevar and Kashmar-Torbat ranges are oriented mainly east-west at the southern border of the KK, where Bezq (2940 m a.s.l.) and Kuh-e Gar (2937 m a.s.l.) are the highest peaks. There are several low and high plains as well as foothills in the area between these main mountain ranges (Memariani et al. 2016a). The isolated Bolshoi Balkhan range (up to 1883 m a.s.l.) forms the northwestern periphery of the Kopet Dagh and is surrounded by the sand deserts east of the Caspian Sea (Kurbanov 1994). The vegetation of the Bolshoi Balkhan is quite peculiar in its structure, composition and outlook, and does not repeat that of the Kopet Dagh (Proskuriakova 1971).

The KK is considered as a separate floristic province within the IT region. The area is actually a transitional zone and a corridor connecting different phytogeographical units of the IT region, i.e. the central Iranian deserts, the Aralo-Caspian (Turanian) deserts, the Central Asian, Afghanistan, and Alborz Mountains, and also the Hyrcanian province of the ES region. The area might have been isolated in earlier geological times, resulting in allopatric speciation of many related species of the surrounding area. The separate biogeographic identity of the KK has been emphasized by several plant geographers (Fet 1994b; Takhtajan 1986; Kamelin 1970; Kamelin 1973; Meusel et al. 1964, 1978, 1992).

There are extensive floristic data on Khorassan published in connection with the Flora Iranica (Rechinger 1963–2015), Flora of Iran (Assadi et al. 1988–2018), and several local floristic studies (e.g. Akhani 1998, 2005; Ghahreman et al. 2006;

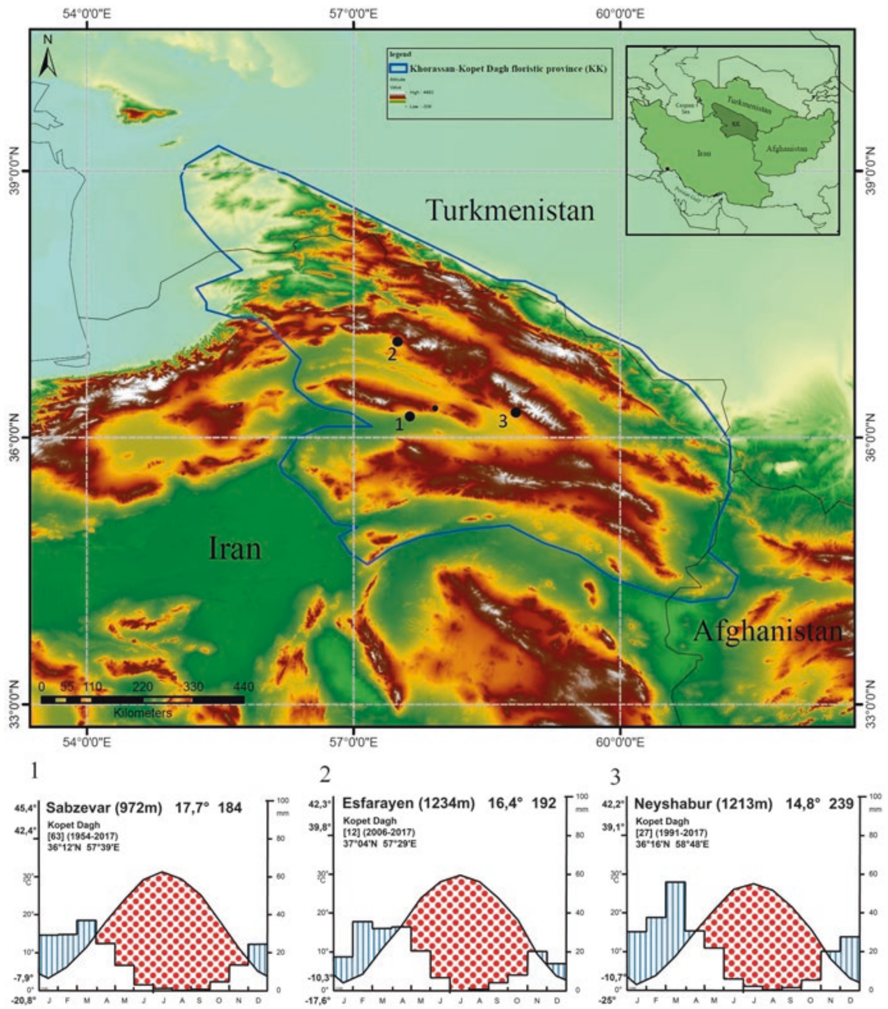

Fig. 3.1 Geographical delimitation and topography of the KK floristic province in northeastern Iran and partly in southern Turkmenistan and the climatic diagrams from different regions

Gholami et al. 2006; Memariani et al. 2009, 2016c; Saberi et al. 2010; Amiri and Jabbarzadeh 2011; Atashgahi et al. 2018). Since the publication of the Flora Iranica, many new species have been recorded for the flora of Khorassan or newly described from the area and listed in a series of papers as supplements to the Flora Iranica (Ghahremaninejad et al. 2005, 2010, 2012; Joharchi et al. 2007, 2011). The Turkmen part of the KK province was floristically explored in the course of the preparation of the *Manual of Plants of Turkmenistan* (Nikitin and Geldikhanov 1988). Memariani et al. (2016a) provided a comprehensive and up-to-date evaluation of the plant bio-diversity, distribution patterns, and biogeography of the whole area of the KK floristic province. Memariani et al. (2016b) determined a level of about 14% endemism and showed the Red-Listing and clear distribution patterns of the endemic species in the area. However, the province is strongly influenced by the flora of the surrounding mountains and deserts, in particular by Central IT elements (Memariani et al. 2016a). Actually, the KK is part of the Irano-Anatolian mountain system, which is recognized as one of the 35 so-called hotspots of biodiversity in the World (Mittermeier et al. 2011).

3.2 Geology

A detailed geological description of the KK was carried out by the National Iranian Oil Company (NIOC) during the 1960s and 1970s (Kalantari 1969; Afshar-Harb 1969, 1979; Hubber 1976). The Northern Khorassan and Kopet Dagh sedimentary basin formed after the closure of the Paleotethys Ocean and the convergence of the Iranian and Turanian plates following the Middle Triassic orogeny. Relatively continuous sediment deposition took place in this basin from the Jurassic through the Neogene (Berberian and King 1981; Afshar-Harb 1994). The Jurassic sediments in the basin are divided into Bashkalateh, Chaman-Bid and Mozduran formations composed mainly of sandstones, limestones, marls, and dolomites. The Cretaceous sediments include nine formations, i.e. the Shurijeh, Tirgan, Sarcheshmeh, Sanganeh, Aitamir, Abderaz, Abtalkh, Neyzar and Kalat, composed of sandstone, conglomerates, marl, mudstone, and dolomite. The sedimentary structure of the Paleogene is composed of different formations, including the Pesteligh, Chehel-Kaman, and Khangiran (Hubber 1976; Haghipour and Aghanabati 1989). The thickness of these sediments is normally 4 km and reaches up to 9 km in the Iranian portion but only about 2.5 km in the eastern parts, indicating that the Sarakhs area was more stable than the other areas of the basin (Afshar-Harb 1979). The Kopet Dagh basin was folded during the Paleogene and created many anticlinal traps, such as those that contain the Khangiran and Gonbadli gas fields in NE Iran (Mahboubi et al. 2006).

Sedimentary rocks constitute much of the continental crust of KK, especially in the Kopet Dagh range. Binalood is composed mainly of metamorphic rocks in its central and eastern parts and partly of sedimentary rocks in the western parts. Igneous and ophiolitic rocks occur widely in the Sabzevar and Kashmar-Torbat ranges. The main plains of the KK are composed of Quaternary deposits. The entire area is characterized by high seismic activity.

3.3 Climate

Due to distance from the oceans, the climate of the area is distinctly continental and drier than the nearby mountainous areas (Fig. 3.2). Based on available data, the mean annual precipitation usually is 175–300 mm in the plains and foothills and 300–380 mm in the high mountains. However, less precipitation falls in the transitional zones between the Karakum desert in the north and the central Iranian deserts in the south, and higher precipitation is expected in isolated areas of montane oak forest (*Quercus castaneifolia*) in the humid valleys of the western Aladagh range in North Khorassan. The precipitation has an uneven annual distribution throughout the area and falls predominantly in late autumn, winter and early spring, from October to May (Memariani et al. 2016a). A prolonged summer drought (from June to September) is common (Fig. 3.1). The highest mean monthly air temperatures occur from June to August. The maximum temperature in the warmest month rarely exceeds 45 °C. The lowest mean monthly temperatures are from December to February, with cold-month average minima below freezing point and down to −25 °C in high mountains (Djamali et al. 2011).

Using the Bioclimatic Classification System (Djamali et al. 2011) and its improved version (Djamali et al. 2012), most of the KK mountain area is covered by a Mediterranean or Irano-Turanian xeric-continental bioclimate, except for the high mountain areas in the central KK, where a Mediterranean or Irano-Turanian pluviseasonal-continental bioclimate can be found with shorter summer droughts and higher annual precipitation values (Fig. 3.1). An Irano-Turanian desert-continental climate covers mainly the eastern KK lowlands and part of the Daregaz low plains in the northern part of the area, with a much longer dry season that lasts at least 8 months (Fig. 3.1).

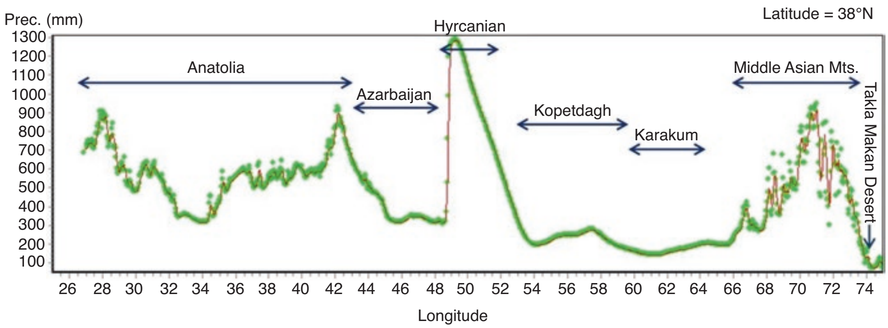

Fig. 3.2 A transect of mean annual precipitation (mm) from the Western IT (Anatolia) to the Eastern IT (the Middle Asian Mountains) region along 38° N latitude, showing the position of the Kopet Dagh Mountains. (After Memariani et al. 2016a)

3.4 Flora and Phytogeography

3.4.1 Plant Diversity

The vascular flora of the KK floristic province includes a total of 2576 species or infraspecific taxa belonging to 702 genera and 112 families. The Dicots as the most diverse plant group are composed of 84 families, 562 genera and 2145 species which comprise 83.2% of the total flora. The Monocots, with 21 families, 130 genera and 409 species, comprise 15.9%. The least diverse groups are the Gymnosperms, with 3 families, 4 genera and 12 species; and Pteridophytes, with 4 families, 6 genera and 11 species. The floristic composition of the area shows the dominance of Angiosperms and a 5:1 ratio of Dicots to Monocots which is typical of Iranian and Middle Asian floras. Totally, 52 Bryophyte species have been recorded from Khorassan province, mainly from wet places in the western KK, comprising 11.9% of the Iranian Bryoflora (Akhani and Kürschner 2004).

The largest families are the Asteraceae (426 species or infraspecific taxa), Fabaceae (290), Poaceae (196), Brassicaceae (177), Apiaceae (136), Caryophyllaceae (125), Chenopodiaceae (107), and Lamiaceae (102). Thirteen families, each with more than 40 species, comprise 71.5% of the flora. The richest families in the number of genera are Asteraceae, Poaceae, Apiaceae, and Brassicaceae, with 99, 77, 69 and 64 genera, respectively (Table 3.1).

The largest genera in the flora of the KK are *Astragalus* (Fabaceae; 158 species) and *Cousinia* (Asteraceae; 108), *Allium* (Amaryllidaceae; 42), *Euphorbia* (Euphorbiaceae; 31), *Silene* (Caryophyllaceae; 31), *Alyssum* (Brassicaceae; 28), *Acantholimon* (Plumbaginaceae; 26), *Acanthophyllum* (Caryophyllaceae; 26), *Trigonella* (Fabaceae; 23), *Vicia* (Fabaceae; 22) and *Veronica* (Plantaginaceae; 21)

Table 3.1 The largest families of vascular plants in the flora of the KK

Family	Species	Genera
Asteraceae	426	99
Fabaceae	290	27
Poaceae	196	77
Brassicaceae	177	64
Apiaceae	136	69
Caryophyllaceae	125	23
Chenopodiaceae	107	37
Lamiaceae	102	30
Boraginaceae	80	23
Rosaceae	71	16
Amaryllidaceae	46	3
Polygonaceae	44	7
Ranunculaceae	42	12
99 other families	734	215
Total	2576	702

are among the other polymorphic genera (Table 3.2). In all, 1110 species belonging to 592 monotypic and oligotypic genera (with ≤5 species) comprise 43% of the flora. *Nikitinia* (Asteraceae) was considered as the only endemic genus within the area before it has been reduced as a section within *Klasea* (Martins and Hellwig 2005). *Diaphanoptera* (Caryophyllaceae) and *Sclerorrhachis* (Asteraceae) are two subendemic genera in the flora of the KK.

3.4.2 Phytogeography

As a separate floristic province within the IT region, the KK is located at the crossroad between different areas and provinces of the IT region and the Hyrcanian province of the ES region. The geographic position of the area has led to a unique mixture of elements from the surrounding areas and the presence of many widespread, wide-ranging elements. Simultaneously, the core IT species and many local and narrowly distributed endemic species have produced a biogeographically distinctive area. Memariani et al. (2016a) distinguished 28 distribution patterns for the KK flora classified in five main categories, namely Widespread, Tri-regional, Bi-regional, ES and IT elements (Table 3.3).

The relatively wide extent of the area and the diversity of different habitats have made suitable conditions for many ruderal plants and weeds as well as hygrophilous and aquatic plants. About 295 widespread species comprise 11.4% of the KK flora, including Pluri-regional (PL), cultivated, sub-cosmopolitan (SCO), and cosmopolitan (COS) elements.

The wide-range Tri-regional species make up to 7.5% of the KK flora. They occur concurrently in the IT and two other adjacent regions of the ES, M, and/or the SS regions. Three patterns can be distinguished in this category including IT-ES-M, IT-M-SS, and IT-ES-SS. The IT-ES-M is the main pattern of the Tri-regional elements with 173 species (6.8%). Bi-regional species (14.3%) show four different

Table 3.2 The largest genera of vascular plants in the flora of KK

Genera	Species no.	Endemism (%)	Genera	Species No.	Endemism (%)
Astragalus	158	44	*Gagea*	20	10
Cousinia	107	59	*Scorzonera*	20	0
Allium	42	36	*Scrophularia*	20	25
Euphorbia	31	13	*Taraxacum*	20	5
Silene	31	16	*Bromus*	19	5
Alyssum	28	0	*Artemisia*	18	11
Acantholimon	26	54	*Polygonum*	17	0
Acanthophyllum	26	23	*Centaurea*	16	12
Trigonella	23	22	*Onobrychis*	15	20
Vicia	22	5	*Echinops*	15	0
Veronica	21	14	*Valerianella*	15	0

Table 3.3 Numbers and proportions of plant species in different phytogeographical groups in the flora of the KK (Memariani et al. 2016a). (For abbreviations, please refer to the text)

Phytogeographical groups		Taxa no.	Taxa (%)
Widespread	PL	215	8.3
	SCO	41	1.6
	Cultivated	20	0.8
	COS	19	0.7
	(Total)	***(295)***	***(11.4)***
Tri-regional	IT- ES- M	173	6.7
	IT- M- SS	19	0.7
	IT- ES- SS	2	0.1
	(Total)	***(194)***	***(7.5)***
Bi-regional	IT- M	175	6.8
	IT- ES	136	5.3
	IT- SS	38	1.5
	ES- M	18	0.7
	(Total)	***(367)***	***(14.3)***
Euro-Siberian (ES)	ES ^{EH}	28	1.1
	ES ^{HY}	15	0.6
	ES	8	0.3
	(Total)	***(51)***	***(2.0)***
Irano-Turanian (IT)	IT ^{KK}	356	13.8
	IT ^{C}	331	12.8
	IT or IT^{omni}	261	10.1
	IT $^{C\,\&\,E}$	220	8.5
	IT $^{W\,\&\,C}$	110	4.4
	IT $^{KK\text{-}E}$	96	3.7
	IT $^{KK\text{-}Alborz}$	87	3.4
	IT $^{KK\text{-}Afgh.}$	83	3.2
	IT $^{Aralo\text{-}Caspian}$	37	1.4
	IT $^{Cauc.\text{-}Turk.}$	30	1.2
	IT ^{E}	25	1.0
	IT $^{Cauc.\text{-}Alborz}$	15	0.6
	IT ^{Alborz}	15	0.6
	IT ^{W}	3	0.1
	(Total)	***(1669)***	***(64.8)***
	Whole KK flora	**2576**	**100.0**

distribution patterns among which the IT-M and IT-ES are the main ones with 175 (6.8%) and 136 (5.3%) species, respectively.

In the western and southwestern parts of the KK, mainly in wet valleys of the Ghorkhod Protected Area (just east of the Golestan National Park) and the western Aladagh mountains (Darkesh and Jowzak forests), some isolated Hyrcanian relict forests have loosely affected the phytogeographical spectrum of the area by their ES elements of up to 2%. Actually, some Euxino-Hyrcanian, Hyrcanian, and a few omni- ES species occur in wet valleys of the KK at the easternmost extremes of their distribution range (Memariani et al. 2016c).

The IT elements (1669 species, 64.8%) constitute a considerable proportion of the flora of the KK. Based on the delimitation of the IT chorotypes proposed by Akhani (1998) and Memariani et al. (2016a), several distribution patterns can be distinguished in this group. A significant number of the IT species, i.e. 356 species (14%), are local or narrowly endemic species that do not occur outside the defined boundaries of the KK. The endemic KK pattern (IT^{KK}) is followed by the Central (IT^{C}) and overall IT/IT^{Omni} groups with 331 (13%) and 261 (10%) species, respectively. The foothills and mountains of the KK represent the northern limits of many Central IT elements. The eastern and/or western range of those species occurring either widely in the whole IT region, the Central-Eastern IT (220 species) and/or Western-Central IT (110 species) are connected in the KK mountains. These five chorotypes (i.e. IT^{KK}, IT^{C}, IT/IT^{Omni}, $IT^{C\&E}$, and $IT^{W\&C}$) constitute about 50% of the KK flora which reflect the relative importance of local endemism and the central areas of IT region in the phytogeography of the KK.

Moreover, the KK flora shows a remarkable phytogeographical link to the adjacent Middle Asian, Alborz, Afghan, and Caucasian mountain ranges. Several Eastern IT species (mainly the Middle/Central Asian) have a disjunct distribution in KK or show a connected pattern running through Afghanistan (i.e. $IT^{KK\text{-}E}$ and IT^{E}, totally with 121 species). A number of these plant species have been discovered and recorded for the flora of Iran during the last 15 years (Aydani et al. 2006; Joharchi and Akhani 2006; Memariani et al. 2007; Fritsch and Maroofi 2010; Memariani and Arjmandi 2013; Joharchi and Nejati 2015; Memariani et al. 2016c; Arjmandi et al. 2016; Nasseh and Joharchi 2019; Behroozian et al. 2019) and this demonstrates the role of the KK mountains as a refuge for the Middle/Central Asian flora. There are also several species occurring mainly in the KK mountainous areas, and further west in the eastern Alborz and sometimes even into the central and western Alborz (i.e. $IT^{KK\text{-}Alborz}$, 87 species) as well as in KK and slightly eastward to the western and north-central parts of Afghanistan (i.e. $IT^{KK\text{-}Afgh.}$, 83 species). Several species occur mainly from the Caucasian mountains through the Alborz to the KK or occur in the Caucasus/Alborz/Zagros with few disjunct locations in the KK (i.e. $IT^{Cauc.\text{-}Turk.}$, $IT^{Cauc.\text{-}Alborz}$, IT^{Alborz}, and IT^{W}, totally with 63 species). Although KK is mainly a mountainous area, there are several halophytes and some psammophyte elements of the Turanian deserts (i.e. $IT^{Aralo\text{-}Caspian}$, 37 species) in the vast plains and foothills between the mountain systems of the area. These elements sometimes penetrate further south to the central Iranian deserts.

3.5 Endemism

An inventory and appraisal of the whole endemic flora of the KK generated an updated checklist of 356 local or narrow endemics; 178 (50%) of these are endemic to Iran, 59 (16.6%) are endemic to Turkmenistan, and 119 (33.4%) are common between the two countries (Memariani et al. 2016b). The level of endemism in the KK flora is about 14% which is higher than the average in the mountains of the Central Asia (Sennikov 2016). Most of the KK endemic species occur in montane steppe communities from the mid-mountain belt to the subalpine zone, but a considerable number (ca. 20%) of the endemic and sub-endemic species belong to the unique foothill and lowland habitats such as calcareous, serpentine and gypsum ecosystems (Kurbanov 1994; Memariani 2018).

The endemic vascular plants of the KK belong to 112 genera and 36 families. The Dicots with 324 taxa (91%) and 29 families are the most diverse endemics in the area. Only 32 (9%) taxa and 7 families belong to the Monocots. There are no endemic Gymnosperms and Pteridophytes in the area. Asteraceae and Fabaceae are the richest families with 105 (30%) and 95 (27%) endemics, respectively. Like in other areas of the IT region, the genera *Astragalus* (69 species) and *Cousinia* (66 species) show the highest number of endemics in the KK followed by *Allium* (15 species) and *Acantholimon* (14 species). Hemicryptophytes (231 taxa, 65%) are the dominant life-form of the endemics which perhaps reflects that the endemics are well adapted to the cold semi-arid climate of the mountainous island of the KK. The next groups are chamaephytes (61 taxa, 17%), geophytes (36 taxa, 10%), therophytes (18 taxa, 5%) and phanerophytes (10 taxa, 3%).

Considering the five geographical zones of the area, the central part of the KK comprises a higher number (227 taxa) of endemic species, but there are fewer endemics in the southern parts (59 taxa) than in the northwestern parts (65 taxa; Table 3.4). A total of 188 taxa (52.8%) are exclusively distributed in each one of the main geographical zones i.e. northwestern, western, central, eastern or southern parts. The other taxa have a common distribution range in two or more zones.

The species turnover map (beta diversity) reveals that four main areas have the highest magnitude of change in endemic composition among the surrounding areas; they are located in the central, eastern, western and northwestern areas, respectively (Fig. 3.3). The relatively vast area in the central KK with a higher species turnover (beta diversity) reveals the great rate of its compositional dissimilarity in endemics of all geographical zones of the KK.

Table 3.4 The number of endemic species of the KK present in the different geographical zones of the KK

Geographical zone	NW	W	C	E	S
Number of KK endemics	65	116	227	144	59
Proportion of total KK endemics	18.3%	32.6%	63.9%	40.6%	16.6%

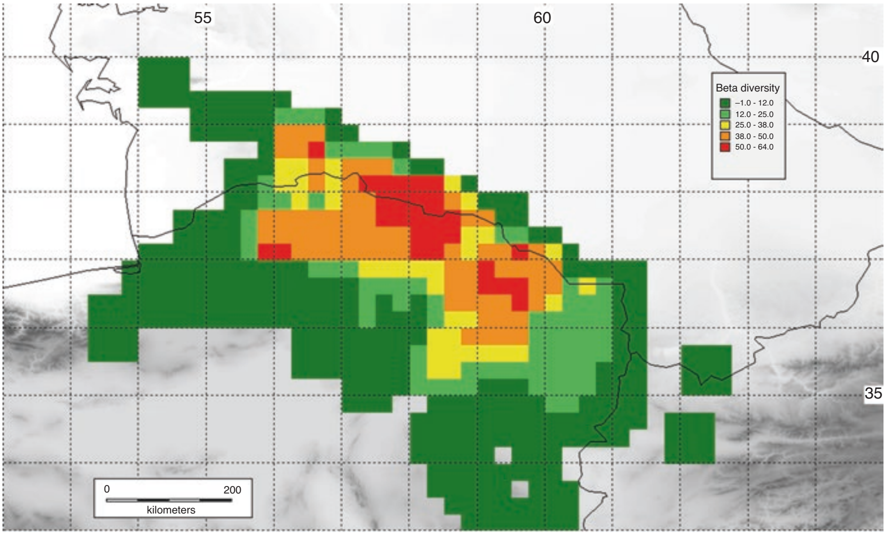

Fig. 3.3 Map of beta diversity (Whittaker's species turnover values) of endemic plants in 15′ grid cell areas of the KK (Memariani et al. 2016b)

3.6 Major Vegetation Types

Despite the uniform and relatively dry climatic conditions throughout the KK, the complicated topography and high habitat heterogeneity as well as a long vegetation history allowed the development of diverse vegetation types in the area. The spatial structure of the vegetation in many areas of the KK is very complex, and the boundaries between mountain belts are not distinct. Moreover, there are very few comprehensive surveys on the classification of the vegetation in the area. However, several vegetation types in natural and semi-natural environments of the area have been distinguished (Memariani et al. 2016a):

3.6.1 Isolated and Relict Hyrcanian Montane Forests and Shrublands

In western parts of the KK (western Aladagh range in Darkesh and Jowzak area), about 80 km away from the easternmost limit of Hyrcanian forests in the Golestan National Park, some enclaves of the Hyrcanian montane forests and scrubs consisting mainly of *Quercus castaneifolia* occur at elevations of 1200–1900 m a.s.l. (Fig. 3.4a). Due to the rocky and steep slopes of the northern hillsides and valleys of the area, *Q. castaneifolia* is often growing as short trees and shrubs. There are also some rather pure forests of *Carpinus orientalis* along the wet northern valleys

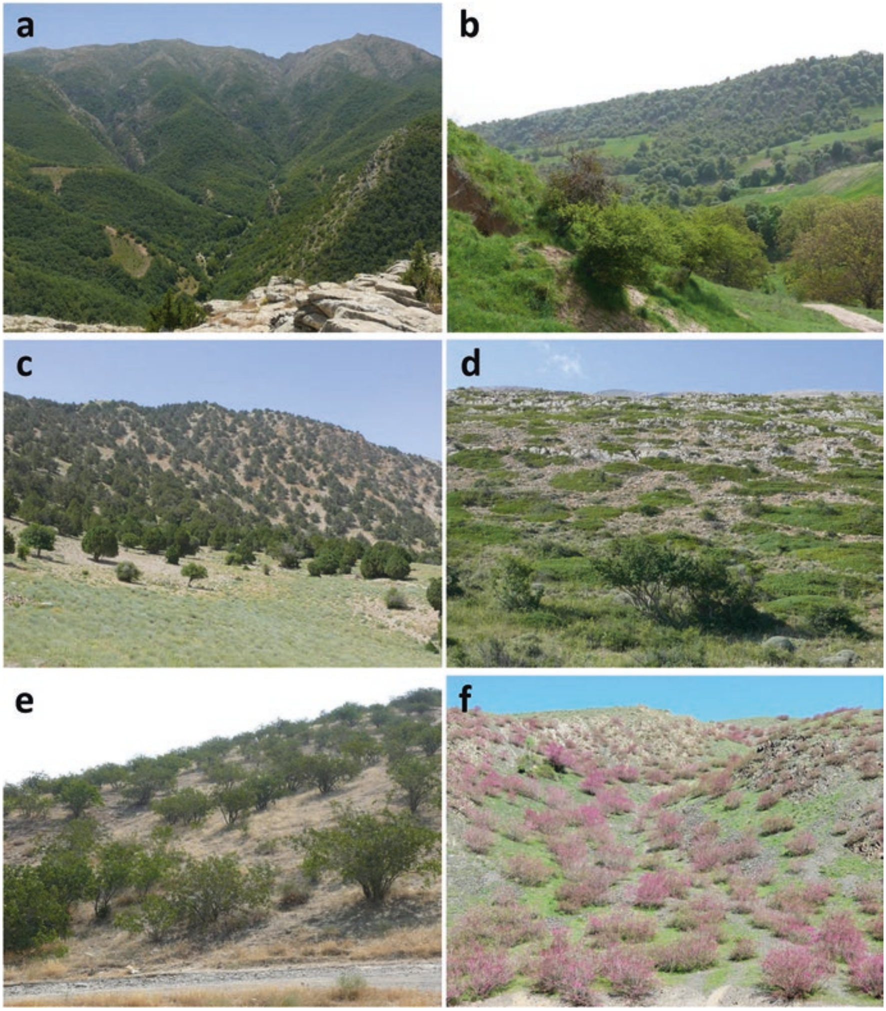

Fig. 3.4 The representative forests, woodlands, and shrublands in the KK mountains. (**a**) Relict Hyrcanian oak forest (*Quercus castaneifolia*) in the western Aladagh mountains; (**b**) Open *Acer monspessulanum*-*Crataegus* spp. shrubland in the western KK; (**c**) *Juniperus polycarpos* woodland and adjacent *Artemisia kopetdaghensis* mountain steppe in the Ghorkhod Protected Area; (**d**) *Juniperus communis* scrub on northern slopes of Ghorkhod Mt.; (**e**) *Pistacia vera* woodland in the Jangal-e Khajeh Protected Area, the eastern KK; (**f**) *Cercis griffithii* open scrub in the Arghavan valley, Binalood mountains

of the Ghorkhod Protected area. *Acer cappadocicum*, *Mespilus germanica*, *Prunus divaricata*, *Euonymus velutina*, *Pyrus boissieriana*, *Cornus sanguinea* subsp. *australis* and some *Crataegus* species are the main tree and shrub species in this vegetation type.

3.6.2 Juniperus *Woodlands*

Juniperus polycarpos var. *turcomanica* woodlands dominate a vast area in the middle to high mountains of the KK and extend from the northwestern Kopet Dagh to eastern Khorassan in the Bardu and Bezd mountains in Torbat-e Jam. The altitudinal range of these woodlands varies from 850 m a.s.l. in the Raz and Jargalan region up to 2400 m a.s.l. on Ghorkhod Mt. These woodlands have disappeared or have been damaged at many lower, accessible areas by the human. In the NW Kopet Dagh (Turkmenistan), single juniper trees may be found at altitudes of 200–300 m a.s.l. (Fet 1994a). However, well-developed *Juniperus* woodlands can be seen in some protected areas, such as the eastern parts of the Golestan National Park, Salook National Park, Sarani Protected Area, Kopet Dagh Nature Reserve (Turkmenistan), Tandooreh National Park, and the Ors-e Sistan (Hezar-Masjed) Protected Area. Very dense old-growth stands of *Juniperus polycarpos* occur in the Ghorkhod Protected Area (Fig. 3.4c) and the Golestan National Park (Memariani et al. 2016c). Very diverse woody and herbaceous species accompany these woodlands. Open juniper woodlands in the middle and higher belts intermix with *Paliurus spina-christi* and *Acer monspessulanum* scrub, *Artemisia* communities and mountain thorn-cushion steppes.

Juniperus communis and *J. sabina* scrubs form carpet-like vegetation patches on exposed rocks in subalpine areas of the western KK, especially on the northern slopes of the Aladagh, Ghorkhod and on the top of several mountains in the Golestan National Park at altitudes from 1600 to 2600 m a.s.l. (Fig. 3.4d). However, towards the east these occur mostly as individual shrubs or in small patches that do not form actual communities except for the rocky northern slopes of Ghorkhod Mt. On the rocky lower slopes of these mountain areas, *J. communis* may cover the understory of *Carpinus orientalis* scrub.

3.6.3 Pistacia vera *Woodlands*

The isolated xerophilic stands of the wild pistachio (*Pistacia vera*), classified as subtropical semi-savanna, occur between altitudes 800 and 1200 m a.s.l. from the western to eastern Kopet Dagh and also in adjacent areas of the Paropamisus foothills in the Badghys, Pulikhatum and Kushka forest reserves, which cover a total of 75,000 ha (Zlotin 1994; Khanazarov et al. 2009). Well-developed woodlands of *P. vera* (Fig. 3.4e), with a surface area of 17,500 ha, are located in the Jangal-e Khajeh Protected Area adjacent to the Turkmenistan border in the eastern Kopet Dagh (Karimi et al. 2009). The only remaining populations of *P. vera* in the western KK are located in the Qazanqayeh forest reserve (7000 ha), in the east of the Maraveh Tappeh (Golestan province). Very scattered wild pistachio woodlands can be seen in the central Kopet Dagh, in the Kuruhaudan area of Turkmenistan (Kamakhina 1994) and the Polgerd and Daregaz area of Iran. Due to the low precipitation and high maximum temperature, the understory layer is mainly covered by winter and early-spring ephemeroids, including grasses such as *Poa bulbosa* L. and the sedge *Carex pachystylis* J.Gay (Popov 1994). The wild pistachio woodlands provide valuable genetic resources for *P. vera* which is grown commercially worldwide for its nuts, and Iran is the major pistachio producer in the world.

3.6.4 Open Mesophilic Shrublands

There is a suitable microclimate along the moist valleys of the KK mountains for shrubland vegetation types. These open mesophilic shrublands have different species composition depending on the altitude and slope aspect. *Acer monspessulanum* subsp. *turcumanicum* is the main endemic component of these plant communities in the west to east-central KK, along with *Cotoneaster, Crataegus*, *Lonicera* and *Prunus* species (Fig. 3.4b). The successional scrubs of *Paliurus spina-christi* grow in valleys and along seasonal rivers and streams of the northwest and western KK. In the mesic conditions of the western Aladagh and Ghorkhod ranges, the understory of these open shrublands and scrubs (šibljak communities) is enriched by many KK endemics and also by Hyrcanian and ES species. These communities are accompanied by other shrubby species, such as *Jasminum fruticans*, *Rhamnus pallasii*, *Rubia florida*, and *Colutea porphyrogramma*. Along permanent rivers, especially in the western KK, there are usually narrow strips of mountain riparian communities composed of *Juglans regia* and *Platanus orientalis* (mainly cultivated), *Cornus sanguinea* subsp. *australis*, *Fraxinus angustifolia*, *Lonicera floribunda*, *Prunus divaricata*, and *Rubus sanctus*. The understory layer is mainly covered by mesophilic herbaceous species. In some parts of the Binalood Mountains, mainly in the Arghavan valley, there is a Mediterranean type of open scrub formed by *Cercis griffithii* (Fig. 3.4f).

3.6.5 Montane Steppe Shrublands

Well-developed and very diverse mountain steppes form the main formations in the mid-mountain belt above the semi-desert *Stipa-Artemisia* steppe. These are mainly thorn-cushion communities and grassy mountain steppes, or combinations, with scarce shrubs depending on altitude, humidity, soil type and degree of disturbance. *Astragalus verus* is usually the most dominant species of these habitats. Well-developed *Elymus hispidus* grassland covers higher mountains in some areas, where scattered *Acer* or *Crataegus* shrubs can also be seen (Fig. 3.5d). Montane steppe shrublands are highly enriched by many diverse and endemic plants, such as species from the genera *Astragalus*, *Cousinia*, *Allium*, *Euphorbia*, *Silene* and *Alyssum* which may form some unique plant communities or intermix and make patches

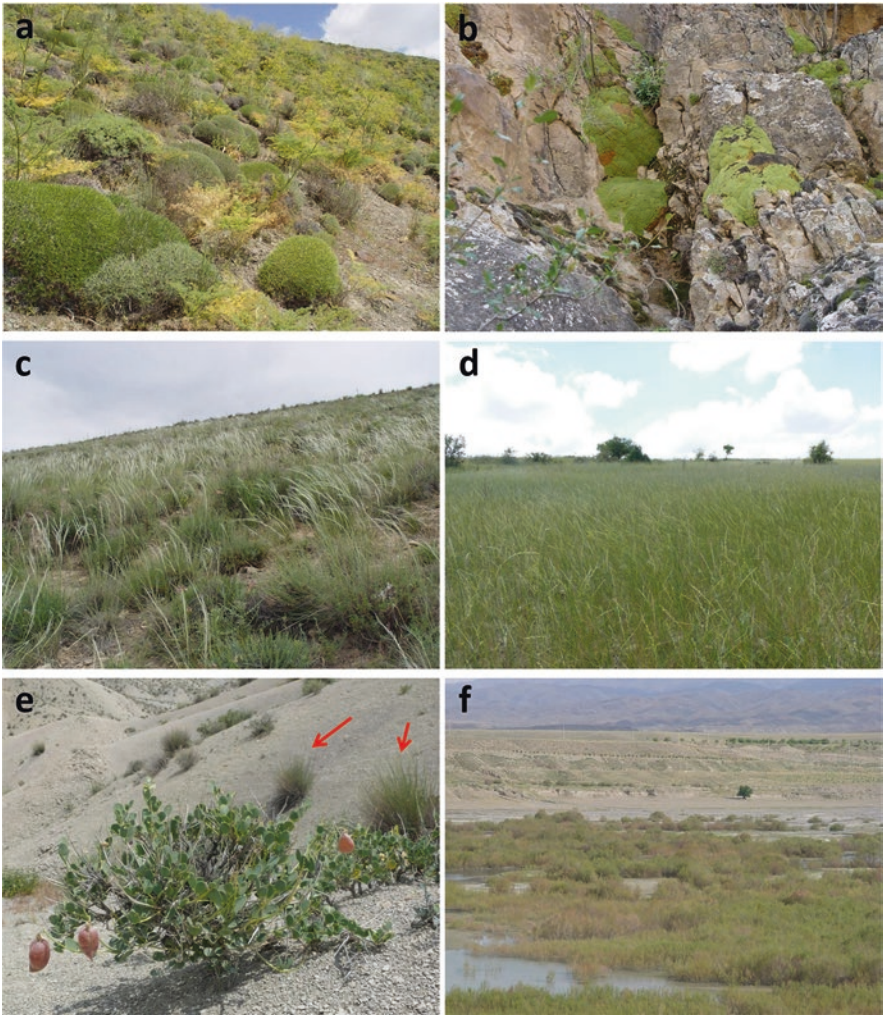

Fig. 3.5 Some representative mountain steppes, foothill and plain vegetation in the KK. (**a**) Thorn-cushion vegetation in subalpine areas near the summit of the Binalood; (**b**) A typical cliff vegetation with dominant *Gypsophila aretoides* in the Aladagh mountains; (**c**) *Stipa-Artemisia* steppe in northern foothills of the Binalood mountains; (**d**) *Elymus hispidus* grassland in the Ghorkhod Protected Area; (**e**) *Colutea gifana* (Critically Endangered) with *Klasea leptoclada* (Endangered) in the background (arrows) on calcareous/marl hills of the western KK in North Khorassan; (**f**) *Tamarix* scrub community along the Abghad river in northern plains of the Binalood range

within other vegetation types in mountainous areas, as in *Juniperus* woodlands and open shrublands.

3.6.6 Subalpine Thorn-Cushions

These mountains are not so high to support high alpine habitats but the subalpine vegetation types are well-developed in high elevations. These habitats are mostly covered by thorn-cushion formations which usually composed of *Onobrychis cornuta*, *Acantholimon*, and *Acanthophyllum* species and tragacanthic *Astragalus*. Grassy steppes, mainly composed of *Festuca valesiaca* Gaudin and *Stipa* species, have developed in protected areas. In some parts, these communities are mixed with tall umbelliferous communities that are dominated by *Ferula, Ferulago* and *Prangos* species (Fig. 3.5a).

3.6.7 Stipa-Artemisia *Steppes (Semi-desert Steppes)*

Stipa-Artemisia communities are among the main vegetation types of the area, occupying lower plains and foothills and forming pure steppe or mixed communities (Fig. 3.5c) depending on elevation, erosion, precipitation and soil salinity. Several *Artemisia* species make shrub steppes, such as *A. inculta* (=*A. sieberi*) in lower plains, or *A. ciniformis* and *A. kopetdaghensis* in foothills and mid-mountains (Fig. 3.4c). These communities include relatively diverse annuals and they form different associations in the area. The mid-mountain *Stipa-Artemisia* communities are intermixed and co-dominated by several grasses of mountain steppes, especially *Festuca valesiaca* and *Stipa* spp. or with dwarf shrubs such as *Ephedra intermedia* and *Hymenocrater* species (Fet 1994a).

3.6.8 Chasmophytic Vegetation

Steep rocky slopes and walls in valleys and canyons provide suitable, inaccessible habitats for the diversification of many chasmophytic species in the area. Although plant associations in these habitats have not been well documented, they are identified by several characteristic species, such as *Dielsiocharis kotschyi, Dionysia tapetodes*, *Graellsia integrifolia*, *Gypsophila aretioides* (Fig. 3.5b), *Parietaria judaica*, *Rosularia subspicata*, and *Scrophularia variegata*. At lower altitudes in the western part of the KK, cliff vegetation is usually associated with C4 grasses (Akhani and Ziegler 2002; Memariani et al. 2016c).

3.6.9 *Edaphic Vegetation on Serpentine, Calcareous and Gypsum Soils*

Various types of marl, gypsum, serpentine, and calcareous formations dating from the Oligocene to Cretaceous substrates, occur in the KK (Afshar-Harb 1994). The vast foothill areas of the west-central KK in North Khorassan Province are covered by marl hills and calcareous formations with a flora much more differentiated than in adjacent areas (Fig. 3.5e). The ophiolitic rocks have produced serpentine soils in vast areas of the Sabzevar and Kashmar-Torbat ranges. There are also several veins of gypsum hills in these ranges, especially in Robat-e Sefid. The vegetation on such hills is very sparse and poor in species. The carbonate-rich soils, the serpentine and gypsum, the very dry substrate, and the lack of organic material represent stressful conditions for many plant species. Therefore, highly specialized xerophilous species grow on such soils. These habitats are well known for having local edaphic endemics (Rechinger 1989; Eftekhari et al. 2002; Memariani 2018).

3.6.10 *Halophytic Vegetation*

Vast areas of the main plains between the mountain systems of the KK and also along with salt and brackish springs and seasonal saline streams are covered by saline soils and inhabited by diverse halophytic communities. The main halophytic vegetation types are the riparian *Tamarix* scrub communities along with the seasonal or permanent saline and brackish rivers and streams (Fig. 3.5f), plus *Phragmites australis*, and C4-dominated annual halophytic vegetation in ruderal and saline wastelands, and shrubby halophytic and *Haloxylon ammodendron* communities. Shrubby halophytic communities are formed mostly by *Anabasis aphylla*, *Halocnemum strobilaceum*, and *Salsola arbusculiformis*.

3.6.11 *Psammophyte Vegetation*

The peripheral plains of the KK have been penetrated by sand-desert elements, mainly on fixed sandy soils or sand-clay alluvial plains. These are mainly communities of *Haloxylon ammodendron*. They form on fixed sands – or are cultivated in some areas, especially around Sabzevar and Sarakhs towards Taybad. Other woody species are rare in these communities except for *Ephedra strobilacea* and *Astragalus bazarganii*, but the community is relatively rich in herbaceous ephemeroid plants, especially in early spring with higher precipitation. These include *Carex physodes*, *Eminium lehmannii*, *Iris longiscapa, Tulipa lehmanniana*, and *Ungernia trisphaera*.

3.6.12 Aquatic, Riverine and Hygrophilous Communities

Several aquatic and hygrophilous vegetation types occur within and around temporary and permanent water resources, such as springs, streams, rivers, waterfalls and small lakes. The plant diversity around Bazangan Lake, the largest permanent lake in the area, has been documented by Gholami et al. (2006). Some of the main species of these communities, formed mainly along freshwater streams, are *Cyperus longus*, *Epilobium hirsutum*, *Eupatorium cannabinum*, *Lythrum salicaria*, *Mentha longifolia*, *Phragmites australis*, *Typha latifolia*, *Veronica anagallis-aquatica*, and *Juncus*, *Carex*, *Salix* and *Populus* species.

3.6.13 Alien and Ruderal Communities

Intensive human activities have affected the natural vegetation of the area during the last century. Many alien, weedy and ruderal species have colonized the disturbed vegetation types in urbanized and grazed areas, roadsides and cultivated lands. *Ailanthus altissima*, a fast-growing exotic tree, has invaded the riparian vegetation of the Tandooreh National Park.

3.7 Conservation

In recent decades, the increase in the human population, urbanization, and industrialization caused extensive degradation in the natural ecosystems and the biodiversity of the KK. Overgrazing and over-exploitation are among the main disturbance factors. Since the last century, the unique *Juniperus* woodlands of the KK have been damaged because of the gathering of firewood and the cutting of timber, except in inaccessible or protected areas. Vast *Pistacia vera* woodlands have been over-exploited for nut and resin production (Zlotin 1994) or through overgrazing (Popov 1994). Habitat loss and continuing aridification of the area threaten its unique plant biodiversity through the extinction of several narrow endemics as well as many mesophilic and regionally rare species inhabiting moist valleys of the western KK. While several areas are currently under protection, the woodland habitats continue to experience heavy logging and over-grazing, and enforcement is not always adequate to promote forest regeneration (Atamuradov et al. 1999). About 1.3 million ha of the KK and surrounding transition zones (ca. 8% of its surface area) are officially protected under different protection schemes. Among the 38 designated protected regions in the area, 4 are National Parks, 20 Protected Areas, 5 Wildlife Refuges, and 6 Natural Monuments in Iran and 3 are Nature Reserves in Turkmenistan (Memariani et al. 2016a). However, most of these areas have been managed only for the last 15 years, and their natural habitats have been moderately degraded and experienced a disturbance history. Only a few areas have a history of more than 30 years of protection, for example, the Golestan and Tandooreh National Parks, the Ghorkhod and Sarani Protected Areas, and the Miandasht and Khosh Yeilaq wildlife refuges, all in Iran. Many important plant areas, such as the relict *Quercus castaneifolia* montane forests in the western Aladagh, the floristically rich valleys on the northern slopes of the Salook and Binalood mountains, and several fragile ecosystems and vegetation types of the area, particularly the edaphic vegetation on serpentine, calcareous and gypsum soils, are not under legal protection. Plant biodiversity and ecosystems in the area need more effective *in situ* conservation through the establishment of protected areas and taking into account the distribution of vegetation types and centers of plant diversity and hot spots for threatened flora.

Memariani et al. (2016b) prepared the Red-List of the endemic flora of the KK (see some examples in the Fig. 3.6) and revealed that a total of 200 (56%) endemic taxa are globally Threatened including Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) taxa (Table 3.5). Moreover, 32 taxa (9%) that were considered to be Near Threatened (NT) are likely to be qualified for a threatened category in the near future (IUCN 2011). Only 29 widespread and abundant endemic taxa have been evaluated as Least Concern (LC) which means a low risk of extinction. Two endemic species, *Cousinia oreoxerophila* and *Dionysia kossinskyi* are estimated to be extinct (EX) in the KK (Kamakhina 1994). A considerable number of endemic taxa (26.1%) in the KK are categorized as DD because of inadequate information on their taxonomy and/or distribution for Red Listing.

The endemic taxa under extremely high (CR), very high (EN) and high (VU) risk of extinction, and also the centers of endemism are priority targets for conservation actions. There are well-established protected areas in many endemic hotspots of the area partly supporting *in situ* conservation of main populations of several threatened species; for example the Tandooreh National Park, Sarani Protected Area, Dorbadam P.A., Sarigol P.A. (Iran) and the Kopet Dagh Nature Reserve (Turkmenistan) in the central KK; Hezar-Masjed P.A. in the eastern KK; Golestan N.P. and the Ghorkhod P.A. in western KK; and the Syunt-Khasardag N.R. (Turkmenistan) in the northwestern KK. However, several areas with a high endemic richness or endemic distinctiveness are not officially protected such as eastern parts of the Binalood range, the Aladagh range and northern slopes of the Salook Mt. Almost all populations of endemic taxa outside the protected areas are severely subjected to one or more threatening factors, mainly habitat loss through over-grazing, agricultural activities, road constructions, expansion of human settlements and industrial areas. Range loss can lead to the global extinction of many of these endemic plants. Recently, some efforts have been initiated for the conservation of endemic and threatened plant species of the KK (Nadjafi et al. 2006; Kiani et al. 2010, 2013). However, more work is needed for *ex situ* conservation of these prioritized taxa using seed banking, *in vitro* propagation and cultivation in botanical gardens.

Fig. 3.6 Selected Red-Listed plant species endemic to the KK. (**a**) *Allium aladaghense*, an endangered species and endemic to the Aladagh, Salook, and the Ghorkhod Mt. in the western KK (Memariani et al. 2012); (**b**) *Iris ferdowsii*, an endangered and endemic species in the Hezar-Masjed mountain range in the east-central KK (Memariani and Joharchi 2017); (**c**) *Astragalus fuhsii*, a vulnerable species endemic to the western Kopet Dagh and Binalood ranges; (**d**) *Hedysarum monophyllum*, a vulnerable species and endemic to gypsum and marl hills in the west-central KK; (**e**) *Cousinia edmondsonii*, a critically endangered species known only from the summit of Ghorkhod Mt. in the western KK; (**f**) *Psephellus galactochrous*, an endangered and endemic species to calcareous foothills in the west-central KK; (**g**) *Diaphanoptera stenocalycina*, an endangered species endemic to the saline plains the south of Ghorkhod and Aladagh ranges in the western KK; (**h**) *Veronica khorassanica*, a Near Threatened endemic plant widely distributed from the west to the east of the KK mountains

Table 3.5 Red List categories for the KK endemic flora

IUCN Red List Categories	Extinct (EX)	Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Near Threatened (NT)	Least Concern (LC)	Data Deficient (DD)	Not Evaluated (NE)
Number of Species	2	24	72	104	32	29	93	0

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Chapter 4
The Alborz Mountain Range

Jalil Noroozi, Amir Talebi, and Moslem Doostmohammadi

Abstract The Alborz is one of the richest mountain ranges in SW Asia in terms of plant diversity which is mainly due to the heterogeneous topography, climate and wide elevational range. It lies at the intersection of two major phytogeographical regions, as well as two global biodiversity hotspots. A total of 3617 vascular plant species are known from this mountain range and the rate of endemism is ca. 10%. The elevational distribution of vascular plants ranges from 26 m below sea level up to 4850 m above sea level. Different vegetation types can be found on the north and south faces and at different elevational zones. Hyrcanian forests, montane steppe shrublands, wetlands, gypsophilous communities, Juniper woodlands, chasmophytic communities, subalpine tall herb umbelliferous communities, alpine and subnival communities are among the major vegetation types of this mountain range. The Alborz has a high conservation priority due to the high concentration of rare species and at the same time it experiences very intensive land-use and other human activities which threaten its unique and diverse flora.

Abbreviations

ES	Euro-Siberian
IT	Irano-Turanian
M	Mediterranean
SS	Saharo-Sindian

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4.1 Introduction

With a total elevational range of ca. 5700 m, the Alborz is the highest mountain system of SW Asia. It is a west-east ranging mountain chain in north Iran, shaping a curve south of the Caspian Sea, separating the coastal plains of the Caspian Sea from the central plateau of Iran (Fig. 4.1). The Alborz rises sharply from the Caspian Sea at 26 m below sea level up to the summit of the highest peak (Damavand) with an altitude of 5671 m a.s.l. It is divided into three parts, i.e. the western (Talish mountains, which is connected to the Azerbaijan Plateau in north-west Iran), central, and eastern Alborz reaching to the Kopet Dagh mountains in north-east Iran. The bulk of the high mountain peaks of the Alborz are concentrated in the central Alborz (Fig. 4.1).

Diverse climates on the north and south faces and at the different elevations (Khalili 1973; Djamali et al. 2011), a heterogeneous topography and a wide elevational range, resulted in a rich plant diversity and high levels of endemism (Noroozi et al. 2018, 2019b). The Alborz is located at the crossroads of two major phytogeographical regions (the IT and ES regions; Zohary 1973; Léonard 1991/1992), and it is situated at the intersection of two global biodiversity hotspots (Irano-Anatolian and Caucasian hotspots; Mittermeier et al. 2011). It has functioned as a corridor for migration of plant species, bridging eastern and western Eurasia (Manafzadeh et al. 2014). Wendelbo (1971) introduced the "Alborz distribution pattern" based on congruent distribution patterns of several plant species; Klein (1991) discussed the endemic diversity of the Alborz based on the alpine species; Noroozi et al. (2018) identified the Alborz as an area of endemism, and Noroozi et al. (2019a) identified major parts of the Alborz as centres of endemism and pointed out their conservation gaps. The central Alborz and western Alborz (Talish mountains) are separated by the Sefidrud valley, and recent floristic analysis showed that the flora of the Talish on its western face (IT part) is more closely related to the Azerbaijan Plateau than to the central Alborz (Noroozi et al. 2019b). Consequently, in this study we consider the Alborz area of endemism (Noroozi et al. 2018, 2019b) as our study area, and this covers the high mountains east of the Sefidrud valley (Fig. 4.1).

Compared to the other mountain ranges of the Iranian Plateau, the flora and vegetation of the central Alborz is better studied. Aucher-Eloy (collecting period: 1834–1837) and Theodor Kotschy (collecting period: 1842–1843) were the first major herbarium plant collectors in the high elevations of the Alborz and most of the species were described by Boissier, (1842–1859, 1867–1884). Additionally, Bunge (1860), Kotschy (1861a, b), Buhse (1899a, b) and Gilli (1939a, b, 1941a, b) studied the flora of some parts of this mountain range. The vegetation of the Hyrcanian forests is well known compared to the other vegetation types (Gholizadeh et al. 2020 and references therein). The phytosociology and ecology of the south-facing slopes and alpine habitats of the central Alborz have been intensively investigated (Klein 1982a, 1984, 1987, 1988, 2001; Klein and Lacoste 1989, 1994, 2001; Naqinezhad et al. 2009; Noroozi et al. 2010, 2014; Kamrani et al. 2011; Naderi et al. 2012; Akhani et al. 2013; Ravanbakhsh et al. 2016). However, we know very

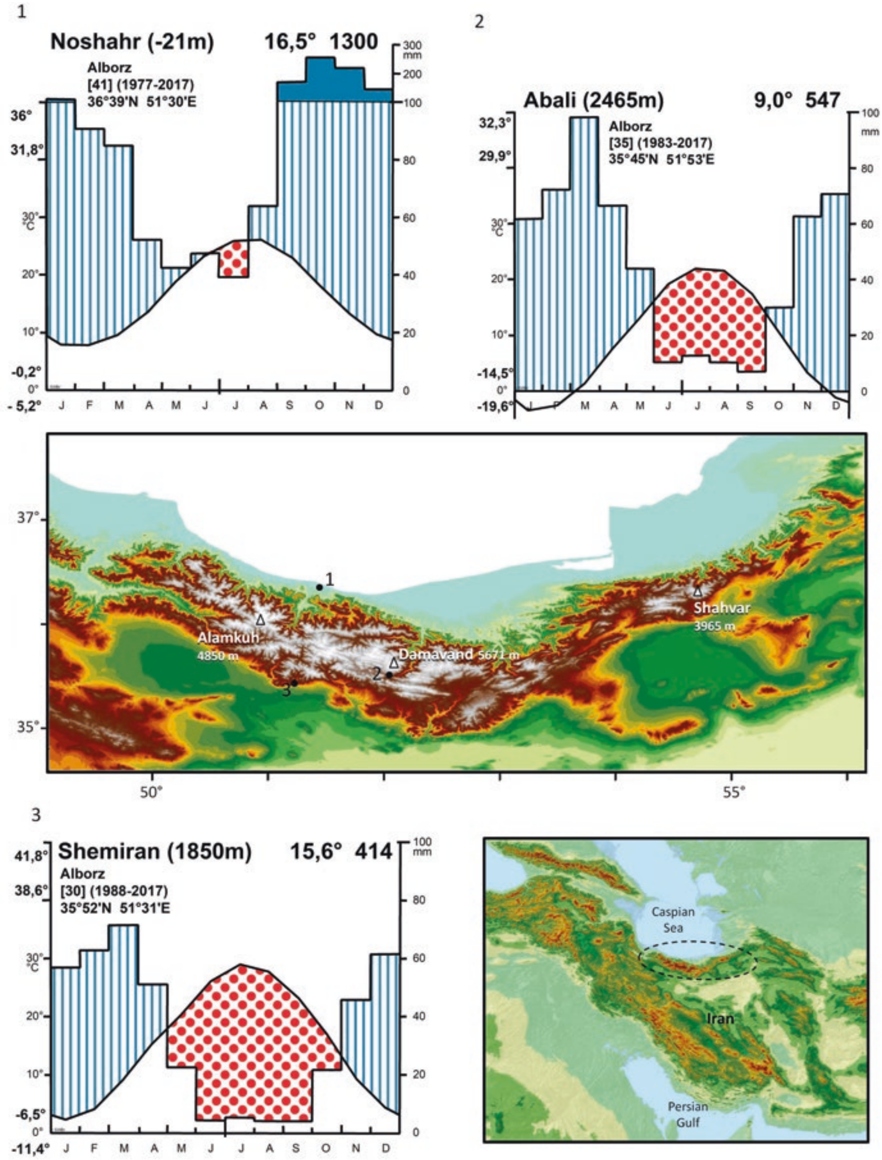

Fig. 4.1 Location of the Alborz in northern Iran. Climatic diagrams of weather stations (1–3) on north- and south-facing slopes represent completely different climates. The Damavand and Alamkuh are two highest mountain peaks of the central Alborz, and the Shahvar is the highest mountain peak of the eastern Alborz

little about the vegetation of the south-facing slopes and alpine zone of the eastern Alborz.

Despite well documented data on the flora and vegetation types of the Alborz, which mostly are local studies dealing with the flora and vegetation of the single mountains, there is lack of a comprehensive study presenting the plant diversity of this mountain range. This contribution presents a short review to the flora, phytogeography and vegetation of the Alborz based on updated knowledge. All plant species which have been recorded in the Alborz were documented and their chorology and distributions in different mountain ranges were analyzed.

4.2 Geology

The high mountains of the Iranian Plateau have been uplifted following the collision of the tectonic plates creating the Arabia-Eurasia convergence (Jackson and McKenzie 1984). The uplift and formation of these mountains have been active since the Late-Cretaceous (Stöcklin 1968; Berberian and King 1981). The geology and evolution of the Alborz is summarized by Djamali (2008) and here we use that information. The Alborz mountain range faces the South Caspian basin on the north and the Central Iranian Plateau basin on the south, and belongs to the Alpine-Himalayan orogeny with a long tectonic history dating back to the Mesozoic and Tertiary (Stöcklin 1974). The geological formations of carbonate and clastic material ranging from the Precambrian to the Mesozoic create the main body of the Alborz (Stöcklin 1968). The uplift of the Alborz has seen three major tectonic phases related to the Arabia-Eurasia continental collision, the Cretaceous to Palaeocene, the Eocene to Lower Oligocene, and the Middle Miocene to Recent compressions (Guest et al. 2007). The high elevations of the Alborz are mostly featured by Eocene volcanic rocks (Stöcklin 1968). The only Quaternary volcanic activity has happened in the Damavand Mt. in the central Alborz and created a volcano with an elevation of 5671 m a.s.l. (Davidson et al. 2004). There are some permanent glaciers at higher elevations in the central Alborz, *i.e* in Alamkuh and Damavand. Glaciation was extensive in the high elevations of Iran during the Pleistocene, and the climatic snowline was 600–1100 m lower than the present level (Ferrigno 1991).

4.3 Climate

Based on the Global Bioclimatic Classification System (Rivas-Martínez et al. 1999), the north and south-facing slopes of the Alborz belong to two highly different bioclimatic zones (Djamali et al. 2011). The north-facing slopes represent a Temperate macrobioclimate specially in the western parts, but the south-facing slopes and alpine habitats represent a Mediterranean macrobioclimate (Djamali et al. 2011).

The humid conditions on the north-facing slopes of the Alborz lead to the development of temperate deciduous forests on those slopes. The area has a mesic and warm climate, with rainy summers and mild winters (Fig. 4.1). The annual precipitation ranges from ca. 2000 mm in the western part to 700 mm in the eastern part. From west to east and from the lowland to the high elevations of these forests the precipitation gradually decreases (Khalili 1973; Djamali et al. 2011). If we cross the Alborz from north to south, the climate changes dramatically from humid warm temperate to continental semiarid, with summer drought. The precipitation regime of the alpine zone is similar to that on the south-facing slopes, i.e. of the mediterranean-type, but with a higher precipitation and significant amounts of snow in the winter and snow patches that can stay until mid-summer at elevations above 3500 m a.s.l. In general, in these mountains the precipitation depends on both the latitudinal position and the elevation of a place (Khalili 1973; Noroozi and Körner 2018).

4.4 Flora and Phytogeography

4.4.1 Floristic Diversity

In total, 3617 native vascular plant species in 876 genera and 146 families have been recorded from the Alborz. The most species-rich families are Asteraceae (517 species), Fabaceae (391), Poaceae (265), Brassicaceae (201), Apiaceae (181), Caryophyllaceae (173), Lamiaceae (173), Rosaceae (151), Boraginaceae (122) and Scrophulariaceae (120; Fig. 4.2). The largest genera are *Astragalus* (Fabaceae; 172 species), *Cousinia* (Asteraceae; 75), *Silene* (Caryophyllaceae; 48), *Euphorbia* (Euphorbiaceae; 48), *Veronica* (Scrophulariaceae; 41), *Carex* (Cyperaceae; 40), *Potentilla* (Rosaceae; 39), *Allium* (Alliaceae; 38), *Vicia* (Fabaceae; 38) and *Taraxacum* (Asteraceae; 37; Fig. 4.3). The number of plant species mentioned for the Alborz is incomplete, as new taxa are still being described and reported.

These mountains are rich in bulbous plants, attracting many hobby botanists and ecotourists to visit the region (Fig. 4.4). *Allium* (Alliaceae; 38 sepcies), Orchids (Orchidaceae; 34), *Gagea* (Liliaceae; 22), *Tulipa* (Liliaceae; 12), *Iris* (Iridaceae; 11), *Colchicum* (Colchicaceae; 9), *Eremurus* (Asphodelaceae; 6), *Crocus* (Iridaceae; 5), *Scilla* (Liliaceae; 5), *Arum* (Araceae; 3), *Fritillaria* (Liliaceae; 3), *Gladiolus* (Iridaceae; 3) and *Lilium* (Liliaceae; 1) are among the most important bulbous plants of the Alborz. *Lilium ledebourii* (Fig. 4.4d) is the only *Lilium* species of Iran; it rarely occurs in the central Alborz and the northwest Talish mountains, near the border of Iran and Azerbaijan.

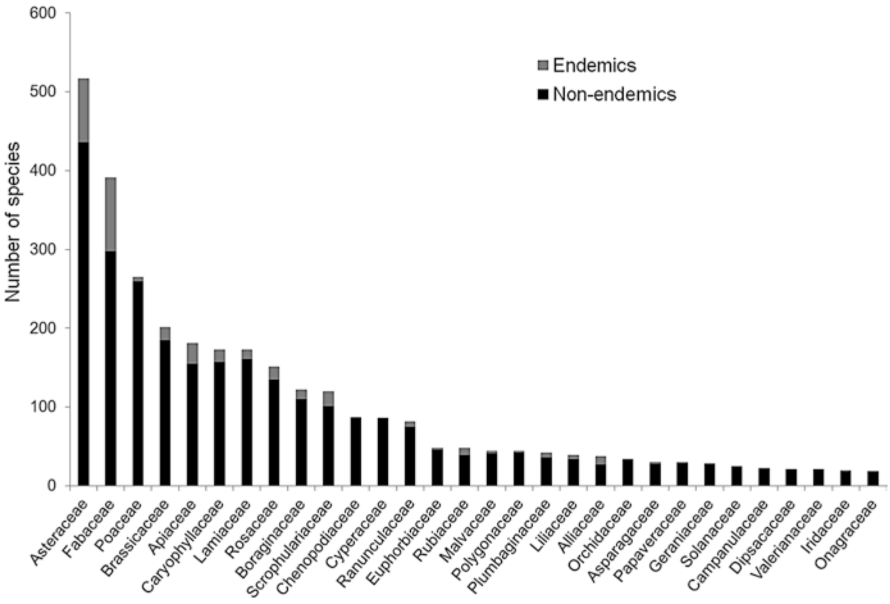

Fig. 4.2 Number of species in the 30 most species rich families of the Alborz vascular flora (the number of endemic and non-endemic species are separated by different shades)

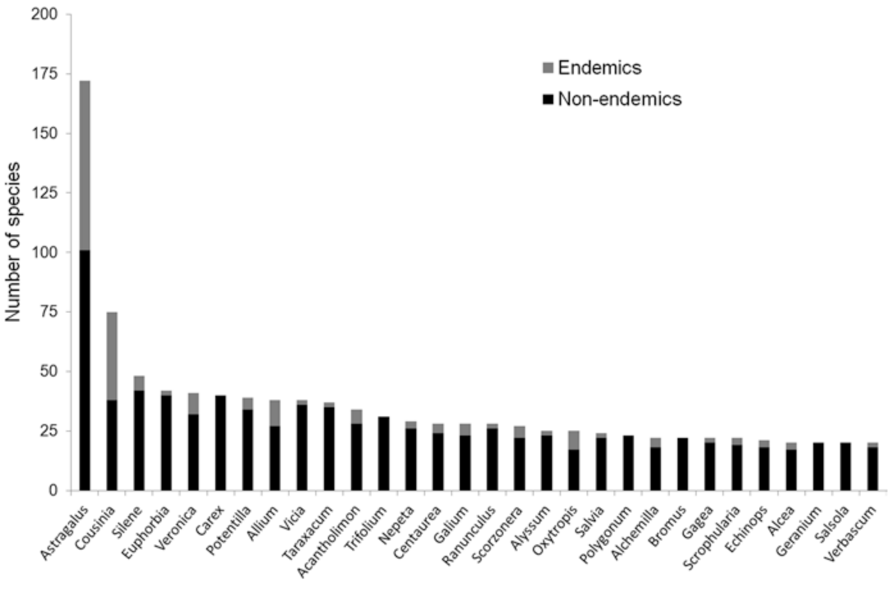

Fig. 4.3 Number of species in the 30 most species rich genera of the Alborz vascular flora (the number of endemic and non-endemic species are separated by different shades)

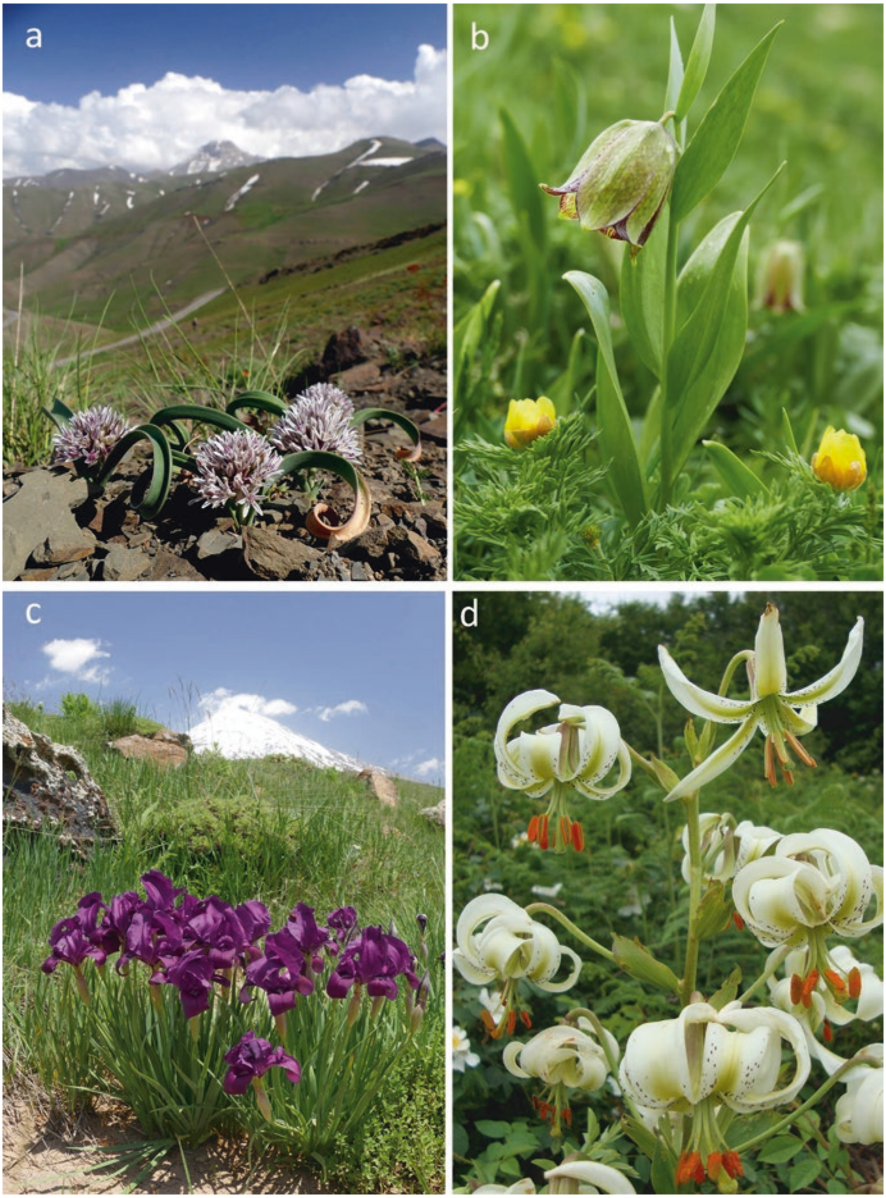

Fig. 4.4 A few examples of bulbous species of the Alborz. (**a**) *Allium derderianum* (2800 m a.s.l.; photo JN); (**b**) *Fritillaria kotschyana* and *Adonis wolgensis* (3000 m a.s.l.; photo JN); (**c**) *Iris barnumiae* subsp. *demawendica* (2600 m a.s.l.; photo JN); (**d**) *Lilium ledebourii* (2000 m a.s.l.; photo AT)

4.4.2 Phytogeography

The Alborz stretches along the boundaries of the ES and IT regions, which predominate, respectively, on the north- and south-facing slopes (Zohary 1973). The ES region covers the southern shores of the Caspian Sea up to 3300 m a.s.l. on the north face of the Alborz (Zohary 1973; Klein 2001). This region is characterized by temperate deciduous forests from Caspian Sea level up to ca. 2500 (2850) m a.s.l., and higher up steppes from ca. 2500 to 3300 m a.s.l. (Klein 2001). The Hyrcanian forests served as a refuge during the Pleistocene glacial periods and contain several Arcto-Tertiary elements, such as *Celtis australis*, *Parrotia persica, Pterocarya fraxinifolia* and *Zelkova carpinifolia*, and Indo-Malaysian elements such as *Albizia julibrissin, Buxus hyrcana, Diospyros lotus* and *Nelumbo nucifera* (Zohary 1973; Frey et al. 1999; Akhani et al. 2010). Despite its own endemic elements (110 species; Noroozi et al. 2019b), there are near to 300 species which are widely distributed in the ES region. Some biogeographers, such as Meusel et al. (1965–1992) and Takhtajan (1986) included the Hyrcanian forests in the IT region (see Manafzadeh et al. 2017). But we believe that the climatic, physiognomic and floristic similarity of these forests to the ES region is highly remarkable. Consequently, we follow Zohary (1973) and Browicz (1989), and classify the Hyrcanian forests in the ES region.

One of the important biogeographical characters of these forests is the absence of *Rhododendron, Abies, Picea* and *Pinus* (Hedge and Wendelbo 1978), which are usually treeline elements. The reason for this lack is an open question (Djamali 2008). Moreover, *Taxus baccata* is the only large conifer in these forests (Klein 2001). It represents relict populations, and probably its distribution has been limited during the post-glacial period (Djamali 2008).

The vegetation types of south-facing slopes and alpine habitats of the Alborz belong to the IT region (Zohary 1973; Klein 2001; Noroozi et al. 2008; Akhani et al. 2013). The area is characterized by a continental climate and is mostly covered by steppe vegetation types. Several characteristic genera of the IT region are very species-rich in this part of the Alborz and frequently occur in different habitats (see floristic section).

Chorological analyses reveal the phytogeographical position of the Alborz (Fig. 4.5). With a proportion of 57%, the IT elements play the most important role, followed by ES elements (11%; which are concentrated in the Hyrcanian forests), IT-M (10%), Cosmopolite and Pluri-regional (9%), IT-ES (8%) and IT-ES-M (5%). The IT chorotype is conspicuous on south-facing slopes and in the alpine zone, and the ES chorotype on north-facing slopes. Our analyses of the floristic composition of this mountain range revealed the high similarity to the Zagros, Anatolia and the Caucasus (Fig. 4.6), which could be due to their strong topographic connections with the Alborz. Here we present some examples for the most common chorotypes.

(Sub)Cosmopolites These are widely distributed species in different continents and biogeographical regions including Cosmopolite and Pluri-regional elements. Nine percent of the Alborz flora belongs to this group, such as *Acorus calamus,*

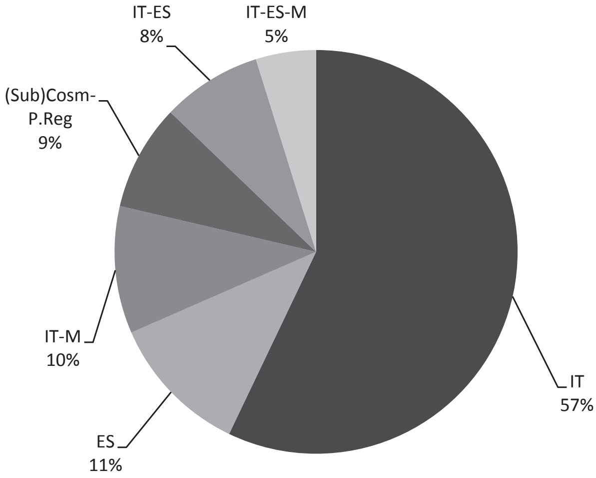

Fig. 4.5 Phytochoria of the species of the Alborz. Cosm: Cosmopolite; P.Reg: Pluri-regional

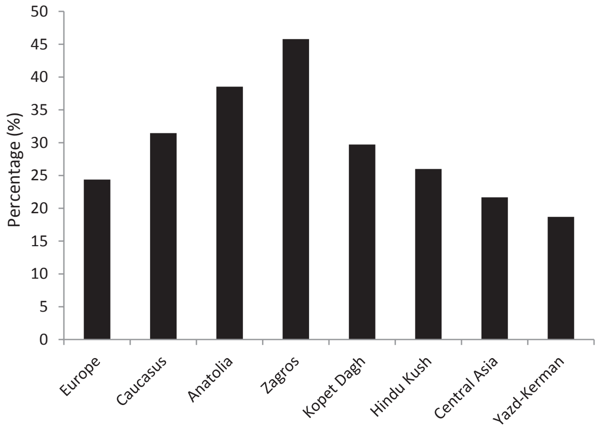

Fig. 4.6 Floristic affinity of the Alborz with other mountain ranges. The Y-axis is the percentage of species common with the Alborz

Cerastium cerastoides, C. glomeratum, Chenopodium foliosum, Cystopteris fragilis, Dryopteris filix-mas, Euphorbia maculata, Galinsoga parviflora, Isolepis cernua, Lythrum salicaria, Oxyria digyna, Plantago maritima and *Urtica dioica.* These species are mostly found at lower elevations in the Alborz and their proportion decreases with increasing elevation.

IT-ES-M This distribution pattern comprises 5% of the Alborz flora, with e.g. *Adonis aestivalis*, *Anthemis tinctoria, Inula oculus-christi, Lepidium perfoliatum, Linum austriacum, Silene vulgaris, Sisymbrium altissimum, Taraxacum serotinum, Teucrium scordium* and *Verbascum blattaria.*

IT-M Nearly 10% of the Alborz flora belongs to this group. There is relatively a strong floristic connection between these two regions. At genus level, *Haplophyllum* is mainly distributed within the territory of these two regions with a small extension to the south (Manafzadeh et al. 2014). Some species with this distribution pattern are *Acinos rotundifolius, Allium ampeloprasum, Arceuthobium oxycedri, Camphorosma monspeliaca, Cerastium dichotomum, Conringia orientalis, Filago pyramidata, Gladiolus segetum, Gypsophila perfoliata, Helianthemum salicifolium, Hordeum geniculatum, Krascheninnikovia ceratoides, Salvia sclarea, Sideritis montana, Stipa capillata, Suaeda altissima, Torilis heterophylla, Turritis laxa* and *Velezia rigida.*

IT-ES Despite the different climates of these two regions there are species with wide distributions in these two neighboring regions (8%). This distribution can be seen particularly in the widely distributed species of alpine habitats. As the climate of alpine habitats is almost similar in all biogeographical regions (Körner 2003), this distribution type is to be expected in widely distributed alpine species (see Noroozi et al. 2008). Here are several examples with such a distribution: *Androsace villosa, Draba siliquosa, Carex flacca, Cyperus glomeratus, Dracocephalum thymiflorum, Limonium gmelinii, Polygonum kitaibelianum, Potentilla gelida, Salvia aethiopis* and *Thalictrum simplex.*

IT Elements A high proportion of the Alborz flora is IT elements (57%). The largest genera in the IT part of the Alborz are *Astragalus* (164 species), *Cousinia* (71), *Acantholimon* (34), *Allium* (34), *Silene* (31), *Taraxacum* (31), *Nepeta* (26), *Potentilla* (25), *Euphorbia* (24), *Scorzonera* (24), *Oxytropis* (23), *Alyssum* (20), *Gagea* (20) and *Veronica* (20). Some of the widespread species in the IT territory are *Aethionema trinervium, Atriplex lasiantha, Carex pamirica, Celtis caucasica, Centaurea pulchella, Conringia planisiliqua, Cymbolaena griffithii, Dactylorhiza umbrosa, Halostachys belangeriana, Lallemantia peltata, Prangos pabularia, Silene odontopetala, Trigonella monantha, Tripleurospermum parviflorum, Veronica pusilla* and *Xeranthemum longipapposum.*

ES Elements The elements of this region are remarkable in the Alborz (11%), the majority occurring in the Hyrcanian region. The most species-rich genera are *Alchemilla* (21 species), *Saxifraga* (8 species), *Carex* (7), *Tilia* (7), *Asperula* (6), *Campanula* (6), *Cardamine* (6), *Euphorbia* (6), *Ranunculus* (6), *Rubus* (6), *Acer* (7), *Alcea* (5), *Astragalus* (5), *Dianthus* (5) and *Stachys* (5). The most widely distributed ES elements are *Acer platanoides, Allium paradoxum, Arabis gerardii, Astragalus glycyphyllos, Bromus ramosus, Cardamine bulbifera, Carex sylvatica, Carpinus betulus, Corydalis marschalliana, Euphorbia amygdaloides, Neottia nidus-avis, Petasites hybridus, Rumex sanguineus* and *Vincetoxicum scandens*.

Caucasus and Irano-Anatolian Biodiversity Hotspots This refers to species that are distributed all over the high mountains of SW Asia, i.e. Anatolia, the Caucasus, the Alborz, the Zagors, the Yazd-Kerman and the Kopet Dag-Khorassan. Here are some examples as *Alyssum szovitsianum, Aristolochia bottae, Arnebia pulchra, Bromus tomentellus, Cardamine uliginosa, Carex oreophila, Cirsium ciliatum, Crataegus microphylla, Dianthus orientalis, Euphorbia boissieriana, Geranium gracile, Lepidium vesicarium, Myosotis lithospermifolia, Pedicularis sibthorpii, Rumex caucasicus, Salix elbursensis, Scrophularia amplexicaulis* and *Ziziphora capitata.*

Irano-Anatolian Biodiversity Hotspot This biodiversity hotspot, which covers Irano-Turanian part of the high mountains of the Anatolian, Transcaucasian and Iranian Plateaus, embraces a high amount of local and narrowly distributed species but still there are some species which are widely distributed in the entire or major part of the region, such as *Acanthophyllum acerosum, Aethionema grandiflorum, Amygdalus communis, Arabis aucheri, Astragalus chrysostachys, Astragalus microcephalus, Chaerophyllum macropodum, Corydalis verticillaris, Elymus tauri, Iris acutiloba, Isatis kotschyana, Physoptychis gnaphalodes, Salvia atropatana, Silene aucheriana, Thymus pubescens* and *Verbascum cheiranthifolium.*

Caucasus Biodiversity Hotspot It covers the areas between the Black and Caspian Seas and is restricted to parts of six countries, i.e. Armenia, Azerbaijan, Georgia, Iran, Russia and Turkey (Mittermeier et al. 2011). More than 6500 vascular plant species are known from this region of which near to a quarter are endemic, representing the highest level of endemism in the Temperate Zone of the Northern Hemisphere (Solomon et al. 2013). There are species in the Hyrcanian region which are widely distributed in the territory of the Caucasus, such as *Alchemilla caucasica, A. rigida, Dryopteris caucasica, Bupleurum marschallianum, Paeonia wittmanniana, Potentilla adscharica, P. polyschista, Pterocarya fraxinifolia, Saxifraga cartilaginea, Trinia leiogona, Veronica ceratocarpa, Vincetoxicum scandens, Viola somchetica* and *Zelkova carpinifolia*.

Widely Disjunct Distributions The disjunct distributions are among the interesting aspects of biogeography (Thorne 1972). In the Alborz, there are some remarkable disjunct distributions. For example *Parrotia* (Hamamelidaceae), which is a Tertiary relict element, for a long time was known as a monotypic genus endemic to the Hyrcanian forests. However, a sister species of *P. persica* was found in eastern China (*P. subaequalis*; Li and Del Tredici 2008); this creates a disjunction of ca. 5600 km. These two species are quite similar in growth habit and morphology, and molecular analyses suggest that these species diverged around 7.5 million years ago, during the Lower Miocene (Li and Del Tredici 2008). Other disjunctions are more common in high alpine and subnival elements due to the high degree of isolation. *Paraquilegia* (Ranunculaceae) is a Central Asian and Himalayan alpine element with 11 species, but one species (*Paraquilegia caespitosa*; Fig. 4.16c) disjunctly occurs in rocky habitats of the subnival zone of the central Alborz (Noroozi et al. 2011). At the species level, *Alopecurus himalaicus, Carex melanantha* and *Taraxacum baltistanicum* are subnival elements with highly disjunct distributions (see Noroozi et al. 2011).

4.5 Endemism

The Alborz is known as an area of endemism (Noroozi et al. 2018), and compared to the other mountain ranges of Iran is the richest one in terms of density of endemics (Noroozi et al. 2019a, b). This is mostly due to the topogrpahic and climatic heterogenity and wide elevational amplitude (Noroozi et al. 2018). In total, 371 species are restricted to the Alborz of which 80% are IT and 17% are ES elements and the rest are bi-regional. Some of the endemics are widely distributed along the Alborz but the majority are range-restricted (278 species) and limitied to a single mountain or a small geographical region (Noroozi et al. 2019b). Fabaceae (93 species), Asteraceae (81), Apiaceae (26), Scrophulariaceae (19), Brassicaceae (16), Caryophyllaceae (16) and Rosaceae (16) are the families that are richest in endemics (Fig. 4.2). The genera that are richest in endemic species are *Astragalus* (71 species), *Cousinia* (37), *Allium* (11), *Veronica* (9), *Oxytropis* (8), *Acantholimon* (6) and *Silene* (6; Fig. 4.3). The rates of endemism in some of these genera are very high. For instance, near to 50% of *Cousinia,* and 40% of *Astragalus* species are endemic to the Alborz and all of them are IT elements. In these mountains, the proportion of endemism increases along the elevational gradient which mainly results from the increased isolation at higher elevations (Noroozi et al. 2011, 2018).

Some of the most important endemic species which congruently are distributed along the Alborz are *Acantholimon demavendicum, Alcea gorganica, Allium grande, Arabis rimarum, Astragalus atricapillus, A. capax, A. nurensis, A. platysematus, A, rosellus, A. subalpinus, A. vereskensis, Ballota platyloma, Bufonia koelzii, Bupleurum flexile, Caccinia strigosa, Campanula lourica, Consolida teheranica, Crepis asadbarensis, C. willemetioides, Delphinium ursinum, Dionysia aretioides, Epipactis rechingeri, Erigeron hyrcanicus, Galium aucheri, Iranecio elbrusensis, Isatis gaubae, Lepechiniella wendelboi, Salvia hypoleuca, Scrophularia gaubae, Stachys laxa*and *Veronica aucheri*. For more information about the hotspots of endemics in the Alborz see Noroozi et al. (2019a).

4.6 Major Vegetation Types

Hyrcanian forests, Juniper woodlands, montane steppe shrublands, wetlands, gypsophilous communities, subalpine umbelliferous communities, alpine and subnival vegetation types are among the major vegetation types of the Alborz mountain range. In general, the Alborz is better studied than the other mountain ranges of Iran, as regards the flora and vegetation. Especially the ecology and vegetation of the Hyrcanian forests and alpine habitats are well studied in the central Alborz. However, some of the habitats are poorly known and then our knowledge is only based on the scattered floristic studies. Here we present briefly the major vegetation types of this mountain range.

4.6.1 Hyrcanian Forests

The high precipitation and mild climate of the Hyrcanian region facilitates broad-leaved dense forests (Fig. 4.7). Gholizadeh et al. (2020) classified the vegetation

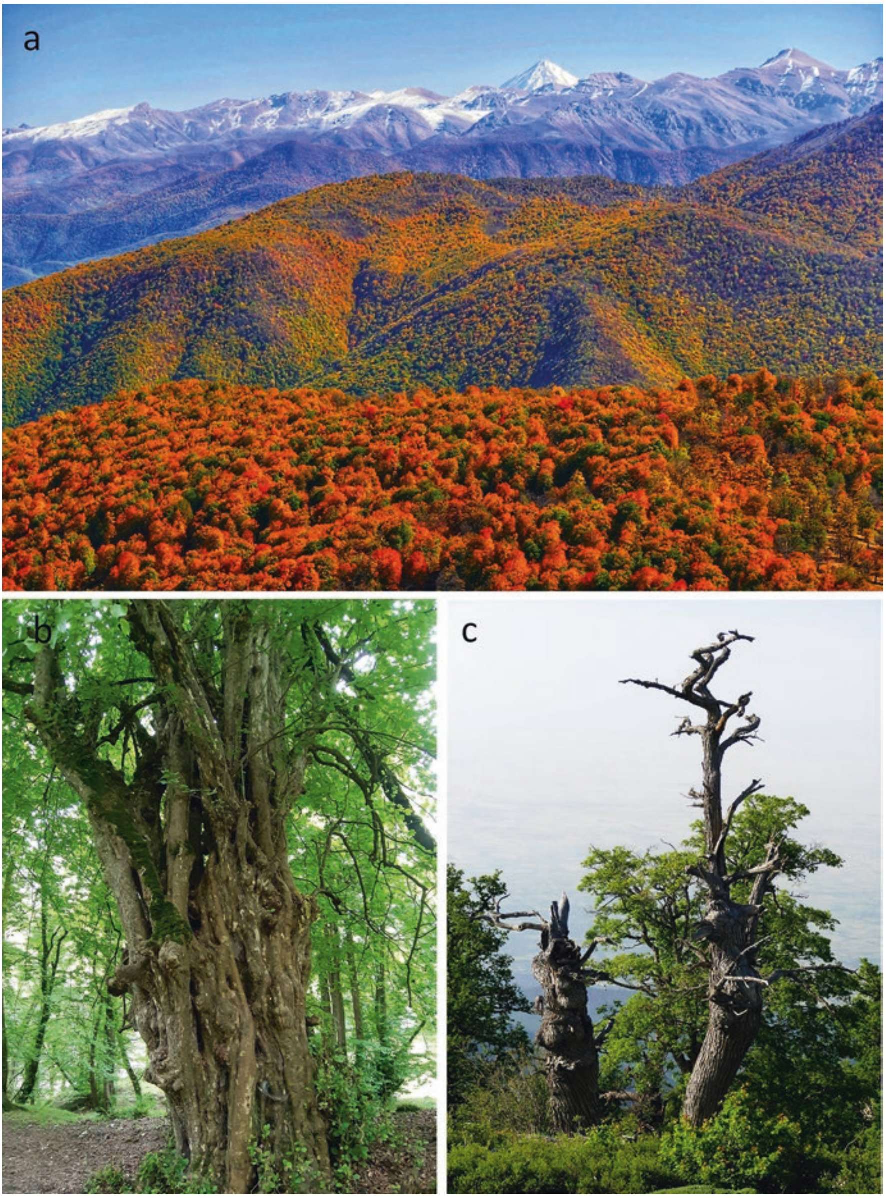

Fig. 4.7 Hyrcanian forests. (**a**) North-facing slopes of the Alborz; (**b**) *Parrotia persica,* 300 m a.s.l.; (**c**) *Quercus macranthera*, 2200 m a.s.l. (photos JN)

types of these forests in the four European classes (*Alnetea glutinosae, Alno glutinosae-Populetea albae, Carpino-Fagetea sylvaticae, Quercetea pubescentis*) which shows its floristic and vegetational similarity to the European forests. This study strongly supports the idea that Hyrcanian forests belong to the ES region (Zohary 1973; Browicz 1989) and not the IT region (Meusel et al. 1965–1992; Takhtajan 1986).

These forests are altitudinally divided into three zones as lowland, montane and subalpine deciduous forests (Zohary 1973; Rastin 1983; Klein and Lacoste 1989; Frey et al. 1999; Akhani et al. 2010; Gholizadeh et al. 2020). Among the Hyrcanian elements, which are widely distributed in these forests, we list *Acer velutinum, Alchemilla citrina, A. melancholica, Centaurea hyrcanica, C. zuvandica, Crepis willemetioides* and *Parrotia persica* (Fig. 4.7b).

The lowland zone is determined by the upper limit of frost-sensitive tree species (Frey et al. 1999), ranging from the Caspian coast level up to 700 (1000) m a.s.l. The dominant and characteristic trees of this zone are *Acer cappadocicum*, *Albizia julibrissin*, *Alnus glutinosa*, *Buxus hyrcana*, *Danae racemosa*, *Ficus carica*, *Gleditsia caspica*, *Melia azedarach*, *Mespilus germanica*, *Parrotia persica*, *Populus caspica*, *Pterocarya fraxinifolia*, *Quercus castaneifolia*, *Tilia platyphyllos* and *Zelkova carpinifolia* (Frey et al. 1999; Hamzeh'ee et al. 2008; Siadati et al. 2013; Sagheb Talebi et al. 2014; Gholizadeh et al. 2020).

The montane zone is occupied mostly by beech forest, from 700 (1000) up to 1800 (2000) m a.s.l. and dominant tree species are *Acer platanoides*, *A. velutinum*, *Alnus subcordata*, *Carpinus betulus*, *Diospyros lotus*, *Fagus orientalis, Fraxinus excelsior*, *Ilex spinigera*, *Sorbus graeca*, *S. torminalis* and *Ulmus glabra* (Zohary 1973; Frey et al. 1999; Gholizadeh et al. 2020). The most important environmental factors affecting the species composition of these montane habitats are elevation, annual precipitation, mean annual temperature, slope inclination and soil properties (Moradi et al. 2016).

The upper zone of the forests is covered mostly by *Quercus macranthera* (Fig. 4.7c), ranging from (1800) 2000 to 2500 (2850) m a.s.l. (Klein and Lacoste 1989). Other characteristic tree and shrub species of this zone are *Acer hyrcanum, A. campestre, Carpinus orientalis*, *Crataegus pentagyna*, *Lonicera caucasica* and *Pyrus boissieriana* (Klein and Lacoste 1989; Naqinezhad and Esmailpoor 2017; Gholizadeh et al. 2020). The potential treeline of these forests was calculated at 3300 m a.s.l. but absence of appropriate treeline taxa (e.g. Pinaceae species) and strong anthropological activities (overgrazing) limit the upper limit of the forest to ca. 2500 m a.s.l. (Noroozi and Körner 2018).

Some of the most beautiful and showy species of these forests are *Crocus speciosus, Cyclamen elegans, Erythronium caucasicum*, *Galanthus transcaucasicus*, *Lilium ledebourii, Ornithogalum bungei* and *Paeonia wittmanniana*. There are many orchid species in these forests, such as *Anacamptis pyramidalis, Cephalanthera caucasica, Ophrys scolopax, Orchis adenocheila, O. mascula* and *O. simia*.

4.6.2 Juniperus excelsa *Woodlands*

Some areas of the south-facing slopes of the Alborz, in stands between 1900 to 3000 m a.s.l. elevation, are covered by *Juniperus excelsa* woodlands (Fig. 4.8a; Ravanbakhsh et al. 2016). However, some single individuals can be seen at lower (1500 m a.s.l.) and higher elevations (up to 3300 m a.s.l.) too (Noroozi and Körner 2018). The territory of these woodlands is reduced due to the anthropogenic activities (Zohary 1973; Akhani et al. 2010, 2013). Sparse communities of *Juniperus excelsa* exist along the south face of the Alborz (Frey et al. 1999; Ravanbakhsh et al. 2016), but extensive Juniper woodlands occupy the subalpine zone of the eastern Alborz (Fig. 4.8a). Ravanbakhsh et al. (2016) studied the species composition of these woodlands in detail. Predominant shrubs that dominantly co-occur are *Amygdalus lycioides, Berberis integerrima, Cerasus microcarpa, Cotoneaster nummularioides* and *Lonicera nummulariifolia*. Dominant herbaceous species are *Alyssum minus, Artemisia aucheri, Astragalus verus*, *Bromus tectorum, Crucianella glauca, Eremurus spectabilis, Euphorbia cheiradenia, Lamium amplexicaule, Hypericum scabrum, Minuartia meyeri, Psathyrostachys fragilis, Senecio vernalis* and *Viola modesta.* Other gymnosperm vegetation units in the Hyrcanian zone comprise *Cupressus sempervirens* (Fig. 4.8b) and *Thuja orientalis* woodlands which are sparsely developed in the rain-shaded valleys with Mediterranean climate conditions and a predomination of M elements (Akhani et al. 2010).

4.6.3 Montane Steppe Shrublands

This vegetation type covers the semi-arid slopes of the Alborz at the southern side from ca. 1400 m a.s.l. up to ca. 2500 m a.s.l. (Fig. 4.9) and is dominated by thorn-cushions, grasses and scattered shrubs, such as *Amygdalus* (Fig. 4.9a), *Crataegus,*

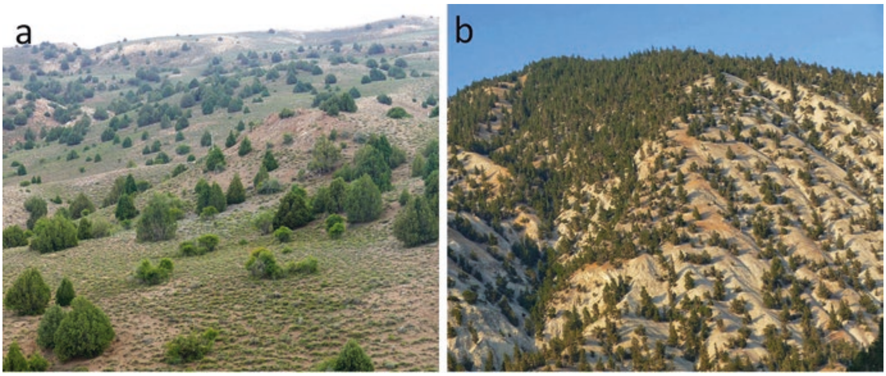

Fig. 4.8 (**a**) *Juniperus excelsa* woodlands (eastern Alborz, 2500 m a.s.l.); (**b**) *Cupressus sempervirens* woodlands (near Sefidrud valley, 1500 m a.s.l.; photos JN)

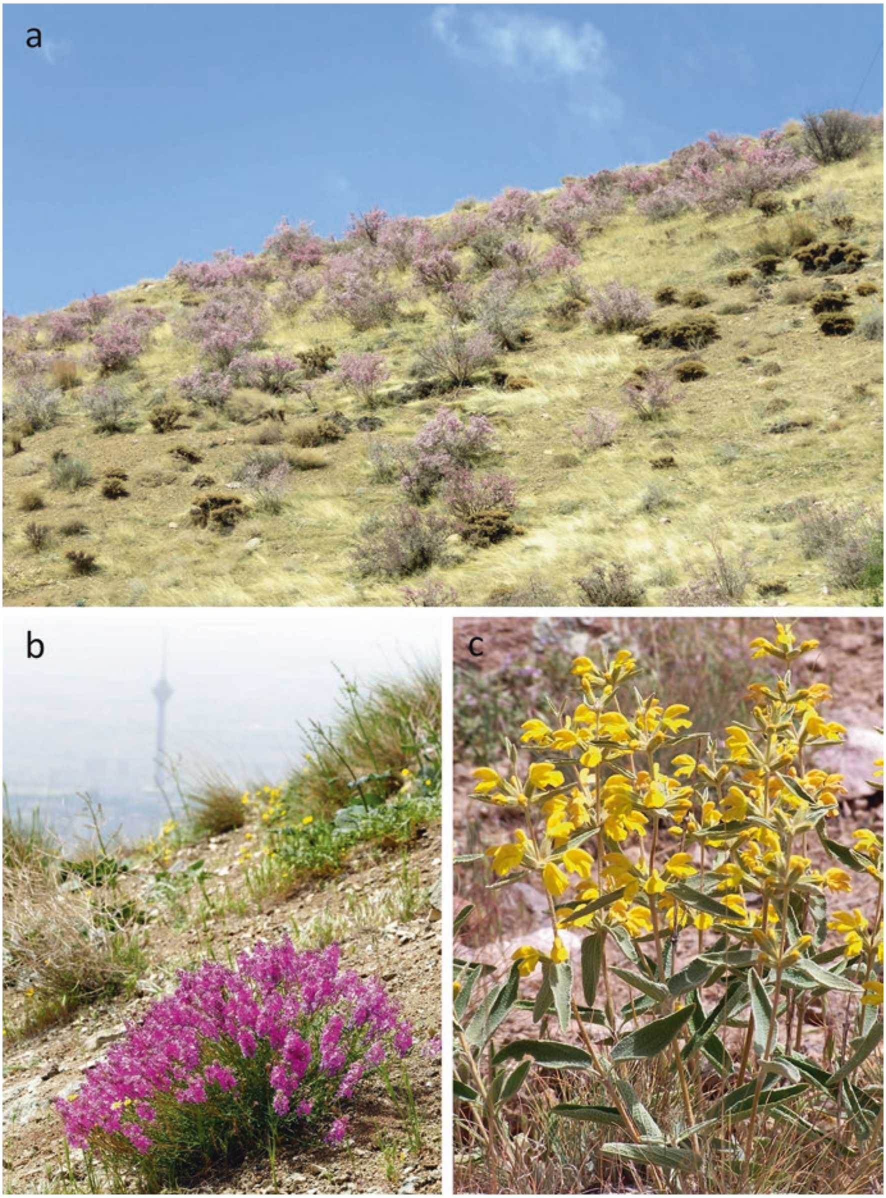

Fig. 4.9 Montane steppe shrublands. (**a**) *Amygdalus lycioides* and *Astragalus verus* (central Alborz, 2500 m a.s.l.; photo AT); (**b**) *Aethionema grandiflorum* (Tuchal Mt. 2400 m a.s.l.; photo JN); (**c**) *Phlomis olivieri* (Tuchal Mt. 2000 m a.s.l.; photo JN)

Cotoneaster, Rosa, etc. This is one of the richest vegetation types of the Alborz in the IT part (Mahdavi et al. 2013). The precipitation is around 400–500 mm per year. The most dominant and frequent species in this zone is *Astragalus microcephalus* and then *A. iranicus, A. verus* (Fig. 4.9a)*, Eryngium billardieri, Gundelia tehranica, Stipa arabica* and *Stipa hohenackeriana.* This vegetation type can be classified in the *Astragalo-Brometea* class (Quezel 1973), and other dominant species of this zone are *Aegilops columnaris, A. kotschyi, Aethionema grandiflorum* (Fig. 4.9b)*, Alyssum linifolium, Boissiera squarrosa, Bromus tomentellus, Carduus pycnocephalus, Centaurea virgata, Ceratocephala falcata, Chardinia orientalis, Convolvulus gracillimus, Crepis sancta, Erodium cicutarium, Holosteum glutinosum, Lamium amplexicaule, Linaria simplex, Minuartia meyeri, Phlomis olivieri* (Fig. 4.9c)*, Rochelia persica, Scariola orientalis, Senecio glaucus, Stachys inflata, S. lavandulifolia, Taeniatherum caput-medusae, Thymus kotschyanus, Tulipa montana, Vulpia ciliata, Xeranthemum longipapposum* and *Ziziphora tenuior*.

4.6.4 Wetlands

Although the majority of the south-facing slopes of the Alborz are dry and xerophytic, mesophytic communities can be found as well (Fig. 4.10). However, they are confined to the patchy, scattered wetlands surrounded by xerophytic communities from montane to subalpine zones. A total of 323 vascular plant taxa are recorded

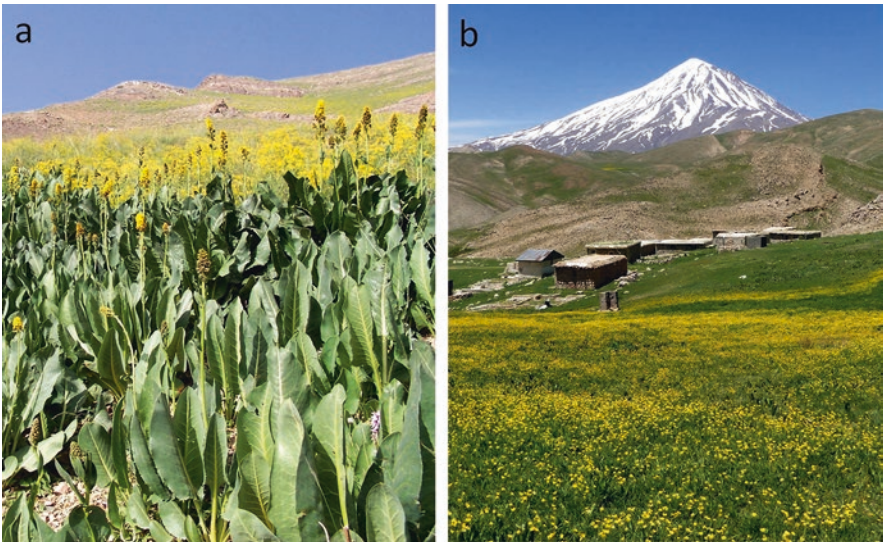

Fig. 4.10 Wetland vegetation types in the central Alborz. (**a**) *Ligularia persica* (2800 m a.s.l.); (**b**) *Ranunculus kotschyi* (2500 m a.s.l.; photos JN)

from wetlands on the southern faces of the Alborz by Naqinezhad et al. (2010). The most dominant species of the Alborz wetlands are *Allium schoenoprasum, Cardamine uliginosa, Campanula glomerata, Carex* spp.*, Cirsium vulgare, Dactylorhiza umbrosa, Eremopoa persica, Heracleum persicum, Juncus inflexus, Ligularia persica* (Fig. 4.10a)*, Linum catharticum, Mentha longifolia, Primula auriculata, Ranunculus kotschyi* (Fig. 4.10b)*, Stellaria persica, Swertia longifolia, Tanacetum balsamita, Urtica dioica, Veronica anagalis-aquatica* and *V. hispidula* (Naqinezhad et al. 2009, 2010; Kamrani et al. 2010, 2011). Most of species of these habitats are widely distributed and the rate of endemism is very low compared to the other vegetation types of the Alborz (Vanderplank et al. 2014).

4.6.5 Gypsophile Vegetation Types

Gypsum outcrops are widely distributed worldwide and are clearly distinguishable from neighbouring substrates, and like islands (dry islands) harbor high amount of endemics (Pérez-García et al. 2018). The gypsophile plants are well adapted to very xeric environments with very special chemical soil conditions, and only certain plant lineages can survive in these environments (Moore et al. 2014). Iran is the richest country in terms of gypsophile plants and 24% of the gypsophytes of the world (91 taxa) are recorded from Iran (Pérez-García et al. 2018). These habitats are sparsely scattered in the Alborz, especially in the lower montane zone. The most specialized species of these habitats are *Acantholimon cymosum*, *Astragalus fridae, A. podolobus, A. semnanensis, Calligonum junceum* (Fig. 4.11)*, Centaurea lachnopus, Euphorbia gypsicola, Gypsophila mucronifolia, Haplophyllum robustum, Lomatopodium staurophyllum, Moltkia gypsacea* and *Nepeta eremokosmos* (Eftekhari and Asadi 2001; Pérez-García et al. 2018; Rabizadeh et al. 2018).

4.6.6 Chasmophytic Vegetation

These habitats are common from the low montane up to the subnival zone. Klein (2001) classified these vegetation types in the class of *Asplenietea rupestris* which is common in Europe. Some of the character species of this class in the Alborz are *Arabis caucasica* (which takes the place of *Arabis alpina*)*, Asplenium ruta-muraria, A. viride* and *Cystopetris fragilis.* These species are widely distributed in the Eurasian mountains. All elevational zones of these habitats have their own dominant and character species. But some species occur in the Irano-Anatolian region only, such as *Gypsophila aretioides* (Fig. 4.12a)*, Scrophularia variegata* and *Silene odontopetala* (Fig. 4.12b). One of the endemic species of the Iranian Plateau which is restricted to rocky habitats is *Dielsiocharis kotschyi.* It is widely distributed in the Alborz, Zagros, Kerman-Yazd and Kopet Dagh mountains. *Tanacetum kotschyi* has a similar distribution pattern and the order *Tanacetalia kotschyi*, with an alliance

Fig. 4.11 Gypsophile vegetation type in the central Alborz between Tehran and Semnan (*Calligonum junceum,* 1500 m a.s.l.; photo JN)

and an association, was provisionally described for the communities of these habitats in the Alborz (Klein 1982b). The most frequent species of rock habitats in the montane zone in the central Alborz are *Ceterach officinarum, Eriocycla olivieri, Parietaria judaica, Silene schafta* and *Rosularia persica* (Akhani et al. 2013). The character species of subalpine and alpine rocks are *Crucianella gilanica, Gypsophila aretioides, Potentilla cryptophila, Sempervivum iranicum, Cystopteris fragilis, Graellsia stylosa, Scrophularia variegata, Silene odontopetala* and *Tanacetum kotschyi.* The following species are also typical species of rocky sites in the Alborz: *Arenaria polychnemifolia, Campanula lourica, Corydalis rupestris, Dionysia aretioides* (Fig. 4.12c)*, Draba aucheri, Erigeron hyrcanicus, Galium subvelutinum, Juniperus communis, Lamium tomentosum, Laser rechingeri, Minuartia lineata, Nepeta shahmirzadensis, Pimpinella tragium, Pseudosedum multicaulis, Salvia xanthocheila* (Fig. 4.12d)*, Satureja isophylla, S. mazanderanica, Silene meyeri, S. sojakii, Stachys laxa, Tanacetum hololeucum, Valeriana sisymbriifolia, Viola rupestris* and *V. spathulata* (Klein 1982b; Klein 2001; Noroozi 2005).

Fig. 4.12 Chasmophytic habitats. (**a**) *Gypsophila aretioides* (3300 m a.s.l.; photo AT); (**b**) *Silene odontopetala* (3000 m a.s.l.; photo JN); (**c**) *Dionysia aretioides* (1500 m a.s.l.; photo AT); (**d**) *Salvia xanthocheila* (2600 m a.s.l.; photo JN)

4.6.7 Subalpine Tall Herbs and Umbelliferous Vegetation Types

The south-facing slopes of the Alborz, in the subalpine zone with steep scree inclinations, are covered by tall herbs and umbelliferous vegetation types which are usually dominated by tall plants of the Apiaceae family, such as *Ferula, Ferulago* and *Prangos* (Fig. 4.13). These stands occur usually at elevations between 2500 and 3300 m a.s.l. but in some areas even reach up to 3600 m a.s.l. The average species richness per 25 m^2 is 25 species. *Prangos uloptera* (Fig. 4.13a) is the most dominant species of this vegetation in most of the Alborz, but in some regions it is replaced by *Diplotaenia cachrydifolia* (Fig. 4.13b), *Ferula gummosa* (Fig. 4.13c), *F. ovina, F. persica* or *Prangos ferulacea.* The provisional phytosociological class of *Prangetea ulopterae* was described by Klein (1987) for these vegetation types in the Alborz. Other frequent species are *Achillea vermicularis, Acinos graveolens, Alyssum minus, Arrhenatherum kotschyi, Asperula setosa, Astrodaucus orientalis, Bupleurum exaltatum, Chaerophyllum macropodum, Cousinia adenosticta, C. hypoleuca, Cruciata taurica, Echinops elbursensis, Festuca sclerophylla, Fibigia suffruticosa, Helichrysum oligocephalum, Hypericum scabrum, Lappula microcarpa, Melica persica, Mesostemma kotschyana, Polygonum polycnemoides, Psathyrostachys fragilis, Rheum ribes, Rumex elbrusensis* and *Silene aucheriana* (Klein 1987; Akhani et al. 2013).

4.6.8 Alpine Zone

A total of 516 vascular plant taxa are known from the alpine habitats of the Alborz (subalpine, alpine, subnival zones), of which 141 taxa (27%) only occur there (Noroozi et al. 2016). The richest genera in the alpine zone of the Alborz are *Astragalus* (31 taxa), *Alchemilla* (16), *Veronica* (16), *Oxytropis* (15), *Potentilla* (15), *Silene* (14), *Allium* (10) and *Cousinia* (10). The proportion of hemicryptophytes increases along the elevational gradient and nearly 75% of the alpine species have this life form (Noroozi et al. 2008). Although chamaephytes (especially as thorn-cushions) constitute only ca. 15% of the species of the alpine habitats of the region, their coverage makes them the most dominant life form of these habitats (Klein 1982a, 1988; Noroozi et al. 2010). From the alpine to the subnival zone, the chamaephytes decrease sharply and above 4250 m a.s.l. they disappear completely.

The species composition and vegetation types in these habitats are mainly shaped by topography and snow melting regimes (Noroozi et al. 2010; Noroozi and Körner 2018), which is a general trend in the alpine habitats of the globe (Körner 2003). Across a few meters distance at the same elevation, the growing season can differ several months (see Fig. 4.14; Noroozi and Körner 2018). Three major vegetation types can be recognized in this zone (Klein 1982a, 1984, 1987, 2001; Noroozi et al. 2010, 2014):

Fig. 4.13 Subalpine tall herbs and umbelliferous vegetation types. (**a**) *Prangos uloptera* (3300 m a.s.l.); (**b**) *Diplotaenia cachrydifolia* (3200 m a.s.l.); (**c**) *Ferula gummosa* (2600 m a.s.l.; photos JN)

Thorn-cushion grasslands in the subalpine and alpine habitats are very common and mostly cover windswept slopes dominated by tragacanthic species, such as *Acantholimon demawendicum, Arenaria insignis*, *Astragalus iodotropis*, *A. macrosemius* (Fig. 4.15a), *Onobrychis cornuta*, and tall grasses such as *Alopecurus textilis, Bromus tomentosus, Festuca alaica, Piptatherum laterale* and *Poa araratica* (Klein 1982a, 1988; Noroozi et al. 2010). The plant communities of these areas are classified in the *Drabetalia pulchellae* (Noroozi et al. 2010). Other dominant species are *Campanula stevenii* subsp. *beauverdiana, Cousinia crispa, C. multiloba, Draba pulchella, Galium decumbens, Helichrysum psychrophilum, Marrubium astracanicum, Minuartia lineata*, *Oxytropis persica, Pedicularis pycnantha, Polygonum molliiforme, Tanacetum polycephalum, Thymus pubescens, Trachydium depressum, Tragopogon kotschyi* and *Veronica kurdica*. For more detailed information see Klein (1982a, 1988) and Noroozi et al. (2010).

Snowbed communities occupy the grounds which are free from snow for a few months or weeks (Fig. 4.14, 4.15b). They are vastly distributed in the oroarctic and arctic, but become scattered to the south (Kürschner et al. 1998). These communities are dominated by rosettes and small herbs because the growing season is very

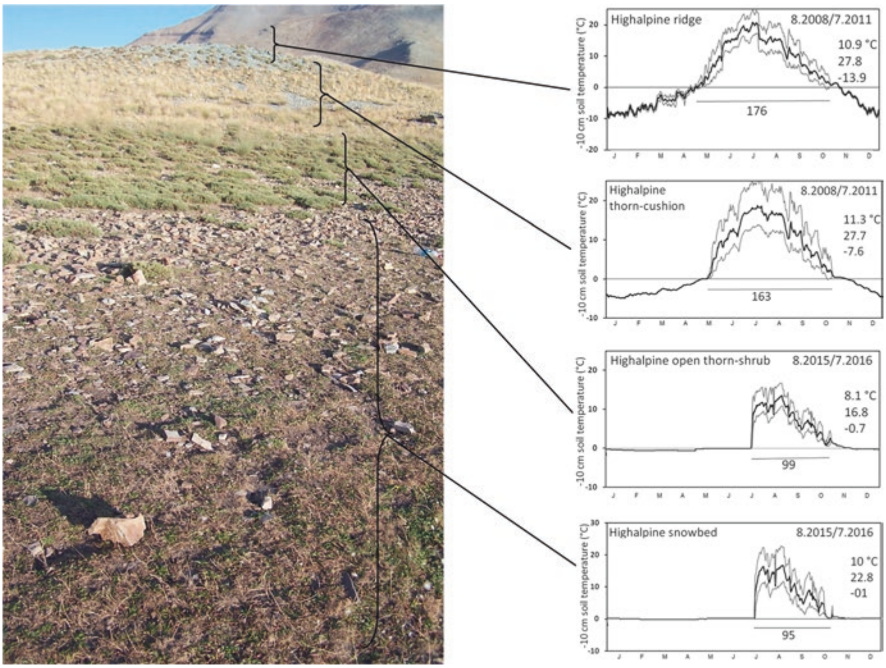

Fig. 4.14 Different plant communities of the high alpine zone of the Alborz (Tuchal Mt., 3700 m a.s.l.; photo JN), from a depression to the top of a mound. The diagrams show the soil temperatures in different communities along a gradient at the time when the snow has melted. For more details see Noroozi and Körner (2018)

short for development of tall plants and chamaephytes (Noroozi et al. 2010). A few species are adapted to live in such a short growing period. Therefore the plant diversity is poor in these communities (ca. 5 species per 25 square meters). These communities are classified in the *Taraxaco brevirostris-Polygonion serpyllacei* alliance which ecologically is very close to the class *Salicetea herbaceae* in Europe (Noroozi et al. 2010). They are usually restricted to the depressions and runnels, and surrounded by thorn-cushion grasslands (Fig. 4.14, 4.15b). The most dominant species of these communities are *Alopecurus aucheri, Carum caucasicum, Catabrosella parviflora*, *Cerastium cerastoides, Plantago atrata, Polygonum serpyllaceum, Ranunculus crymophilus* (Fig. 4.15b), *Sibbaldia parviflora, Taraxacum brevirostre* and *Trifolium radicosum* (Klein 1982a; Noroozi et al. 2010).

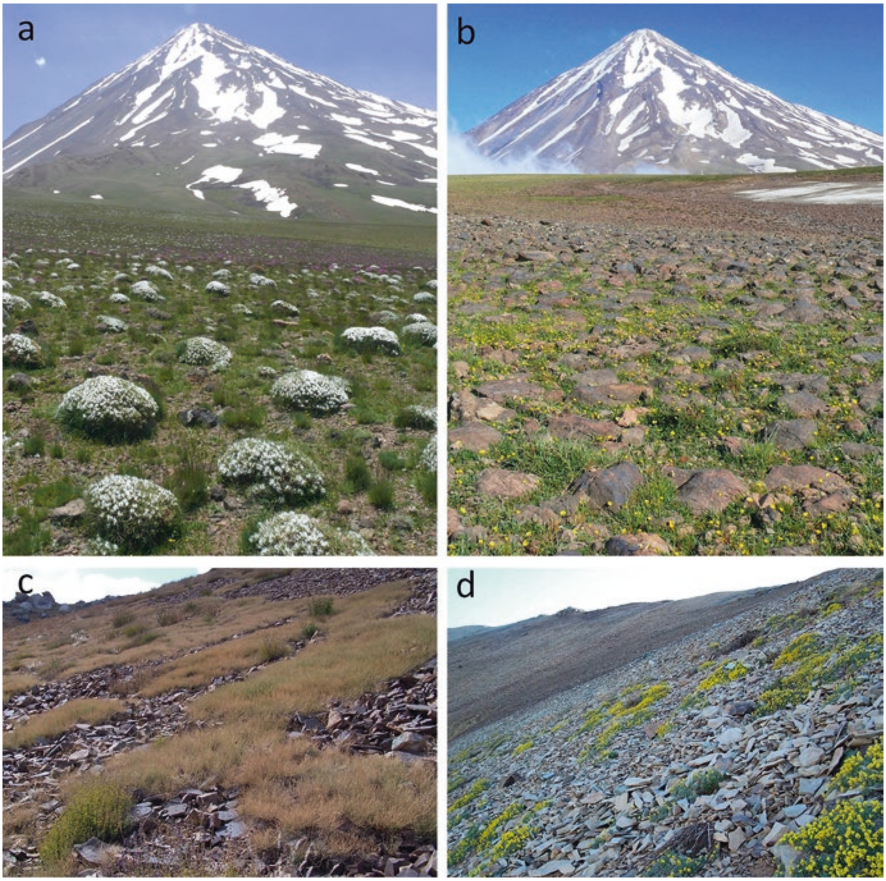

Fig. 4.15 (**a**) Alpine thorn-cushion grasslands (*Astragalus macrosemius*, Damavand Mt., 3600 m a.s.l.); (**b**) Snowbed communities (*Ranunculus crymophilus* community, Damavand Mt., 3650 m a.s.l.); (**c & d**) Alpine scree vegetation types. (**c**) *Cicer tragacanthoides*; (**d**) *Physoptychis gnaphalodes* (both photos from Tuchal Mt., 3600–3700 m a.s.l.; photos JN)

Alpine screes are classified in the *Didymophyso aucheri-Dracocephaletea aucheri* class and *Physoptychio gnaphalodis-Brometalia tomentosi* order by Noroozi et al. (2014). These communities are mostly transitional between the subnival and high alpine zones. The most characteristic species of these habitats are *Cicer tragacanthoides* (Fig. 4.15c), *Elymus longiaristatus, Euphorbia aucheri, Galium aucheri, Leonurus cardiaca* subsp. *persica, Nepeta racemosa, Physoptychis gnaphalodes* (Fig. 4.15d), *Vicia ciceroidea* and *Ziziphora clinopodioides* subsp. *elbursensis*. Some thorn-cushion grassland elements can be also dominant in these stands, e.g. *Alopecurus textilis, Astragalus macrosemius* (Fig. 4.15a, 4.16a), *Bromus tomentosus* and *Poa araratica* (Noroozi et al. 2014). In general, the scree habitats of the Iranian mountains have a high proportion of endemics compared to other habitats (Vanderplank et al. 2014).

4.6.9 Subnival Zone

The majority of subnival zone in the Iranian Plateau is concentrated to the central Alborz. In the Alborz, the elevations above ca. 3800–4000 m a.s.l. are the subnival zone, where the vegetation cover is not continuous and mostly scattered. The soil is poorly developed and the ground is dominated by screes and rocks. The environmental condition of these elevations is extremely harsh, because of strong winds, very low temperatures, a very short growing season and intensive irradiation (Noroozi et al. 2014; Noroozi and Körner 2018). Subnival plants are among the most cold-adapted plant species. Some species occurring in these habitats find their optimum distribution in these habitats, but species of the alpine and subalpine zones also reach these habitats (Noroozi et al. 2011). A total of 151 species have been recorded from the subnival zone of the Iranian mountains of which 51 species are truely subnival species (Noroozi et al. 2011). Some of subnival species of the Alborz are *Achillea aucheri, Asperula glomerata* subsp. *bracteata* (Fig. 4.16a), *Astragalus atricapillus, Cerastium purpurascens, Chamaesciadium acaule, Didymophysa aucheri* (Fig. 4.16b), *Draba siliquosa, Dracocephalum aucheri, Erysimum elbrusense, Lamium tomentosum, Lepechiniella persica, Oxytropis kermanica, Myopordon damavandica, Oxytropis takhti-soleimanii, Paraquilegia caespitosa* (Fig. 4.16c), *Pseudocamelina glaucophylla, Saxifraga iranica, Scutellaria glechomoides, Senecio iranicus, Veronica aucheri* and *V. paederotae* (Klein and Lacoste 2001; Noroozi et al. 2011). The plant communities of these habitats are classified in the *Didymophyso aucheri-Dracocephaletea aucheri* class and *Didymophysetalia aucheri* order (Noroozi et al. 2014). Only Mt. Damavand (5671 m a.s.l.) exceeds the upper limit of vascular plants in the Alborz, i.e. 4850 m a.s.l. The species reaching up to the upper limit of occurrence of vascular plants in the central Alborz are *Cerastium purpurascens* var. *elbrusense*, *Didymophysa aucheri, Dracocephalum aucheri, Erysimum elbrusense, Paraquilegia caespitosa, Saxifraga iranica* and *Veronica aucheri* (Klein and Lacoste 2001; Noroozi et al. 2014). Annual soil temperatures of the highest record of vascular plants in the Alborz was measured

Fig. 4.16 Subnival scree vegetation types. (**a**) *Asperula glomerata* subsp. *bracteata* and *Astragalus macrosemius* (4200 m a.s.l.), and the Alamkuh glacier in the background; (**b**) *Didymophysa aucheri* (Alamkuh, 4000–4200 m a.s.l.); (**c**) *Paraquilegia caespitosa* (Alamkuh, 4400 m a.s.l.; photos JN)

(Noroozi and Körner 2018), which is comparable to that of the highest record of vascular plants in the Alps (Körner 2011). The soil temperatures in both regions are very low in winter (they can drop down to −20 °C), and at night time is mostly below zero even in the growing season. Moreover, the growing season is too short. The biodiversity of these habitats is threatened most strongly by climate change, which may facilitate an upward shift of species from lower elevations. The result may be that the most cold-adapted species will have to face the competition of species from lower elevations, especially when there is no alternative habitat to move up.

4.7 Conservation

Different kinds of threats are affecting the fragile flora and vegetation types of the Alborz. The lowlands in the north and south faces of the Alborz are under high pressures of urbanization and industrialization activities, man-made fires, logging and tourism. These are more obvious in the lowlands of the Hyrcanian forests (Akhani et al. 2010). At higher elevations, overgrazing (Fig. 4.17a) is one of the most important factors degrading the natural habitats and vegetation. Dominance of poisonous species like *Euphorbia* spp. and spiny thorn-cushion plants indicate the high pressure of pasturalism. The gap between the current upper limit of the Hyrcanian forest line (ca. 2500 m a.s.l.) and the potential forest line, that can sporadically reach up to 2850 m a.s.l., is the consequence of severe trampling of herds of sheep, goats and cattle on the steep slopes (Fig. 4.17b; Noroozi and Körner 2018). This phenomenon is threatening the Hyrcanian forests by shrinking the territory of these ecosystems. The alpine habitats suffer from overgrazing by huge herds, especially in summer time, when the lower elevations are too dry for grazing (Noroozi et al. 2008; Akhani et al. 2013). Road building and mining are other activities which have been disturbing the natural habitats during the last decades. Tree plantation (mostly introduced taxa such as *Cupressus arizonica, Robinia pseudoacacia* and *Pinus eldarica*) on steep slopes of the Alborz (Fig. 4.17c), especially on the southern faces, has changed the species composition of the natural habitats (Akhani et al. 2013). Invasive species also are a considerable problem on the Alborz. One of the most well-known invasive species of the Alborz is *Azolla filiculoides* in wetlands of the Hyrcanian forests, and this is strongly destroying the natural plant and animal communities of these ecosystems. The acceleration of climate warming is another important threat to the flora and vegetation of the Alborz, especially in alpine and subnival habitats. Alpine-subnival species are cold-adapted and the absence of alternative habitats to shift up in the Alborz enlarges this threat.

There are several nature reserves in the Alborz including 16 Protected Areas, 6 National Parks and 4 Wildlife Refuges (Fig. 4.18). However, as the majority of these mountains were identified as centres of endemism, the conservation gaps (centres of endemism which are not protected) are still considerable (Noroozi et al. 2019a).

Fig. 4.17 Anthropogenic activities. (**a**) Overgrazing (Damavand Mt., 3100 m a.s.l.); (**b**) Trampling impact of herds at the forest line in the Hyrcanian region (Alamkuh Mt., 2500 m a.s.l.); (**c**) Planting of tree species on the steep slopes of Tuchal Mt. (north of Tehran, 2000 m a.s.l.; photos JN)

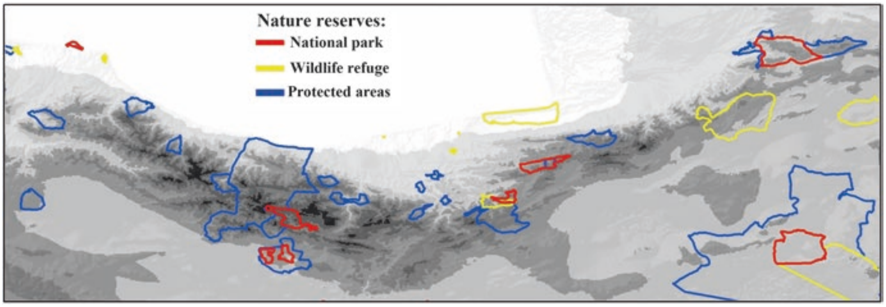

Fig. 4.18 Nature reserves in the Alborz with 16 Protected Areas, 6 National Parks and 4 Wildlife Refuges

Even in the nature reserves, the overgrazing is a big problem (Akhani 1998). A recent study shows that near to 25% of the surface areas of the Iranian nature reserves are under severe anthropological pressure (Karimi and Jones 2020).

The Alborz is an important mountain range not only for its unique biodiversity and high endemicity but also for providing water resources for lowlands. The big cities like Tehran, Karaj, Qazvin, Semnan, etc. in the southern foothills, and Rasht, Noshahr, Sari, Gorgan and many other smaller cities and villages in the Hyrcanian region, are dependent on the water sources of the Alborz. Therefore, the protection of vegetation and biodiversity of the Alborz is not only important for the nature but also for human beings in this region.

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Chapter 5
The Yazd–Kerman Massifs

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Abstract The Yazd–Kerman massifs include the poorly known highlands of central and southern Iran reaching to 4465 m a.s.l. at the highest peak. This area belongs to the Irano–Turanian phytogeographical region and 68% of the flora belongs to this floristic region. Total flora of the area is composed of 1308 vascular plant species of which 8% are endemics. The richest genera in terms of endemic species are *Astragalus* (21 species), *Acantholimon* (13), *Cousinia* (8), *Echinops* (8) and *Nepeta* (7). Hemicryptophytes (36%) and therophytes (32%) are the most dominant life forms. Several vegetation types are distinguishable in various habitats including halophytic vegetation, *Stipa-Artemisia* steppes, psammophytic vegetation, shrublands and woodlands, *Rheum ribes* vegetation, wetland communities, rocky cliff vegetation, subalpine umbelliferous communities and alpine–subnival communities. The protected areas hardly correlate with the biodiversity hotspots in the region and therefore many species are threatened.

Abbreviations

ES Euro-Siberian
IT Irano-Turanian
M Mediterranean
SS Saharo-Sindian
YK Yazd-Kerman

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5.1 Introduction

The Yazd–Kerman massifs comprise several high and isolated mountains located in central and southern Iran (Fig. 5.1). The highest peaks of the YK massifs are Hezar (4465 m a.s.l.), Lalezar (4351 m a.s.l.), Palvar (4233 m a.s.l.), Jupar (4135 m a.s.l.), Shirkuh (4065 m a.s.l.), Khabr (3845 m a.s.l.) and Jebal Barez (3741 m a.s.l.). These high mountains are separated from other mountains by flat plains and lowland semi–desert and desert areas. The great Kavir Desert is situated on the north and Lut Desert on the east.

Even though being partly separated by lowland semi–desert areas, these mountains are strongly connected to each other floristically, and recent studies have recognized them as an integrated unit, either in the form of an area of endemism (Noroozi et al. 2018, 2019b) or as several centres of endemism (Noroozi et al. 2019a). The flora of the YK massifs shows a close phytogeographical connection to other neighboring mountains, especially the Zagros range (Noroozi et al. 2019b). Moreover, they have a remarkable floristic link to the mountains of the Hindu Kush, Central Asia and the Western Himalaya (Noroozi et al. 2008, 2010, 2011; Doostmohammadi and Kilian 2017). High mountains of the YK harbor many species-rich IT genera such as *Astragalus*, *Acantolimon* and *Nepeta* (Zohary 1973). However, the lowland areas are characterized by several psammophytic and halophytic IT species and in the southern territories of the area there is a strong representation of various SS and Somalia–Masai elements (Edmondson et al. 1980; Leonard 1988–1989).

Floristic studies on these mountains date back to the early twentieth century (Bornmüller 1911, 1937, 1938, 1940, 1942), followed by the extensive work of the Flora Iranica (Rechinger 1963–2015) and Flora of Iran (Assadi et al. 1988–2017). Early local floristic studies have been conducted on Jupar Mountain (Freitag and Kuhle 1980) and in Khabr National Park (Edmondson et al. 1980) and more recently on the Bahr–Aseman, Ra'skuh, Riseh, Khabr and Hezar Mountains and the Damgahan valley (Iran Nejad et al. 2001; Zarezadeh et al. 2007; Rajaei et al. 2011; Saberi et al. 2013; Malekpourzadeh et al. 2015; Payande et al. 2016). Since the Flora Iranica, new taxonomic articles have constantly added to the floristic stock of the area, either by reporting range extensions in some species or by introducing new taxa (Ghahreman and Mirtadzadini 2000; Attar et al. 2001; Maassoumi and Vakili 2001; Zarre and Podlech 2001; Mozaffarian 2002; Nordenstam et al. 2002; Jamzad et al. 2003; Podlech and Zarre 2003; Podlech and Maassouni 2003; Mirtadzadini and Attar 2004; Mirtadzadini et al. 2004; Podlech 2004; Ranjbar and Karamian 2004; Ghahremaninejad and Narimisa 2005; Khodashenas et al. 2006; Maasoumi and Mirtadzadini 2006; Mohsenzadeh et al. 2007; Ajani and Ajani 2008; Hamdi et al. 2008; Assadi 2009; Attar and Mirtadzadini 2009; Ajani et al. 2010; Mohsenzadeh et al. 2010; Noroozi et al. 2010; Mahmoodi et al. 2013; Sonboli et al. 2011; Ranjbar 2011; Kilian et al. 2012; Dashti et al. 2014; Mirtadzadini and Attar 2014; Moazzeni et al. 2014; Ranjbar and Mahmoudi 2015; Nejad Falatoury et al. 2016; Moazzeni et al. 2016; Rajaei and Mozaffarian 2016; Doostmohammadi and

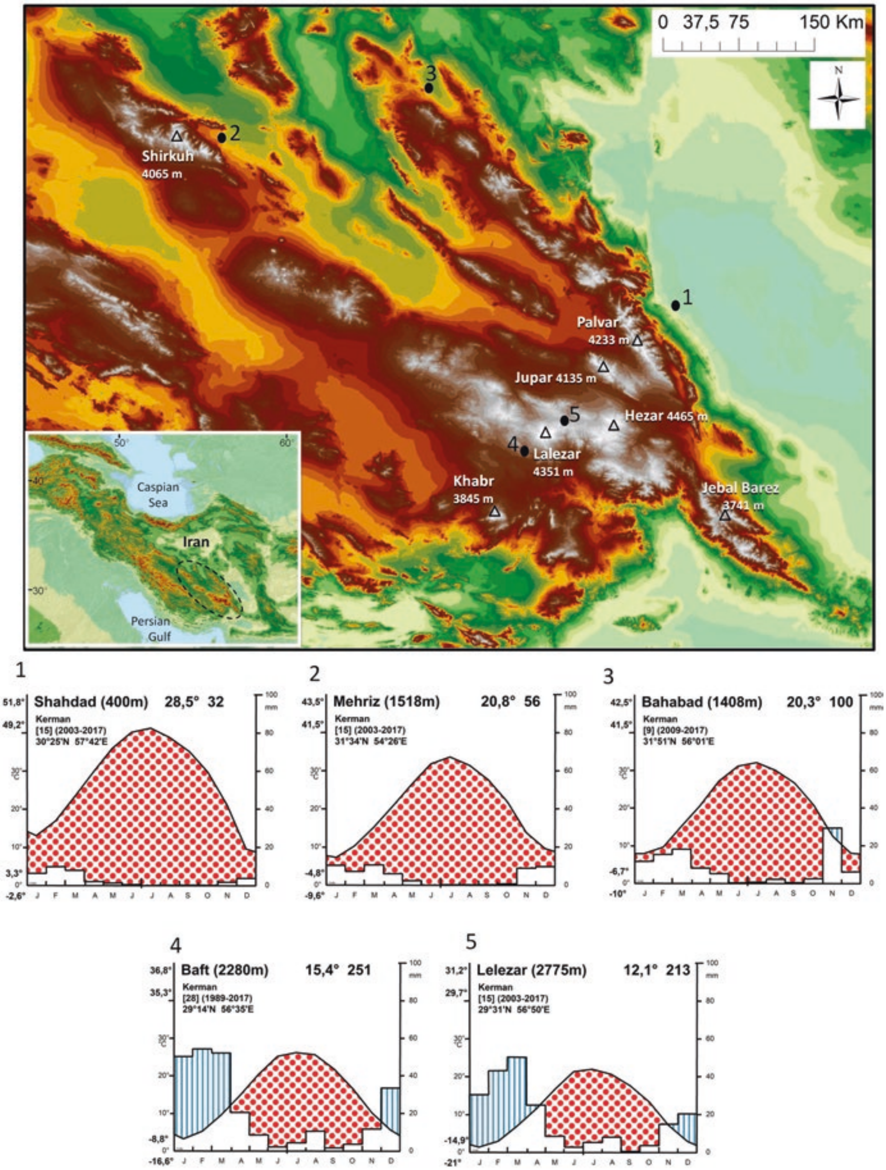

Fig. 5.1 Geographical location of the YK massifs and climatic diagrams of five stations in the area. The highest mountain peaks are shown on the map

Kilian 2017; Pahlevani 2017; Doostmohammadi and Mirtadzadini 2019). The numerous reports and articles, especially in the most recent years, imply that these mountains are not yet well–known and new species are still waiting to be discovered (see above mentioned references). The most common vegetation types of the area were recorded by Zohary (1963), as part of two longer transects crossing the YK massifs. The introduced associations, however, were briefly described by mentioning only two dominant species without any coefficient of abundance–dominance (Leonard 1993). More recently, Leonard (1991–1992) investigated the plant associations of the desert areas and lowland plains of the YK region in more detail. Both studies are restricted mainly to lowlands and flat plains between mountain ranges and no vegetation studies have been conducted on highlands of the area.

Here we give a preliminary overview on the floristic diversity, phytogeographical affinity, vegetation structure and conservation status of the YK massifs. More specifically the statistics are provided for the number of species occurring in the area, their chorology and rate of endemism. Major plant communities and vegetation units in the area are also discussed briefly. Finally, *Bupleurum aitchisonii* (Boiss.) Wolff is reported from the area as an addition to the flora of Iran.

5.2 Geology

The YK massifs are composed of three major tectonic crustal blocks, including the Sanandaj–Sirjan zone, the Central Iranian microcontinent and the Urmia–Dokhtar volcanic belt that are separated mainly by the Nain–Baft fault (Berberian and King 1981; Mehdipour Ghazi and Moazzen 2015). The geological structure and orogeny of the YK massifs is very complicated. These high mountains are mostly composed of Cretaceous limestone and early Tertiary (Eocene) conglomerates (Kerman conglomerate, which consists of limestone, sandstone and basic volcanic components; Freitag and Kuhle 1980; Kuhle 1974). The precursory phases of the Alpine orogeny in Iran lasted from the late Triassic (200 Ma) to the Late Jurassic–Early Cretaceous (ca. 65 Ma; Berberain and King 1981). The subsequent late Cretaceous to middle Tertiary movements constructed the major structural and geographical features of the area and created a continental climate that has lasted up to the present (Stöcklin 1968). After the Eocene period of extensive volcanism, it was mainly during the Oligocene orogenic phase that the mountain ranges of Central Iran took shape. Most of the copper and lead–zinc mineralizations are related to the early Tertiary (Eocene) volcanic activities (Berberian and King 1981; Stöcklin 1968).

Soils of the area can be classified, based on topography, into three main groups including soils of the plains and valleys, soils of the plateaus and soils of the mountains. Valleys and low plains are covered mostly by fine or coarse–textured alluvial soils, halomorphic (solonchak and solonetz) soils and poorly drained saline alluvial soils. Plateaus above 1500 m a.s.l., which constitute a great part of the YK massifs, are mostly composed of desert soils in association with regosols, sand dunes, sierozem and solonchak soils. Soils of mountains and slopes are very shallow and without any clear profile. These soils comprise a high proportion of rock fragments with low rates of weathering. Soils of the dissected slopes and mountains of the YK massifs are mainly formed by complex associations of calcareous lithosols together with desert and sierozem soils, plus lithosols with sierozem and brown soils. Organic matter in these soils is very low (Dewan and Famouri 1964). In some places, like on the Bidkhan volcano (northwest of Lalezar Mountain), volcanic debris also plays a role in the formation of soils in the YK massifs (Khalili Mobarhan and Ahmadipour 2015). The reader is referred to Stöcklin (1968), Dewan and Famouri (1964) and Kuhle (1976) for a detailed survey on the orogeny and geology of the YK massifs.

5.3 Climate

The climate of the YK massifs is characterized by a high degree of continentality, prolonged dry summers and harsh winters. Based on the Bioclimatic Classification System of Iran (Djamali et al. 2011), major parts of the YK massifs are comprised within the Mediterranean desertic continental bioclimate. This bioclimate is characterized by a very low annual precipitation and extended dry season and covers a large part of the Central Iranian deserts. But this bioclimatic system doesn't give a clear view of the climatic conditions and precipitation of all high mountains, as it suffers from a lack of data from higher elevations. The annual precipitation in the city of Baft (2280 m a.s.l.) is 250 mm (Fig. 5.1) and annual precipitation values of 300–450 mm can be assumed for higher elevations, as the precipitation increases by about 100 mm per 1000 m of elevation. Precipitation falls are mostly in the form of snow at higher elevations and during the winter. According to Djamali et al. (2011), some places of high elevation in the YK massifs belong to the Mediterranean xeric continental bioclimate, which also covers the eastern parts of the Zagros and most of the Kopet Dagh Mountains. The presence of a Mediterranean xeric oceanic bioclimate in the southern parts of the YK massifs is of high interest. This bioclimate covers the mountains and foothills of Jebal Barez and the Khabr National Park. The relatively low continentality and a somewhat higher average of winter temperature minima create an appropriate climate in several microhabitats.

There are no glaciers in the YK massifs, but in some colder years, several snow patches persist throughout the year in the valleys and on the north-facing slopes of the Shirkuh, Hezar and Lalezar mountains. Based on geomorphological studies in the Jupar, Hezar and Lalezar mountains, Kuhle (2008) concluded that two late-Pleistocene mountain glaciations (pre–LGP and LGP) have occurred in the area and that a rather low average annual temperature of 11.2 °C and 10.5 °C can be assumed for these highlands in the late-Pleistocene, about 130 and 60–18 thousand years ago.

5.4 Flora and Phytogeography

5.4.1 Paleobotany

The history of vegetation and climate change in the northwest and central Zagros shows the dominance of a cold and dry *Stipa-Artemisia* steppe before 14,000 cal. B.P. which gradually turned into an open scrub of *Amygdalus–Pistacia* plus *Quercus brantii* woodland. Thickening of these woodlands, starting at ca. 6000 cal. B.P., finally established the current–day oak forests of the Zagros (Van Zeist and Wright 1963; Van Zeist 1967; Van Zeist and Bottema 1977). Climatic oscillations and consequent vegetation dynamics in the YK massifs are probably similar to that in the Zagros range, but it is not clear how long after the Holocene amelioration the *Amygdalus-Pistacia* shrublands have expanded to the southeastern areas (Miller and Kimiaie 2006). Another difference is that the YK massifs are much drier and Q*uercus brantii* stands haven't occupied these mountains, so that the present climax situation is *Amygdalus-Pistacia* shrublands.

An extensive degradation of *Amygdalus-Pistacia* shrublands around 2700 cal. B.P. has been recorded from the southern Zagros around lake Maharlu (Djamali et al. 2009) and the southern margin of the YK mountains around Jiroft (Gurjazkaite et al. 2018). These vegetation degradations are presumably due to the intensive human activities which coincided with the beginning of the Persian Empire and continued through the Islamic epoch (Djamali et al. 2009; Gurjazkaite et al. 2018). Similar events may also be assumed for the YK massifs, as these mountains are not very far from the two points that have been studied.

5.4.2 Floristic Diversity

According to our database, 1308 vascular plant species occur within the boundaries of the YK massifs, belonging to 496 genera and 93 families. The Dicots are responsible for most of the diversity of the total flora with 1126 species (86%), in 403 genera and 70 families; the Monocots contribute 167 species (13%), in 84 genera and 18 families. Gymnosperms and Pteridophytes occur in the area with 7 species each. The most diverse families in the area are Asteraceae (204 species), Fabaceae (152), Brassicaceae (94), Poaceae (84), Lamiaceae (81), Caryophyllaceae (61), Apiaceae (54), Boraginaceae (46), Chenopodiaceae (45), and Scrophulariaceae (32; Fig. 5.2). The ten largest families comprise more than 66% of the total flora. The largest genera in the YK massifs are *Astragalus* (Fabaceae; 92 species), *Cousinia* (Asteraceae; 29), *Nepeta* (Lamiaceae; 24), *Acantholimon* (Plumbaginaceae; 22) and *Euphorbia* (Euphorbiaceae; 19; Fig. 5.3).

Hemicryptophytes are the main life form in the YK massifs with 36% followed by therophytes (32%), chamaephytes (18%), phanerophytes (9%) and geophytes (5%). The high number of hemicryptophytes in the YK massifs is also seen in a

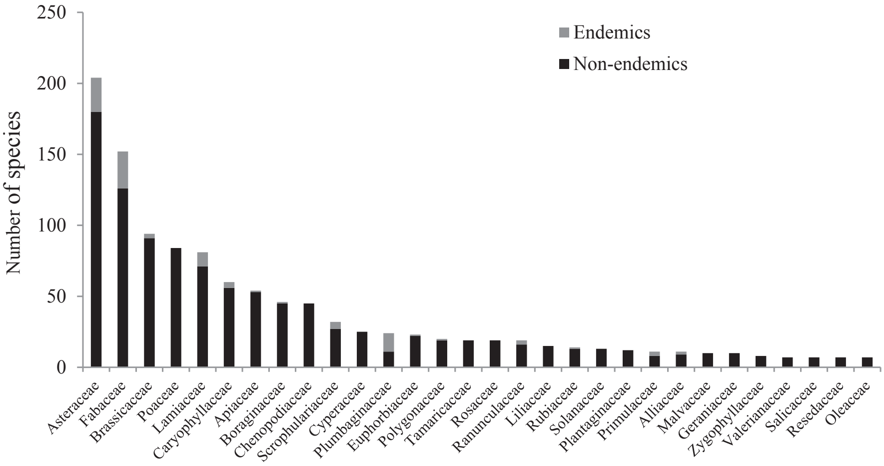

Fig. 5.2 Number of species in the 30 most species rich families of the YK massifs vascular flora (the number of endemic and non-endemic species are separated by different shades)

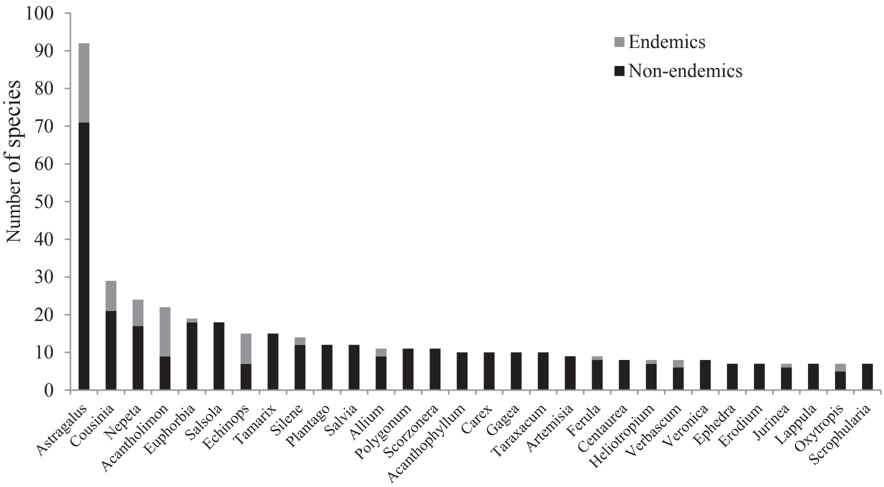

Fig. 5.3 Number of species in the 30 most species rich genera of the YK massifs vascular flora (the number of endemic and non-endemic species are separated by different shades)

similarly high presence in the general life form spectrum of the IT region. It reflects the predominance of a continental climate with harsh winter conditions. The semi–desert lowlands and salty or sandy plains between the mountain blocks of the YK massifs, together with longer dry seasons in these mountains, provide suitable habitats for many IT and SS therophyte species in this area. In fact the proportion of therophytes in the YK massifs is higher than in the other high mountains of the Iranian Plateau (Noroozi et al. 2019b). This should be due to the dry climate of the region. Although large genera of geophytes are important constituents in many IT habitats, the flora of the YK massifs is poor in this life form. *Allium*, *Tulipa* and *Eremurus* are represented in the area by 9, 2 and 2 species, respectively. From the *Fritillaria* species, only *F. persica* occurs in the area. Even *F. imperialis,* with a wide distribution that extends from Anatolia and the Zagros to the Hindu Kush and Kashmir, is absent from the YK massifs.

5.4.3 Phytogeography

The YK massifs are part of the IT phytogeographical region (Zohary 1973; Leonard 1988–1989). Along its southern borders, it gradually passes through a kind of ecotone to the northern borders of the SS regional zone. Doostmohammadi et al. (2018) redefined the territories of the IT region and split it up into an Irano–Turkestanian highland and a Turanian lowland region. According to this concept, the YK massifs belong to the Irano–Turkestanian phytogeographical region and are surrounded by Turanian areas, particularly in the north and east. Many characteristic Irano–Turkestanian genera, such as *Astragalus*, *Cousinia*, *Acantholimon* and *Nepeta* contribute to the high species richness and endemism in the YK massifs. Besides, several Turanian and Saharo–Sindian species have intruded the lowland and flat plains between the mountain blocks.

The floristic relationships between the YK massifs and the neighboring mountains are shown in (Fig. 5.4). Since the YK massifs are spatially close to the Zagros mountain range, their strong floristic connection is expected. Besides, a remarkable floristic link is observed between the YK massifs and the Hindu Kush, the mountains of Central Asia and even the Western Himalaya. This disjunct pattern of distribution has been postulated to be probably the result of post glacial warming that has pushed the species to higher elevations and separated them in widely disjuncted populations (Noroozi et al. 2008, 2011).

The flora of the YK massifs is composed of a mixture of elements from different phytogeographical regions, which are classified here into seven main categories (Fig. 5.5), as follows:

(Sub)Cosmopolites This group also can be categorized as Pluri–regional and includes Cosmopolitan and Circum–boreal high mountain species, such as *Cerastium cerastoides*, *Gentiana aquatica*, *Sagina saginoides,* together with ruderal species and weeds like *Anagallis arvensis*, *Atriplex canescens, Capsella bursa–pastoris, Chenopodium album, Convolvulus arvensis, Euphorbia helioscopia, Gnaphalium luteoalbum* and *Lactuca serriola.* This group comprises about 5% of the flora of the area.

IT-ES-M Just over 3% of the total flora is distributed in three phytogeographical regions. Some representatives are *Achillea millefolium*, *Arenaria leptoclados*, *Chorispora tenella, Crupina vulgaris, Euphorbia falcata, Geranium dissec-*

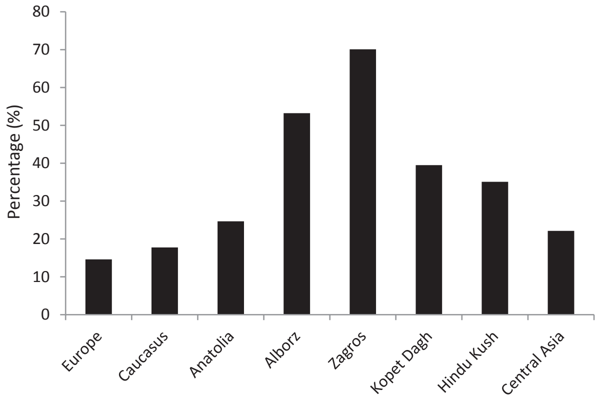

Fig. 5.4 Floristic affinity of the YK massifs with other mountain ranges. The Y-axis is the percentage of species common with the YK massifs

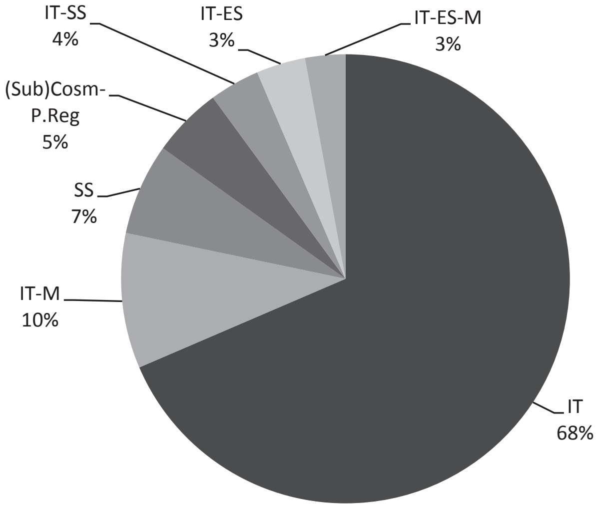

Fig. 5.5 Phytochoria of the species of the YK massifs. Cosm: Cosmopolite; P.Reg: Pluri-regional

tum, Heliotropium europaeum, Lepidium draba, Parietaria judaica, Sisymbrium loesselii and *Trifolium lappaceum*.

IT-M This group of bi–regional elements includes 10% of the species. Some members are *Althaea ludwigii, Atractylis cancellata, Ammi majus, Astragalus hamosus, Calendula alata, Carduus arabicus, Centaurea depressa, Chenopodium botrys, Chrysanthemum coronarium, Crupina vulgaris, Eremopyrum orientale, Erodium laciniatum, Erodium malacoides, Euphorbia falcata, Gladiolus atroviolaceus,* *Gynandriris sisyrinchium, Herniaria cinerea, Matricaria aurea, Melilotus indicus, Thalictrum isopyroides* and *Vicia monantha*.

IT-SS This category includes 4% of total flora. Examples are *Astragalus crenatus, Atriplex dimorphostegia, Brassica tournefortii, Convolvulus oxysepalus, Diplotaxis harra, Erodium deserti, Hyparrhenia hirta, Lappula spinocarpos, Pennisetum divisum, Platychaete aucheri, Poa sinaica, Schismus arabicus, Spergula fallax, Stipagrostis plumosa* and *Tribulus longipetalus*.

IT-ES With 3% of species, it is the smallest group of bi-regional elements. Some representatives are *Carex melanostachya, Lappula heteracantha, Leonurus cardiaca, Luzula taurica, Myricaria germanica, Plantago atrata, Ranunculus arvensis* and *Scrophularia umbrosa*.

SS Elements About 7% of the flora of the YK is composed of the Saharo–Sindian element. Examples are *Alyssum homalocarpum*, *Andrachne aspera, Argyrolobium roseum, Asteriscus pygmaeus, Astragalus schimperi, A. sparsus, Bassia eriophora, Brassica aucheri, Calligonum comosum, Cutandia memphitica, Dipcadi unicolor, Erucaria hispanica, Euphorbia granulata, Fagonia bruguieri, Farsetia longisiliqua, Forsskaolea tenacissima, Gaillonia calycoptera, Gaillonia crucianelloides, Gymnarrhena micrantha, Helianthemum lippii, Neurada procumbens* and *Savignya parviflora.*

IT Elements The Irano–Turanian species (68%) are here dealt within two categories according to Doostmohammadi et al. (2018), including Turanian and Irano–Turkestanian elements.

Turanian or Aralo–Caspian Elements About 2% of the flora is composed of Turanian species. These are mostly psamophytic species occurring in sandy flat plains and include *Bassia eriantha, Calligonum amoenum, C. denticulatum, Cithareloma lehmannii, Climacoptera turcomanica, Euphorbia densa*, *Octoceras lehmannianum*, *Schumannia karelinii, Spirorhynchus sabulosus* and *Stipagrostis karelinii*.

Irano–Turkestanian The Irano–Turkestanian elements are classified in the following subgroups:

Omni–Irano–Turkestanian This group is composed of 154 species with their distribution throughout the Irano–Turkestanian region, from Turkey to Central Asia. Some representatives are *Aethionema trinervium, Amberboa nana, Asperula glomerata, Astragalus campylorrhynchus, Atraphaxis spinosa, Berberis integerrima, Biebersteinia multifida, Celtis caucasica, Clypeola aspera, Cymbolaena griffithii, Dactylorhiza umbrosa, Dianthus crinitus, Drabopsis verna, Eremopyrum distans, Eryngium billardieri, Euphorbia szovitsii, Gagea gageoides, Polygonum polycnemoides* and *Ziziphora clinopodioides.*

Irano–Anatolian Region There are several Irano-Anatolian species with their main distribution from Turkey and Transcaucasus to the Alborz and the Zagros mountains, reaching also the YK massifs from their southeastern ranges. Some representatives are *Allium eriophyllum*, *Anthemis haussknechtii*, *Arum elongatum, Astragalus caraganae, A. finitimus, Carex oreophila*, *Colchicum persicum, Cotoneaster kotschyi, Crataegus atrosanguinea, C. meyeri, Eremostachys macrophylla, Fritillaria persica, Heracleum persicum, Medicago caucasica, Nepeta meyeri, Pimpinella eriocarpa, Salvia hydrangea* and *Tanacetum pinnatum*.

Zagros/YK Pattern of Distribution There are 116 species distributed across the Zagros and the YK massifs. For example *Acantholimon nigricans, Acanthophyllum leucostegium, Aethionema umbellatum, Allium cathodicarpum, Amygdalus elaeagnifolia, Anthemis gayana, Arenaria bulica, Arenaria minutissima, Arenaria persica, Astragalus angustistipulatus, A. campylanthus, A. daenensis, A. pseudoshebarensis, A. yazdii, Centaurea ispahanica, Colchicum bakhtiaricum, Colutea persica, Consolida trigonelloides, Cousinia araneosa, C. eriobasis, Dianthus macranthoides, Dionysia revoluta, Dorema aucheri, Echinops ceratophorus, Eremostachys pulvinaris, Euphorbia khabrica, Ferula assa–foetida, Gypsophila farsensis, Jurinea bungei, Linaria remotiflora, Matthiola flavida, Nepeta depauperata, N. natanzensis, Paronychia bungei, Pimpinella dichotoma, Polygonum dumosum, P. khajeh–jamali, Silene daenensis, S. nurensis, Stachys acerosa, Verbascum hasarense* and *Zerdana anchonioides.*

YK/Hindu Kush–Central Asia Disjunct Distribution There is a remarkable and relatively well known pattern of disjunct distribution from the YK massifs to the Hindu Kush, Central Asia and the Himalaya. This disjunct relationship is more prominent among high alpine and subnival species and has previously been documented for several species by several authors (Hedge and Wendelbo 1978, Noroozi et al. 2008, 2010; Ajani *et al.* 2010; Sonboli *et al.* 2011; Rajaei et al. 2011; Doostmohammadi and Kilian 2017). Some representatives are *Brachyactis roylei, Delphinium uncinatum, Gagea alexii, Lactuca pumila, Levisticum officinale, Parnassia cabulica, Pedicularis cabulica, Salvia rhytidea, Tanacetum fisherae, Tanacetum pamiricum* and *Taraxacum chitralense*. Besides these, some new species have been introduced from the YK massifs as siblings of their eastern populations, such as *Ferula hezarlalehzarica* with relatives in the Hindu Kush and Central Asia (Ajani and Ajani 2008) and *Inula persica* which is related to *I. acuminata* from the Western Himalaya and Kashmir (Ghahremaninejar and Narimisa 2005). Here we report *Bupleurum aitchisonii* (Boiss.) Wolff from alpine elevations (3620 m a.s.l.) on Lalezar Mountain, which provides further evidence for such a floristic connection (Fig. 5.6). The general distribution of *Bupleurum aitchisonii* is in Afghanistan, Tajikistan, Pakistan and India (W Himalaya) and it was not previously reported from Iran (Rechinger and Snogerup 1987; Pimenov and Kljuykov 2015). The material examined is collected in Iran, Kerman province, on the northern slopes of Lalezar Mountain, in a *Cousinia multiloba* community, 29°25′23”N, 56°46′32″E, ca. 3620 m a.s.l., on 18 July 2018; Doostmohammadi 3118 (MIR).

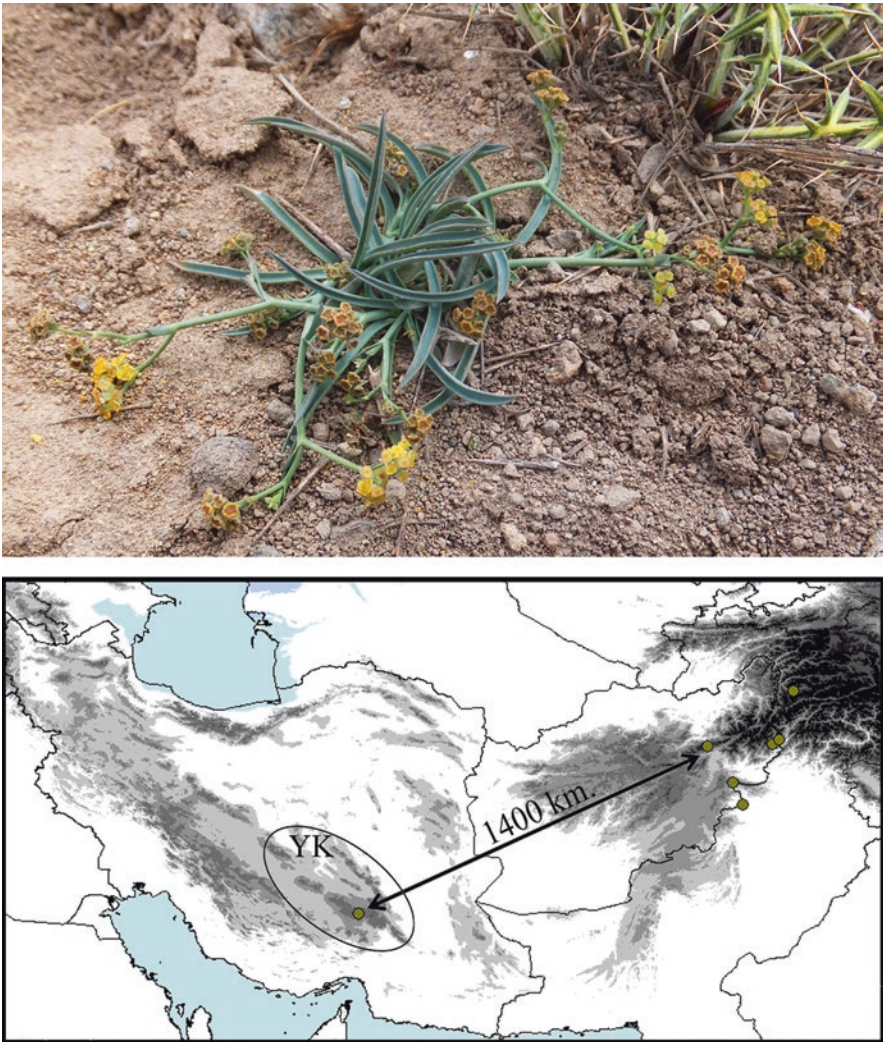

Fig. 5.6 *Bupleurum aitchisonii* on Lalezar Mountain (top) and its distribution (bottom; photo MD)

5.5 Endemism

The YK massifs constitute one of the five recognized areas of plant endemism in Iran (Noroozi et al. 2019b). The isolated nature of these mountains together with wide range of elevation have led to a high rate of allopatric speciation and endemism. There are 109 endemic species restricted to the YK massifs, comprising about 8% of the total flora of the area, belonging to 44 genera and 20 families (Noroozi et al. 2019b). Since these mountains are geographically neighboring the Zagros, and especially the lower elevations are well linked, the YK massifs and the Zagros share many species of low and mid elevations. At higher elevations, however, the number of local endemics remarkably increases and the floristic affinity to the other mountains decreases.

Fabaceae (26 species), Asteraceae (24), Plumbaginaceae (13), Lamiaceae (10), Caryophyllaceae (5), Scrophulariaceae (5), Brassicaceae (3), Primulaceae (3) and Ranunculaceae (3) are the richest families in terms of endemics (Fig. 5.2). The newly discovered, monotypic genus *Yazdana shirkuhensis* (Caryophyllaceae), is endemic to the YK massifs with a restricted distribution in high alpine scree habitats of Shirkuh mountains (Noroozi et al. 2020). There are also some range-restricted genera occur near the borders of the YK massifs. The ditypic genus *Karvandarina* (Asteraceae) occurs in the south of the YK massifs around Baft by *K. aphylla,* and the second species, *i.e. K. cartilaginea*, is distributed in the southwest Iran (Mirtadzadini et al. 2018). The monotypic genus *Zerdana* (Brassicaceae) is restricted to south and central Zagros and the YK massifs (in the Shirkuh and Khabr mountains). *Pseudofortuynia* (monotypic, Brassicaceae) with a main distribution in the east of the Zagros reaches also the northwest of the YK massifs (Khosravi 2003).

Astragalus (21 species), *Acantholimon* (13), *Cousinia* (8), *Echinops* (8) and *Nepeta* (7) have the highest number of endemic species in the area (Fig. 5.3). The general distributions of the endemic–rich genera overlap to some extent and are almost restricted to borders of the Irano–Turkestanian region (Rechinger 1986; Knapp 1987; Doostmohammadi et al. 2018). These species-rich genera have experienced a common climatic and orographic history in Central and SW Asia and share a rather similar historical biogeography (Djamali et al. 2012; Moharrek et al. 2019). In general, it has been suggested that the continued presence of a complex topography since the late Tertiary, which has led to geographical isolation and restricted gene flow, together with a relatively stable continental climate, have had a strong effect on the speciation and current distribution patterns of many species–rich genera of the IT region (Djamali et al. 2012).

Moharrek et al. (2019) have postulated that the center of origin of *Acantholimon* most probably is located in eastern Iran–Afghanistan, and the high diversity and endemism of this genus in the YK massifs is of high interest. Moharrek et al. (2019) also hypothesized that the predominant speciation factor in *Acantholimon* in the SW Asia has probably been the allopatric speciation in restricted populations having relatively similar ecological conditions, rather than adaptation to novel environments and different ecological niches. *Nepeta* is the largest member of the family Lamiaceae in Iran with about 80 species and 60% endemism (Jamzad 2009). In the YK massifs it also has a remarkable number of endemics.

In general, YK has less endemic species compared to the Alborz and the Zagros. The surface area-size of the YK is almost two times bigger than the Alborz (Noroozi et al. 2019b), but the number of species is almost half and the number of endemics is almost a quarter of the Alborz. This is more likely due to the dry climate of the region. The majority of the montane zone is covered with semi-desert steppes which is a unique habitat with poor species diversity. However, with increasing the elevation, especially in high alpine and subninval zone, the situation changes and flora is very isolated with high endemicity (Noroozi et al. 2010, 2019a, b).

As mentioned before many of the endemics are species from high mountains and alpine areas, but there are several endemics distributed in flat plains and lowland habitats (from 1400–2000 m a.s.l.), such as *Echinops aucheri, Euphorbia connata*, *Ferula gabrielii*, *Linaria iranica, Phlomoides kermanica* and *Plantago orzuiensis*. Some of these species indicate phylogenetic affinities with the SS and/or M floras. The enigmatic *Euphorbia connata* is closely related to *E. calyptrata* from north Africa (Riina et al. 2013), *Plantago orzuiensis* is similar to some SS species like *P. ciliata* and *P. amplexicaulis* (Mohsenzadeh et al. 2010) and *Linaria iranica* belongs to *L.* sect. *Versicolores* and is related to the M species *L. tenuis* (Hamdi et al. 2008).

5.6 Major Vegetation Types

There are no phytosociological studies dealing with the vegetation structure of the region. However, here we briefly present some dominant vegetation types of these mountains based on Zohary (1973) and our own observations.

5.6.1 Psammophytic Vegetation

Since the YK massifs are surrounded by lowland semi-deserts and deserts, it is not surprising to see that several sandy habitats are present in the flat plains of the area. They comprise a wide range of habitats from mobile sand dunes to fixed sand hills, sand–clay alluvial plains and gravel–sand foothills. They extend up to the elevation of 2000 m a.s.l. in some places and receive an average annual precipitation of less than 100 mm. The main shrub species are *Haloxylon persicum* and different species of *Calligonum* including *C. bungei, C. denticulatum* and *C. polygonoides*. Other characteristic elements of this vegetation type are *Astragalus* spp. (sect. *Ammodendron*), *Cistanche tubulosa, Euphorbia connata*, *Nepeta mahanensis*, *Schumannia karelinii* and *Spirorhynchus sabulosus*.

5.6.2 Halophytic Vegetation

Various halophytic species cover the saline soils in the marginal lowlands and the alluvial plains between the mountain blocks of the area, from 1400 to 2000 m a.s.l. The most prominent halophytic vegetation occurs along the seasonal brackish streams and is composed of *Tamarix* spp., and mostly annual halophytic species cover the main saline plains, including *Climacoptera turcomanica*, *Halanthium* *rarifolium*, *Limonium iranicum*, *Petrosimonia glauca* and *Reaumuria persica*. Another type of halophytic vegetation in the area is located around Neybid at the deviation of Golbaf–Bam. It is dominated by *Nitraria schoberi* accompanied by *Frankenia pulverulenta, Phragmites australis* and *Puccinellia sevangensis*. Some Central Iranian endemics such as *Anabasis haussknechtii* and *Salsola abarghuensis* also occur in some halo–xerophytic communities.

5.6.3 **Stipa-Artemisia** ***Steppes***

One of the most extensive vegetation types in the area consists of semi–desert and mountain steppes of *Stipa-Artemisia* (Fig. 5.7). It is a diverse vegetation type, with various accompanying species and it is made up of different pure or intermixed communities depending on elevation, soil properties and climatic conditions at different elevations. This vegetation type is distributed from low montane zone up to the subnival zone (1500 up to 4465 m a.s.l.). *Artemisia* is the dominant species in most of the stands but the species composition change from low to high elevation gradually. The dominant *Artemisia* species are *A. inculta* (based on a wide circumscription including *A. sieberi*; Podlech 2013) in the lower plains, and *A. kermanensis* and *A. aucheri* in higher mountain communities. *A. persica* is another representative of the mountain steppes, and dominates in wetter areas and around streams. In lower semi–desert plains it is associated or co–dominated by *Ajuga chamaecistus*, *Convolvulus leiocalycinus, Ebenus stellata, Eremostachys macrophylla, Eryngium billardieri, Hertia intermedia*, *Iris songarica*, *Launaea acanthodes*, *Pteropyrum aucheri*, *Scariola orientalis*, *Zygophyllum atriplicoides* and various annual species. Some representative elements of upper mountains are *Acantholimon chlorostegium, A. scorpius*, *Astragalus anserinifolius, A. huthianus, A. horridus, Centaurea ispahanica*, *Fibigia umbellata, Jurinea dumulosa*, *Matthiola alyssifolia*, *M. flavida*, *Trachydium depressum, Pterocephalus gedrosiacus*, *Salvia hydrangea,* and perennial grasses like *Psathyrostachys fragilis, Stipa haussknechtii* and *S. hohenackeriana*.

5.6.4 Riparian, Riverine and Wetland Vegetation

There are several permanent or temporary rivers and streams in the mountains of the area providing suitable habitats for different hygrophilous plant communities. Sekonj valley in Palvar Mountain and Damgahan Valley in Lakhese Mountain are examples of two deep valleys in the area with prominent species on rocky cliffs and hygrophilous vegetation along the rivers. Main species of these riverine communities belong to *Berberis*, *Clematis, Juncus, Rosa* and *Salix* plus *Calamagrostis pseudophragmites, Cerasus yazdiana*, *Dactylorhiza umbrosa, Epipactis veratrifolia,*

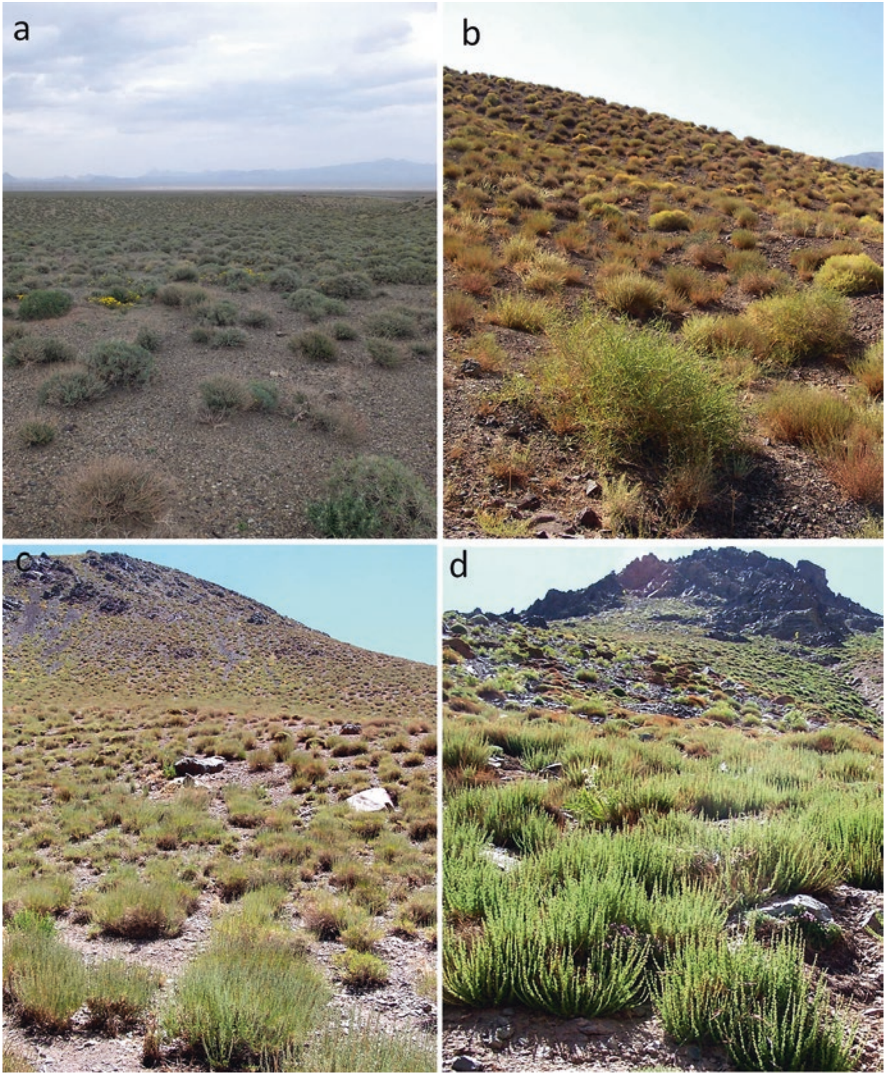

Fig. 5.7 *Stipa-Artemisia* steppes from lower montane up to subnival zone. (**a**) *Artemisia sieberi* (Jebal Barez Mts., 1900 m a.s.l.; photo MD); (**b**) *Artemisia aucheri* (Hezar Mts., 2700 m a.s.l.; photo JN); (**c**) *Artemisia aucheri* (Hezar Mts., 3600 m a.s.l.; photo JN); (**d**) *Artemisia aucheri* (Hezar Mts., 4000 m a.s.l.; photo JN)

Lonicera nummulariifolia, *Nectaroscordum tripedale*, *Salvia rhytidea* and *Teucrium melissifolium*.

Alpine meadow communities and high-altitude wetlands that in some places reach up to 4000 m a.s.l., are another type of hygrophilous vegetation in the area. One prominent example of these habitats can be seen in Takhte Sartashtak in south-west of Hezar Mountain at 3600 m a.s.l. (Fig. 5.8a). Some characteristic species of these communities are *Botrychium lunaria, Cerastium cerastoides, Cirsium rhizocephalum*, *Gentiana prostrata* (Fig. 5.8b), *Inula persica*, *Parnassia cabulica*, *Pedicularis cabulica*, *Primula algida* (Fig. 5.8c), *Taraxacum primigenium* and *Triglochin palustris*.

5.6.5 Shrublands and Woodlands

5.6.5.1 *Tecomella undulata* Communities

At the southern margin of the YK massifs, just at the border of the IT and the SS phytogeographical regions, a community of *Tecomella undulata* (Fig. 5.9a) trees occurs at the Golparaki plain. These low tree woodlands (2–5 m) at the Golparaki region cover an area of more than 50 hectares with a high cover–abundance, and form the largest population in Iran (Rezanejad and Ganjalikhani Hakemi 2017; Rezanejad et al. 2018). The precipitation is 100–200 mm per year and summer temperature exceeds 45 °C. *Acer monspessulanum, Aerva javanica, Amygdalus scoparia, Astragalus fasciculifolius, Convolvulus acanthocladus, Daphne mucronata, Forsskaolea tenacissima, Helianthemum salicifolium, Leysera leyseroides, Otostegia persica, Plantago ovata, Pycnocycla musiformis, Rumex vesicarius* and *Salvia macilenta* are the main accompanying species in this vegetation type.

5.6.5.2 *Pistacia–Amygdalus* Woodlands

Different species of *Amygdalus* (in particular *A. scoparia*, *A. elaeagnifolia* and *A. eburnea*) plus *Pistacia atlantica* and *Acer monspessulanum* build various types of vegetation in the area while the general composition of each community depends widely on geographical location, soil structure, elevation and water supply. They occur from ca. 1500 to 2900 m a.s.l. with an annual precipitation of 150–350 mm. These communities range from almost pure *Pistacia atlantica* forests to *Amygdalus scoparia* woodlands, scrub dominated by *A. elaeagnifolia* and pure *Acer monspessulanum* communities (Fig. 5.9b). Intermixed communities with different coverage of various species occur in several areas and further studies are necessary to correctly specify and determine various vegetation types. At some places like Dalfard and the Jebal Barez Mountains, *A. scoparia* occurs sympatrically with *A. eburnea* and produce a hybrid, *A.* × *iranshahrii*, which contributes to make a remarkable intermixed vegetation unit. Coverage and density of these woodlands vary from place to place and a wide range of species accompany these vegetation stands, such as different species of *Astragalus*, *Acantholimon* and *Artemisia* together with *Crataegus meyeri, Colutea persica*, *Daphne mucronata*, *Ephedra procera*, *Ficus johannis, Pistacia khinjuk, Rhamnus persica* and *Zataria multiflora*. Nuts of *Pistacia atlantica* are much used by local people to prepare a traditional food, and this obviously has a large impact on the soil seed bank of this tree. Additionally, the

Fig. 5.8 Wetlands of the YK massifs. (**a**) High altitude wetland of Takhte Sartashtak (3600 m a.s.l.); (**b**) *Gentiana prostrata*; (**c**) *Primula algida*, (both from Lalezar, 3500 m a.s.l.; photos MD)

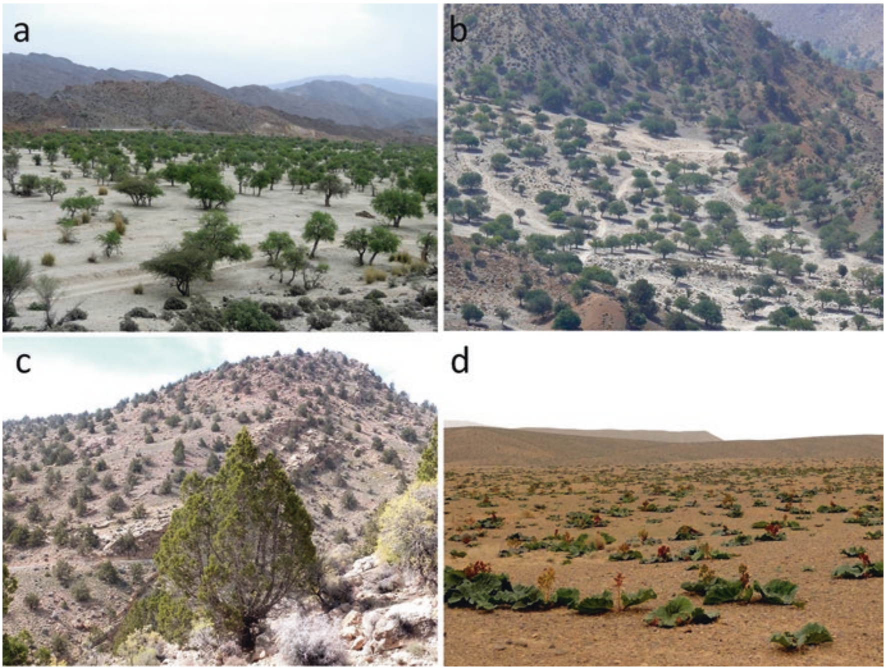

Fig. 5.9 (**a**) *Tecomella undulata* open woodlands in Dalfard valley (1500 m a.s.l.; photo AT); (**b**) *Pistacia atlantica* woodlands in Jebal Barez Mountain (photo JN); (**c**) *Juniperus seravshanica* woodlands (Galuchar region, 2850 m a.s.l.; photo MD); (**d**) *Rheum ribes* community in the Sa'adi Protected Area (2100 m a.s.l.; photo MD)

understory layer is heavily grazed in some places, and that left the soil prone to water erosion. Some representative species of the herb layer are *Acanthophyllum glandulosum, Allium cathodicarpum*, *Biebersteinia multifida*, *Bunium persicum*, *Onosma stenosiphon, Picris strigosa*, *Polygonum spinosum, Senecio glaucus*, *Steptorhamphus persicus* and *Tragopogon caricifolius*.

5.6.5.3 *Juniperus* Woodlands

Juniperus communities (Fig. 5.9c) in the YK massifs are represented by *J. seravschanica* (Adams et al. 2014a; Hojjati et al. 2018). The distribution area of *J. seravschanica* extends from Kyrgyzstan, Tajikistan and Afghanistan to southeastern Iran (including the YK Mountains) and reaches the mountains of northern Oman over the Persian Gulf (Adams et al. 2014b). It is noteworthy that some populations in the northern blocks of the YK Mountains (Kuhbanan highlands) belong to a probably hybrid species with its main distribution area in central Zagros (Hojjati et al. 2018). *Juniperus* trees occur on middle to high mountains from 2000–3550 m a.s.l., usually on steep rocky slopes. Very different and variable woody and herbaceous species accompany these communities, such as *Acer monspessulanum*, *Amygdalus elaeagnifolia*, *Artemisia* spp., *Acantholimon* spp., *Astragalus* spp., *Cotoneaster persicus*, *Daphne mucronata* and *Dorema aucheri*. Major *Juniperus* communities in the YK massifs are in the Khabr National park, Dalfard valley, Sardu and Galuchar region.

5.6.6 Rheum ribes *Vegetation*

The *Rheum ribes* communities (Fig. 5.9d) occur at several localities including the Sa'adi Protected Area, the plains north of Shahrebabak and south of Mehriz. It covers vast areas of flat plains and foothills at elevations of 2000–2300 m a.s.l. This vegetation type occurs also in the Alborz and on the Azerbaijan Plateau but it dominates in subalpine zone at different habitats and with different species compositions. Species diversity in this vegetation type is very low and woody species are scarce, except for scattered *Amygdalus scoparia* stands plus *Acantholimon* spp., *Hertia intermedia* and *Pteropyrum aucheri*. At some places, accompanied by *Eremurus persicus*, it makes beautiful mixed vegetation stands in early spring. Other associated species are mostly ephemerals and include *Allium cathodicarpum*, *Chaenorhinum grossecostatum*, *Heteroderis pusilla, Holosteum umbellatum, Linaria michauxii*, *L. micrantha, Minuartia picta, Senecio glaucus, Valerianella szovitsiana* and *Ziziphora tenuior*.

5.6.7 Subalpine Umbelliferous Communities

Giant umbelliferous species associated with various herbaceous and woody species make a very conspicuous tall–herb vegetation in the montane and subalpine zones of the YK massifs (2200–3800 m a.s.l.), in habitats with a high cover of scree and steep inclination. These communities are dominated by variable umbelliferous herbs, such as *Dorema aucheri, Ferula assa–foetida* (Fig. 5.10a), *Ferula hezarlalehzarica* (Fig. 5.10b) and *Ferulago angulata* (Fig. 5.10c), in different areas.

5.6.8 Chasmophytic Vegetation

Rocky walls and cliffs in the area are found from low montane to the subnival zone (2000–4465 m a.s.l.) with different temperature and precipitation regimes. They harbor a considerable and varied diversity of chasmophytic life forms. Rocky communities in the area are mostly formed by *Campanula kermanica* (Fig. 5.11a), *Corydalis rupestris*, *Crucihimalaya wallichii*, *Dielsiocharis kotschyi*, *Dionysia curviflora*, *D. janthina, D. khatamii, D. oreodoxa, D. revoluta, D. rhaptodes* (Fig. 5.11b,

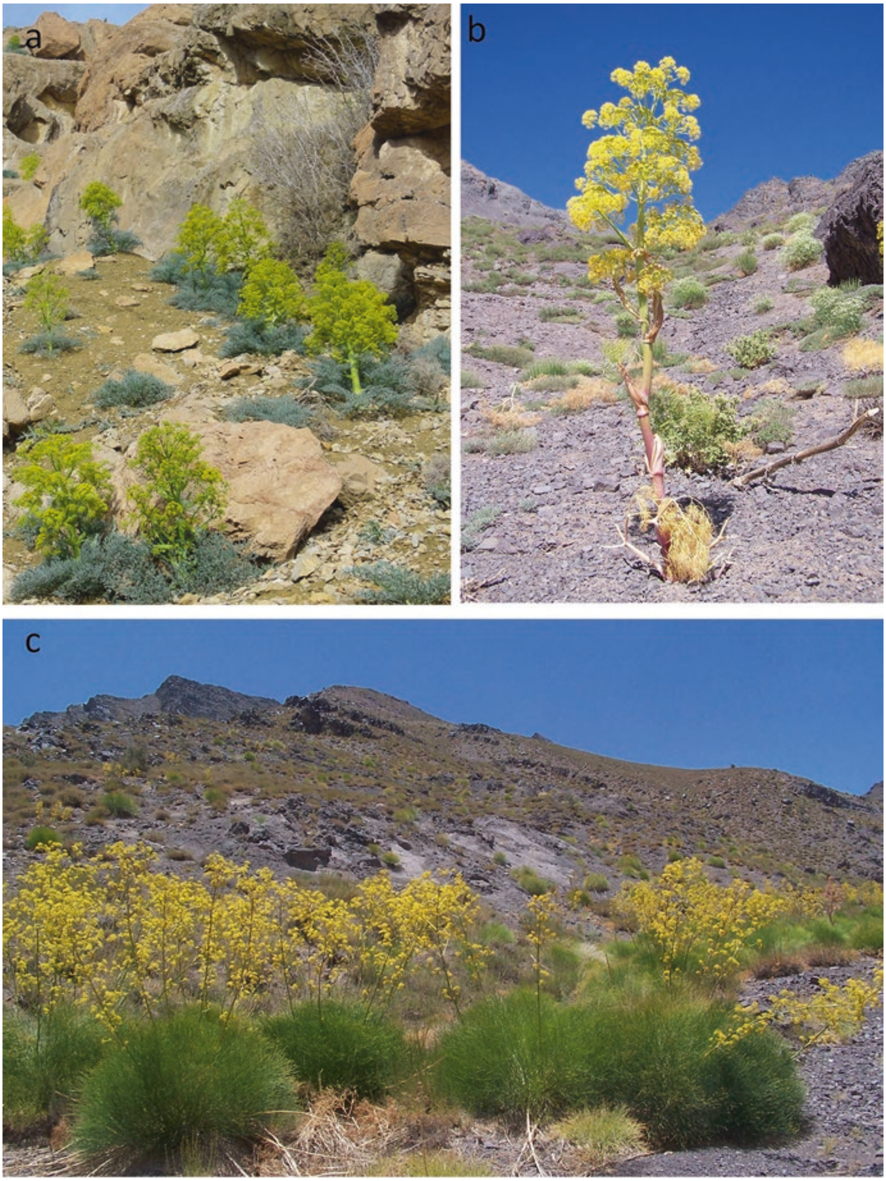

Fig. 5.10 Tall–herb umbelliferous communities. (**a**) *Ferula assa–foetida* (Sa'adi Protected Area, 2500 m a.s.l.; photo MD); (**b**) *Ferula hezarlalehzarica* (Hezar Mts., 2500 m a.s.l.; photo JN); (**c**) *Ferulago angulata* (Hezar Mts., 3300 m a.s.l.; photo JN)

c), *Graellsia saxifragifolia*, *Lactuca hazaranensis*, *L. pumila*, *Parietaria judaica, Phagnalon nitidum* and *Rosularia modesta*.

5.6.9 Alpine–Subnival Communities

Since the YK Mountains are located in the low latitudes with dry climate, the treeline is higher and the subnival belt starts above 4200 m a.s.l. in Kerman. However, top of the Shirkuh Mts. in Yazd with elevation of 4065 m a.s.l. shows a scattered subnival vegetation. Various alpine and subnival vegetation types can be seen in different areas and at different altitudes. *Artemisia aucheri* communities are the dominant vegetation types in the subalpine and alpine areas (Fig. 5.7d), with a high species diversity including several species of *Astragalus*, *Euphorbia* and *Nepeta*. Well–developed communities of *Cousinia multiloba* also can be found. Thorn-cushion communities are located in windswept areas (Fig. 5.12). They are well developed in high alpine zone of the Shirkuh Mts. (Fig. 5.12a, c) but rather scarce in the Hezar-Lalezar (Fig. 5.13b). Dominant species in the Hezar-Lalezar Mountains are *Acantholimon haesarensis*, *Astragalus hezarensis*, *A. lalesarensis*, *Linaria remotiflora, Onobrychis cornuta*, *Polygonum salicornioides, P. spinosum, Semenovia suffrruticosa*, *Stachys acerosa*, together with *Nepeta assurgens, Trachydium depressum* and *Scutellaria multicaulis*. *Thymus carmanicus* occurs in some places on the tops of the mountains and builds communities with high cover–abundance. *Erysimum polatschekii* (Fig. 5.13a) is one of the recently described species which grows on scree grounds of these habitats. In high alpine zone of the Shirkuh Mts., *Artemisia* steppes are less developed and real thorn-cushion grasslands are dominant. Remarkable species of these communities are *Acantholimon modestum, Alyssum muelleri, Arenaria persica* (Fig. 5.12a), *Astragalus microphysa, Cousinia lasiolepis, Eremurus persicus* (Fig. 5.12b), *Helichrysum davisianum, Onobrychis cornuta* (Fig. 5.12c), *Piptatherum laterale, Scorzonera intricata, Stachys obtusicrena, Thymus carmanicus* and *Trachydium depressum*.

Snowbed communities present in these mountains are very scattered in a few depressions, where the snow cover can survive until mid-summer. *Ranunculus eriorrhizus* (Fig. 5.13c, d) is the most dominant species of these habitats.

Subnival zone is covered mostly by screes and special species adapted to these habitats. Species richness in these communities is low, but there is a high rate of endemism. *Allium lalesaricum*, *Crepis heterotricha* subsp. *heterotricha*, *Nepeta lasiocephala* (Fig. 5.14a), *N. natanzensis, Paracaryum lalezarense*, *Pseudocamelina camelinae* (Fig. 5.14c), *Senecio subnivalis, Silene nurensis* and *Zerdana anchonioides* (Fig. 5.14b) are important representative elements of these communities.

Fig. 5.11 Chasmophytic vegetation. (**a**) *Campanula kermanica* (Sekonj valley, 2500 m a.s.l.); (**b**) Close up of *Dionysia rhaptodes*; (**c**) Limestone rocks occupied by *Dionysia rhaptodes* (b & c in Sa'adi Protected Area, 2700 m a.s.l.; photos MD)

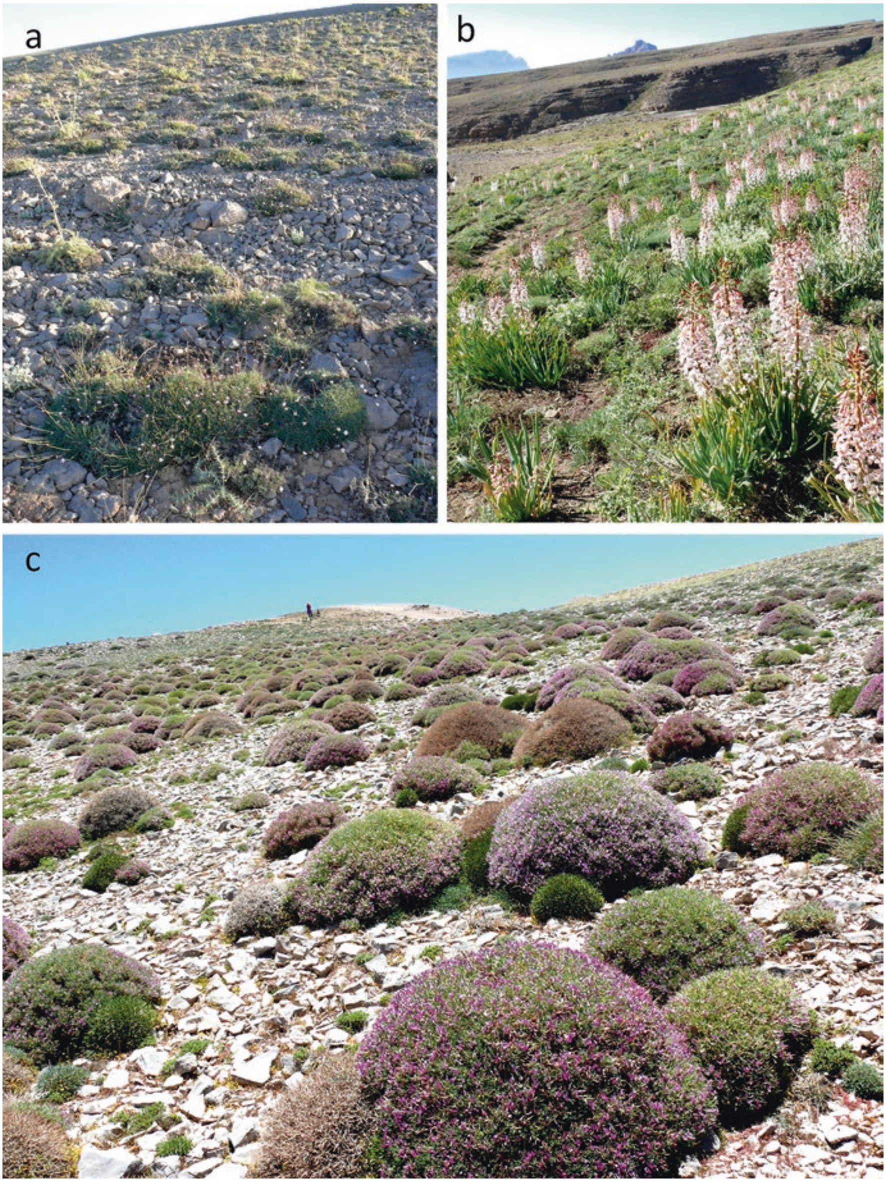

Fig. 5.12 Alpine habitats in the Shirkuh Mts. (**a**) *Arenaria persica* (3800–4000 m a.s.l.); (**b**) *Eremurus persicus* (3600–3800 m a.s.l.); (**c**) *Onobrychis cornuta* (3900 m a.s.l.; photos JN)

Fig. 5.13 Alpine habitats in the Hezar-Lalezar Mts. (**a**) *Erysimum polatschekii* (Lalezar Mts., 4100 m a.s.l.; photo MD); (**b**) *Cousinia* cf. *fragilis*, *Astragalus lalesarensis* (Hezar Mts., 3900 m a.s.l.; photo JN); c & d. Snowbed communities of high alpine zone dominated by *Ranunculus eriorrhizus* in most of the regions; (**c**) Lalehzar Mts., 4100 m a.s.l. (photo MD); (**d**) Shirkuh Mts., 3900 m a.s.l. (photo JN)

5.7 Conservation

Plant diversity of the YK massifs is facing several threats from both regional and global factors. Grazing has been probably the most important and long–lasting destructive pressure on the flora and vegetation of the Iranian Plateau. It is still a big problem in many parts of Iran, even in the protected areas, and an obstacle for conservation assessments and actions. In the YK massifs as well, all vertical belts are under the impact of grazing herds; low plains in the early spring and high alpine habitats during summer (Fig. 5.15). Over-exploitation of several species, especially traditionally used ones, such as *Bunium persicum*, *Zataria multiflora*, *Ziziphora clinopodioides* and particularly the narrow endemic *Dracocephalum polychaetum*, is a potential threat for genetic loss and local extinction. Apart from this, the YK flora is under threat of prolonged drought and also global warming. As mentioned before, the rate of endemism is very high at higher elevations due to the strong isolation from other mountains. The impact of global warming on the alpine flora of the

Fig. 5.14 Scree communities of subnival zone. (**a**) *Nepeta lasiocephala* (Hezar Mts., 4400 m a.s.l.); (**b**) *Zerdana anchonioides* (Shirkuh Mts., 4000 m a.s.l.); (**c**) *Pseudocamelina camelinae* (Shirkuh Mts., 4000 m a.s.l.; photos JN)

Fig. 5.15 Overgrazing (Jebal Barez Mts., 2500 m a.s.l.; photo JN)

YK massifs might in fact be more sever, since these mountains are located at lower latitudes and the high alpine and subnival zones are highly limited and there are no alternative habitats for such species to move up under the impact of climate change. Not only the diversity of plant species, but also the diversity of animal species is very rich in these mountains (Fig. 5.16). Karimi and Jones (2020) estimated that about one quarter of the total area of nature reserves of Iran are under intense human pressure and therefore both expanding protected areas and alleviating anthropogenic activities in the areas under conservation is highly recommended, throughout Iran and particularly in the YK massifs.

There are one National Park, 11 Protected Areas and two Wildlife Refuges lying in the YK massifs (Fig. 5.17). However, the current nature reserves do not correlate well with plant species hotspots in the region (Noroozi et al. 2019a), and conservation actions in these areas are also very poor, as in many other nature reserves of Iran.

Fig. 5.16 Animal diversity of the YK region (Shirkuh Mts.). (**a**) *Polygonia egea* (det. Alireza Naderi); (**b**) *Hipparchia parisatis* (det. Alireza Naderi); (**c**) *Ochotona rufescens*; (**d**) *Paralaudakia microlepis*; (**e**) *Laudakia nupta*; (**f**) *Laudakia* sp.; (**g**) *Ovis orientalis isphahanica* (photos JN)

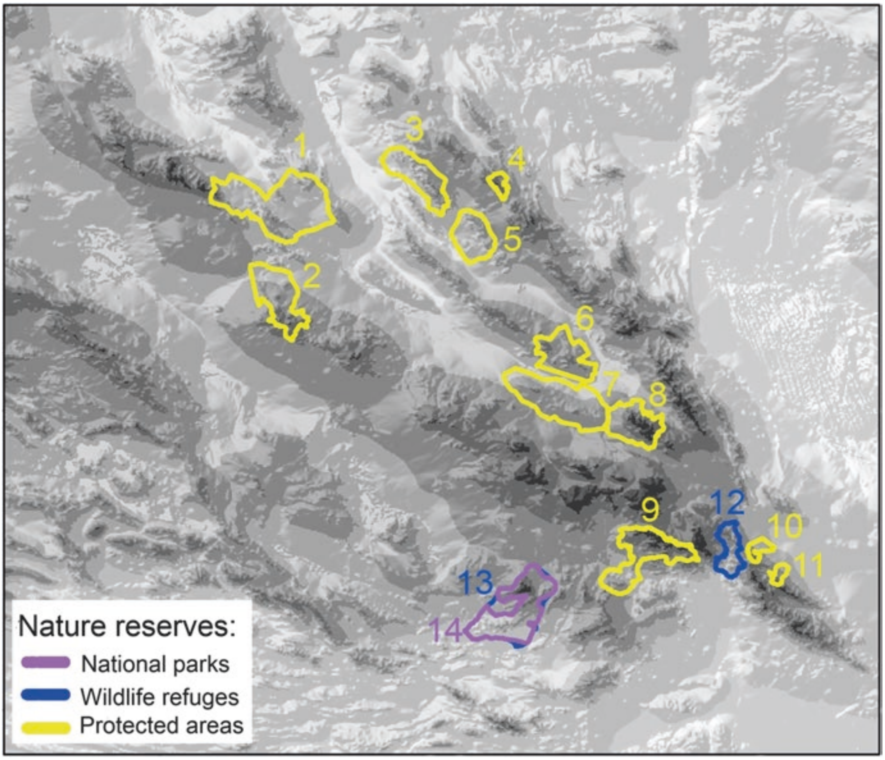

Fig. 5.17 Nature reserves in the YK area (including: 1. Kalmand P.A., 2. Dehaj P.A., 3. Kuhe Bafgh P.A., 4. Kuhe Asiab P.A., 5. Chah Kume P.A., 6. Sa'adi P.A., 7. Bidu P.A., 8. Jupar P.A., 9. Bahr Aseman P.A., 10. Kuhe Shir P.A., 11. Sange Mes P.A., 12. Zaryab W.R., 13. Ruchun W.R. and 14. Khabr N.P.)

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Chapter 6
The Zagros Mountain Range

Jalil Noroozi, Amir Talebi, Moslem Doostmohammadi, and Ali Bagheri

Abstract The Zagros is the largest mountain range of the Iranian Plateau stretching from northeast Iraq to south Iran. It has high mountain peaks reaching the subnival zone in different parts though mostly in the central and southern Zagros. The climate is continental and the precipitation regime is Mediterranean with cold and wet winters and warm and dry summers. Our database lists 3642 vascular plant species from this mountain range. The Zagros is totally located inside of the Irano-Turanian biogeographical region and the Irano-Anatolian biodiversity hotspot. More than 70% of the species are Irano-Turanian elements but widespread species occurring in two or several biogeographical regions are also many. This mountain range is identified as an area of endemism and 21% of the entire flora are Zagros elements. The major vegetation types of the Zagros are oak woodlands, *Amygdalus-Pistacia* shrublands, montane steppe shrublands, wetlands, chasmophytic habitats, subalpine, alpine and subnival zones. Anthropogenic activities are threatening the unique flora and vegetation types of this mountain range and a strong conservation policy is recommended.

Abbreviations

ES Euro-Siberian
IT Irano-Turanian

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M Mediterranean
SS Saharo-Sindian

6.1 Introduction

The Zagros is the biggest mountain range of Iran, extending from northeast Iraq to the south of Iran, with a length of ca. 1300 km and a width of ca. 250 km. This mountain range with an area size of ca. 394,000 km^2 covers around a quarter of the Iranian surface area. The highest summit of this mountain range is Dena Mt. (4409 m a.s.l.) in the southern Zagros. Zardkuh (4220 m a.s.l.) and Oshtorankuh (4050 m a.s.l.) are other high mountain peaks of the Zagros (Fig. 6.1). In the north, it is connected to the Anatolian and Azerbaijan Plateau and in the southeast to the Yazd-Kerman massif. The Zagros range creates a barrier between the Mesopotamian plain and the central plain of the Iranian Plateau.

The Zagros is located in the IT biogeographic region (Zohary 1973), and in the Irano-Anatolian biodiversity hotspot (Mittermeier et al. 2011). This mountain range exhibits strong and striking plant geographical patterns (Hedge and Wendelbo 1978; Akhani 2004, 2007) and has been identified as an “area of endemism” with high amount of endemic elements (Noroozi et al. 2018, 2019b). The huge area size of the Zagros, its diverse climate and topography, and the high elevational amplitude resulted in the development of highly different ecosystems and vegetation types. On its western and southern sides, the Zagros is adjacent to the SS region along a very fragmentary and heterogeneous border.

The first person who collected herbarium plant specimens from the Zagros (in parts of the Isfahan and Shiraz area), was the German naturalist Engelbert Kaempfer (collecting dates: 1664–1668). In the eighteenth and nineteenth-centuries many naturalists/botanists collected plants from the Zagros, e.g. G. A. Olivier and J. G. Bruguière (collecting dates: 1796–1797), P. M. R. Aucher-Eloy (collecting dates: 1835–1838), T. Kotschy (collecting dates: 1841–42), A. Buhse (collecting dates: 1847–1849), H. C. Haussknecht (collecting dates: 1865–1867), A. von Bunge (collecting dates: 1858), and O. Stapf (collecting dates: 1885–1886). Most of the specimens of the nineteenth century have been described in “Diagnoses Plantarum Orientalium Novarum” by Boissier (1842–1859) and in “Flora Orientalis” by Boissier (1867–1884). From the beginning of the twentieth century, there was an increase in botanical studies in the Zagros and plant specimens were mainly collected by F. T. Strauss (collecting dates: beginning of the twentieth century), J. F. N. Bornmüller, (collecting dates: 1943–1960), W. Koeltz (collecting dates: 1940–1945), and P. Aellen (collecting dates: 1948). Most of the species collected by the mentioned collectors have been described in “Flora Iranica” by Rechinger (1963–2015). Subsequently, the flora of the Zagros has been studied by both Iranian and foreign botanists which resulted in the Flora of Iran (Assadi et al. 1989–2018). There are quite some floristic studies done in different parts of the Zagros

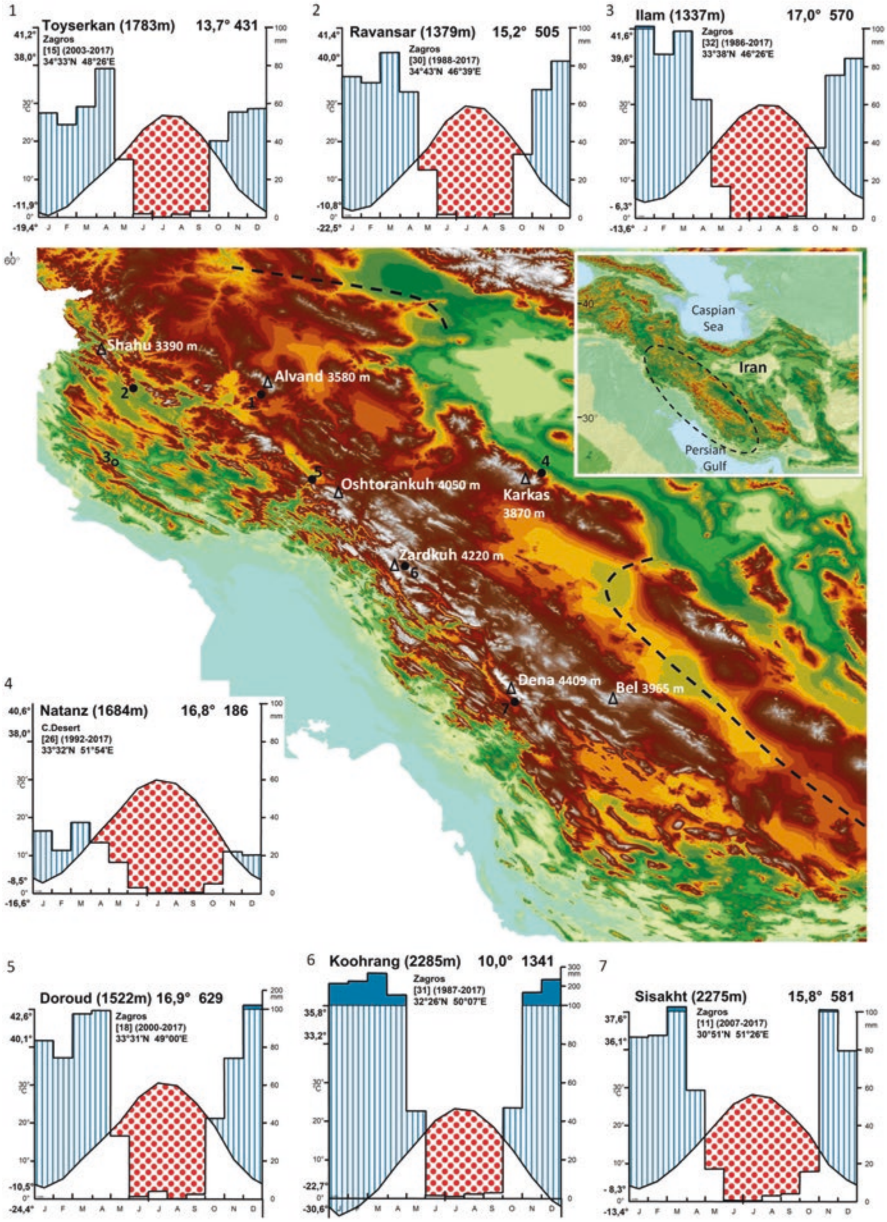

Fig. 6.1 The Zagros mountain range in the western part of Iran and climatic diagrams from different parts of this mountain rage (localities 1–7)

(e.g. Mozaffarian 2008, 2017; Sanandaji and Mozaffarian 2010; Mehrnia and Ramak 2014; Mahmoodi et al. 2015; Dehghani et al. 2016; Dehshiri et al. 2016; Hamzeh'ee 2016; Jalali et al. 2016; Parvizi et al. 2016; Tabad et al. 2016; Veiskarami and Sharifi-Tehrani 2017), but much less on vegetation and phytogeography. Excluding the floristic researches, our knowledge on the vegetation of the Zagros is limited to a few publications (Bobek 1951; Zohary 1971, 1973; Léonard 1981–1989, 1991/1992; Frey et al. 1999; Jafari Kokhedan 2003). There are no published phytosociological studies on this area and our knowledge about the species composition and ecology of the vegetation types is extremely poor. In this chapter, we present briefly the plant diversity, biogeography and vegetation types of the Zagros.

6.2 Geology

Western part of the Iranian Plateau is composed of two major structural units, i.e. the Zagros and Sanandaj-Sirjan Zone, running parallel to the Zagros mountain range on its northeast side (Stöcklin 1968; Berberian and King 1981). The Zagros can be divided into three main geological zones (Berberian and King 1981; Alavi 1994): (1) the Zagros foredeeps which comprise a belt of Neogene sediments in the southwest of the Zagros, (2) the Zagros Folded Zone forming the major part of the Zagros, and (3) the High-Zagros which comprises the highest mountain summits of this mountain range, and that is separated from Central Iran by the Main Zagros Thrust fault (Fig. 2 in Djamali 2008).

This mountain range, as the majority of the Iranian mountain ranges, has formed as a result of the Arabia-Eurasia collision (Jackson and McKenzie 1984). The mountain formation and uplift have started in the Cretaceous-Palaeocene and still continues, thus creating the present compressional tectonic regime in the Iranian mountain belts (Berberian and King 1981). It is part of the larger Alpine-Himalayan collision orogenic system that has started to rise towards the end of the Neotethys Ocean during the Cenozoic (Mouthereau et al. 2012). The Zagros evolved during three chief serial geotectonic happenings: (1) Subduction of the Neo-Tethyan oceanic plate beneath the Iranian lithospheric plates during Early to Late Cretaceous times; (2) Emplacement of some Neo-Tethyan oceanic slivers over the Afro-Arabian passive continental margin in the Late Cretaceous; and (3) Collision of the Afro-Arabian continental lithosphere with the Iranian plates in the Late Cretaceous (Alavi 1994; Alavi 2004). The oldest rocks showing in the Zagros range are Lower Cambrian sandstone and dolomite (Kent 1986).

6.3 Climate

The Zagros shows a wide amplitude of climatic conditions along its westward and eastward escarpments and froms its northern blocks to the southernmost mountain outliers (Fig. 6.1). The main source of precipitation of the Zagros comes from the westerly systems carrying Mediterranean and Black Sea moisture (Alijani and Harmon 1985). The north-south extension of the Zagros range creates a strong rain shadow effect with a much lower annual rainfall on the eastern slopes than on their western counterparts (Alijani et al. 2008). According to modern bioclimatic classifications (Djamali et al. 2011), the Zagros belongs to different bioclimatic zones. Major parts of the western Zagros are under the Mediterranean pulviseasonal continental zone which is characterized by high annual precipitations in winter and early spring, which favors the deciduous oak forests. This mountain range exhibits a Mediterranean xeric continental climate in its northeastern parts and more arid Mediterranean desertic continental conditions in its southeastern parts (Djamali et al. 2011).

The mean annual temperature ranges from ca. 9 °C to 25 °C, and the mean annual precipitation ranges from ca. 300 to 1500 mm depending on latitude and altitude. The number of frost days in the Zagros is also strongly variable and ranges from 10 to 150 days per year (Jazirehi and Ebrahimi Rostaghi 2003). Although several mountains of the Zagros exceed 4000 m a.s.l. only one glacier is recorded, on Zardkuh (Ferrigno 1991), the second highest mountain of the Zagros (Fig. 6.1).

6.4 Flora and Phytogeography

6.4.1 Paleobotany

The history of climate and vegetation change of the Zagros shows various periods of cold and warm conditions. Geomorphological investigations of Wright and Minneapolis (1962) recorded physical evidences of multiple glacial expansions in the Kurdistan area of the Zagros. Palynological studies in Lake Mirabad and Lake Zaribar allowed to reconstruct the history of the vegetation and climatic oscillations in the central and northern Zagros (Van Zeist and Wright 1963; Van Zeist 1967; Van Zeist and Bottema 1977). According to these investigations, an *Artemisia*-Umbellifereae steppe predominated in the northwest and central Zagros during the last glacial period, at about 22,500–14,000 cal. B.P., implying the presence of a cold and dry climate. After 14,000 cal. B.P., slow changes occurred in the vegetation in response to climate changes and an open scrub vegetation of *Pistacia* and *Quercus* became to dominate the Zagros until 6000 cal. B.P. After 6000 cal. B.P. the present vegetation of *Quercus* forests became established in the northern and central Zagros. Palynological investigations in the southeastern section of the Zagros also indicate the predominance of *Quercus brantii* woodland and *Amygdalus-Pistacia* scrub during the late Holocene (Djamali et al. 2009).

Apparently, the postglacial regeneration of oak forests (*Quercus brantii*) in the Zagros was delayed and commenced as from the mid-Holocene (6000 cal. B.P.), not the early-Holocene as in temperate Europe. Djamali et al. (2010) concluded that this delay was the result of a change in precipitation seasonality from a spring-dominated to a winter-dominated regime. They reasoned that the early-Holocene strengthening of the Indian Summer Monsoon in southeast Iran did push a high pressure system over western/northwestern Iran which then reduced the amount of spring precipitation. This typical continental Mediterranean climate was not favorable for deciduous oak species but caused an expansion of *Amygdalus-Pistacia* shrublands over the Zagros. Finally, the retreat and southward movement of the summer monsoon in the mid-Holocene allowed the spring precipitation to increase and subsequently oak forests to re-expand in the Zagros and adjacent regions.

6.4.2 Floristic Diversity

According to our database, 3642 vascular plant species have been recorded from the Zagros, belonging to 792 genera and 122 families. Asteraceae (555 species), Fabaceae (540), Poaceae (215), Brassicaceae (211), Lamiaceae (204), Caryophyllaceae (202), Apiaceae (195), Boraginaceae (142), Scrophulariaceae (118) and Rosaceae (93) are the richest families of the Zagros (Fig. 6.2). *Astragalus* (Fabaceae; 351 species), *Cousinia* (Asteraceae; 109), *Allium* (Alliaceae; 66), *Silene*

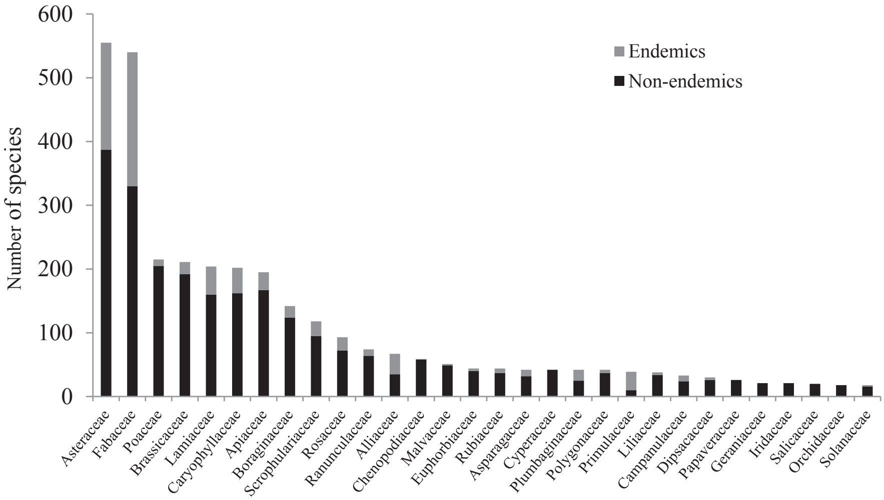

Fig. 6.2 Number of species in the 30 most species-rich families of the Zagros vascular flora (the number of endemic and non-endemic species are shown in different shades)

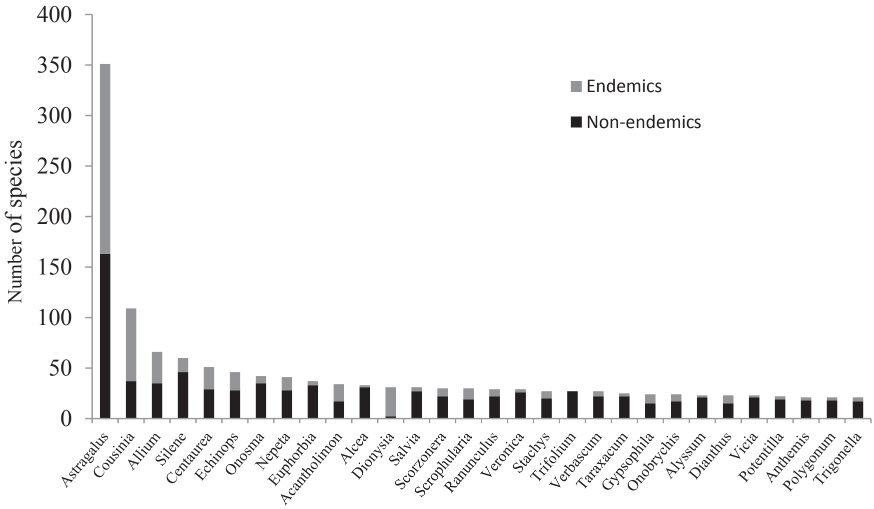

Fig. 6.3 Number of species in the 30 most species-rich genera of the Zagros vascular flora (the number of endemic and non-endemic species are shown in different shades)

(Caryophyllaceae; 60), *Centaurea* (Asteraceae; 51), *Echinops* (Asteraceae; 46), *Onosma* (Boraginaceae; 42), *Nepeta* (Lamiaceae; 41), *Euphorbia* (Euphorbiaceae; 37) and *Acantholimon* (Plumbaginaceae; 34) are the largest genera of the Zagros (Fig. 6.3). We should keep in mind that the list of plant species of these mountains is incomplete and that taxa new for science or newly reported for the region are still being reported and that ca. 7% more species still await discovery in the region (Noroozi et al. 2016).

The life form spectrum of the Zagros flora is dominated by hemicryptophytes (46%), followed by therophytes (28), chamaephytes (19%) and geophytes (9%), respectively. Although phanerophytes comprise a small proportion of the floristic stock of the Zagros, different species of *Quercus* constitute vast open park-like woodlands in different areas, especially in the northern and western part of the range. Another aspect of the flora of the Zagros is its relatively high number of geophytes. Despite the relatively low number of orchid species in Iran, the Zagros represents a remarkable diversity of East-Mediterranean orchids (Renz 1978). The most important bulbous genera in the Zagros are *Allium* (Alliaceae; 66 species), *Gagea* (Liliaceae; 18), *Fritillaria* (Liliaceae; 11), *Iris* (Iridaceae; 10), *Colchicum* (Colchicaceae; 9), *Tulipa* (Liliaceae; 8), *Gladiolus* (Iridaceae; 6), *Eremurus* (Asphodelaceae; 5) and *Crocus* (Iridaceae; 4).

6.4.3 Phytogeography

The whole mountain system of the Zagros is located inside of the IT phytogeographical region and the total of the Zagros mountain system is recognized as a separate unit: the Kurdo-Zagrosian district (Zohary 1973) or Kurdo-Zagrosian subprovince (Takhtajan 1986). Several endemic genera, sections of genera and many endemic species have been shown to represent restricted patterns of distribution along the Zagros (Hedge and Wendelbo 1978; Akhani 2007; Noroozi et al. 2008, 2016, 2018, 2019b). Besides, Mediterranean elements are also strongly represented in the Zagros (Rechinger 1951). In addition, the occurrences of some Euro-Siberian elements, like *Pterocarya fraxinifolia* (Akhani and Salimian 2003) and *Zelkova carpinifolia* (Browicz 1978), in the Zagros imply the complex historical phytogeography of this mountain range. *Pterocarya fraxinifolia,* an Arcto-Tertiary relict element, occurs in the central Zagros (Lorestan and Ilam provinces), quite disjunct from the main range of this species in the Euro-Siberian region (Akhani and Salimian 2003). Surprisingly, there are some isolated species in the Zagros with their closest relatives in the Somalia-Masai region, such as *Hypericum dogonbadanicum* (Robson 1987), or even in tropical Africa, such as *Clinopodium kallaricum* (Bordbar and Mirtadzadini 2019).

The majority of the Zagros species are IT elements (71%) and the rests are bi-regional or pluri-regional elements (Fig. 6.4). IT-M elements are remarkable (11%), but IT-ES (4%) and IT-SS (2%) are less represented.

The Zagros is floristically well connected to the Alborz, followed by Anatolia, Yazd-Kerman, the Kopet Dagh, the Hindu Kush, the Caucasus, Central Asia and the European mountains (Fig. 6.5). Some examples for the most common chorotypes are provided here.

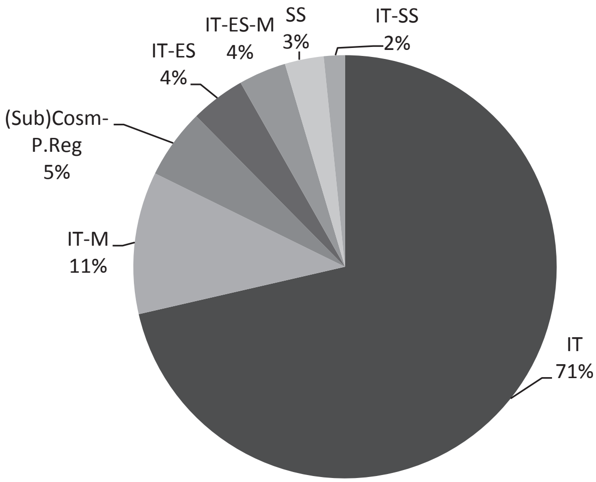

Fig. 6.4 Phytochoria of species of the Zagros. Cosm: Cosmopolite; P.Reg: Pulri-regional

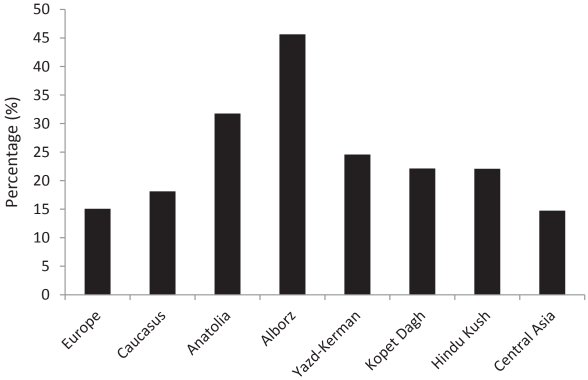

Fig. 6.5 Floristic affinity of the Zagros with other mountain ranges. The Y-axis is the percentage of species common with the Zagros

(Sub)Cosmopolites Small part of the Zagros flora is Cosmopolitic or Pluri-regional (5%), e.g. *Alopecurus pratensis, Apium nodiflorum, Bromus catharticus, Crypsis alopecuroides, Helminthotheca echioides, Lemna perpusilla, Lemna trisulca, Oenothera biennis, Phleum alpinum, Polypogon setosus, Potamogeton alpinus, P. lucens, Trifolium cherleri, Trigonella stellata* and *Triticum dicoccum.*

IT-ES-M Only 4% of the species have this distribution pattern. Examples are *Aegilops cylindrica, Alyssum minutum, Bellevalia sarmatica, Carex hordeistichos, Cirsium canum, Heliotropium suaveolens, Inula helenium, Lathyrus sativus, Linum austriacum, L. catharticum, Myosurus minimus, Oenanthe fistulosa, Plantago lanceolata, Reseda lutea, Stachys annua, Trifolium echinatum, T. leucanthum, Triticum monococcum* and *Valerianella carinata.*

IT-M In the Zagros, 11% of the species are distributed in both regions. Examples are *Adonis flammea, Agropyron trichophorum, Asplenium lepidum, Atractylis cancellata, Bellevalia longipes, Cirsium congestum, Crocus cancellatus, Eryngium creticum, Festuca valesiaca, Heliotropium arguzioides, Hohenackeria exscapa, Juncus subulatus, Lithospermum incrassatum, Moluccella laevis, Morina persica, Ophrys schulzei, Plantago lagopus, Quercus infectoria, Veronica cymbalaria* and *V. scardica.*

IT-ES Only 4% of the species are distributed in these two regions. Examples are *Carex secalina, Celtis glabrata, Epilobium dodonaei, Erysimum cuspidatum, Hedysarum varium, Lepidium cartilagineum, Nuphar lutea,* and *Silene morganae.*

IT Elements As mentioned before, most of species of the Zagros are IT elements (71%). Some of them are widely distributed in this biogeographical region, such as *Asperula glomerata, Chenopodium novopokrovskyanum, Crambe kotschyana, Crataegus pseudoheterophylla, Crucianella macrostachya, Cymbolaena griffithii, Ephedra foliata, Eremopyrum bonaepartis, E. distans, Eryngium billardieri, Euclidium syriacum, Goldbachia laevigata, Odontites aucheri, Polygonum poly-*

cnemoides, Populus afghanica, Sameraria armena, Scariola orientalis, Sophora alopecuroides, Stachys setifera and *Ziziphora clinopodioides.*

Irano–Anatolian biodiversity hotspot Examples of species which characterize this hotspot include *Aethionema grandiflorum, Astragalus campylorrhynchus, A. gossypinus, Centaurea balsamita, Cirsium bracteosum, Codonocephalum peacockianum, Colchicum kotschyi, C. szovitsii, Corydalis verticillaris, Eremostachys macrophylla, Euphorbia microsphaera, Ferula szowitsiana, Heracleum persicum, Iris acutiloba, I. reticulata, Isatis kotschyana, Leontodon asperrimus, Peltaria angustifolia, Pimpinella aurea, Salsola nitraria, Salvia atropatana, Silene aucheriana, Stachys inflata, Trigonella macroglochin* and *Verbascum cheiranthifolium.*

6.5 Endemism

The Zagros has been identified as an "area of endemism" (Noroozi et al. 2018). A total of 747 species are endemic to the Zagros, which is 21% of its total flora (Noroozi et al. 2019b). There are six endemic genera in the Zagros, i.e. *Azilia* (Apiaceae), *Brossardia* (Brassicaceae), *Haussknechtia* (Apiaceae), *Hymenocephalus* (Asteraceae), *Sclerochorton* (Apiaceae) and *Zeugandra* (Campanulaceae).

The richest families in terms of endemic species are Fabaceae (210), Asteraceae (168), Lamiaceae (44), Caryophyllaceae (40), Alliaceae (32), Primulaceae (29) and Apiaceae (28; Fig. 6.2). The most species-rich genera of the Zagros are *Astragalus* (188), *Cousinia* (72), *Allium* (31), *Dionysia* (29), *Centaurea* (22), *Echinops* (18), *Acantholimon* (17), *Silene* (14) and *Nepeta* (13; Fig. 6.3).

The hyperdiverse genus *Astragalus* is also the richest one in the Zagros, in terms of both total species number and endemics, just as in the other mountains of the Iranian Plateau. It has a centre of diversity in Central and SW Asia with a rapid radiation and recent diversification (Bagheri et al. 2017). Its extraordinary diversification is probably the result of the climatic oscillations in the late Pleistocene when the repeated shrinkage and expansion of steppe habitats resulted in allopatric speciation in the isolated subpopulations (Bagheri et al. 2017).

Molecular phylogenetic studies on *Cousinia*, the second largest genus of the region, suggested that the high species diversification of this genus in a relatively small geographical area has probably been mainly allopatric (López-Vinyallonga et al. 2009). Djamali et al. (2012) also concluded that the high rate of allopatric speciation in long–term isolated populations, coupled with a low rate of extinction during the relatively milder glacial periods in the mountains of SW Asia, resulted in the rich diversity and endemism of this genus.

Dionysia (Primulaceae) is a typical IT endemic genus limited to the SW Asian mountains with a total of 54 accepted species (www.theplantlist.org). The centre of diversity of this genus is the Zagros with 29 endemic species (Noroozi et al. 2019b). They are usually cushion forming chasmophytes with yellow, purple, violet or pink

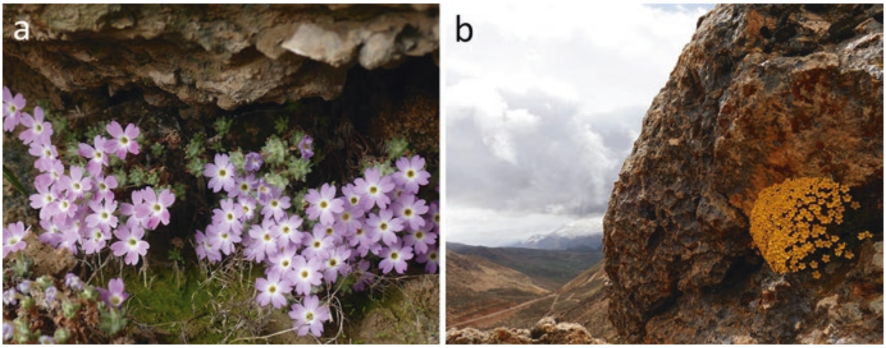

Fig. 6.6 (**a**) *Dionysia archibaldii* in the central Zagros (2500 m a.s.l.); (**b**) *D. lamingtonii* in the central Zagros (2800 m a.s.l.; photos: JN)

flowers (Lidén 2007), e.g. *Dionysia archibaldii* (Fig. 6.6a), *D. lamingtonii* (Fig. 6.6b).

Endemic species are unevenly distributed across the Zagros range and are mostly concentrated in regions in which high mountain peaks create "centres of endemism" (Noroozi et al. 2019a). Topographic complexity and a wide elevational amplitude seem to be the major drivers of the high endemisity in this region (Noroozi et al. 2018).

Most of the endemic species of the Zagros are narrowly distributed (Noroozi et al. 2019b), but there are also endemic species which are widely distributed all over the Zagros, such as *Alcea schirazana, Allium haemanthoides, A. koelzii, Amygdalus haussknechtii, Astragalus darlingtonii, A. ptychophyllus, Campanula humillima, Centaurea persica, Cerasus brachypetala, Convolvulus gonocladus, Elaeosticta nodosa, Galium pseudokurdicum, Hyoscyamus kotschyanus, Malabaila porphyrodiscus, Nepeta laxiflora, N. kotschyi, Phlomis aucheri, Pyrus glabra, Rhabdosciadium aucheri, Scorzonera persepolitana, Stachys pilifera* and *Trachydium kotschyi.*

6.6 Major Vegetation Types

The complex and heterogeneous orography of the Zagros caused a pattern of different climatic conditions and created diverse macrohabitats. However, our knowledge about the ecology and vegetation types of the Zagros is very poor compared to the Alborz and Kopet Dagh mountain ranges. Moreover, the Zagros is a very large mountain range from the northwest to the south of Iran and the flora and vegetation of different parts differ considerably. However, here we just present the major vegetation types of the Zagros, that is common all over this mountain range, and we base our account on previous publications (Zohary 1973; Frey et al. 1999; Jafari Kokhedan 2003) and on our own observations. We include *Quercus* woodlands, *Amygdalus-Pistacia* shrublands, montane steppe shrublands, wetlands, chasmophytic communities, subalpine, alpine and subnival habitats.

6.6.1 **Quercus *Woodlands***

Quercus forests and woodlands (Fig. 6.7) mainly occupy the western Zagros at elevations from 1000 to 2500 m a.s.l. (Sagheb Talebi et al. 2014; Zohary 1973). These woodlands were classified by Zohary (1973) in the provisional class *Quercetea brantii*. It occurs from southeastern Turkey and northeastern Iraq with rather dense forests stretching southeastwards to the south of Iran, gradually turning into wide open steppe-forests with scattered trees, and then finally vanishing in the southeastern Zagros (Sagheb Talebi et al. 2014; Zohary 1973). The bioclimatic range of this vegetation unit corresponds to the Mediterranean pluviseasonal-continental bioclimate, with the precipitation predominantly occurring during the cold season of the year (see Fig. 6.1; Djamali et al. 2011). The annual precipitation ranges from 400 to more than 800 mm (Frey et al. 1999). The expansion of these forests started about 5000 years ago, that is after last glaciation period, as a result of a warmer and moister climate, and reached its maximum expansion at about 2100 to 1700 cal. B.P. after which it remained stable till 400 cal. B.P. (Djamali et al. 2008). The most important tree species of these forests are *Quercus brantii, Q. infectoria* and *Q. libani* (Sabeti 1976). Zohary (1973) described these forests as the Kurdo-Zagrosian steppe-forest, made up mostly of deciduous, broad-leaved trees or shrubs with a dense ground cover of steppe vegetation. *Quercus brantii* is the most dominant and widespread species of these woodlands and occurs throughout the entire range of these vegetation types. In the northern Zagros it is associated with *Quercus infectoria* and *Q. libanii* (as the more common *Quercus* species) and in the central region it is associated with *Q. infectoria* only (Frey et al. 1999). Therefore, based on their *Quercus* species composition, the Zagros woodlands are generally classified into two sections: The southern section with oak communities of purely *Q. brantii* and the northern section where *Q. brantii* intermixes with *Q. infectoria* and *Q. libanii* (Sagheb Talebi et al. 2014).

Along with the *Quercus* species there are some other shrub species that are characteristic, including *Acer monspessulanum, Amygdalus* spp.*, Cerasus microcarpa, C. mahaleb, Cotoneaster* spp.*, Crataegus* spp.*, Fraxinus rotundifolius, Pistacia atlantica, P. khinjuk* and *Pyrus* spp. This habitat is relatively rich in geophytes, including genera of the Orchidaceae (*Ophrys, Orchis, Comperia, Limodorum, Himmantoglossum, Epipactis, Cephalanthera, Dactylorhiza*). Moreover herbaceous and especially annual taxa are well represented in these woodlands. Some more common taxa include *Acanthophyllum bracteatum, Anthemis odontostephana, Arum conophalloides, Biarum carduchorum, Echinaria capitata, Eremostachys laevigata, Euphorbia denticulata, Clypeola aspera, Gentiana olivieri, Hordeum bulbosum, Onosma sericeum, Campanula cecilii, Helianthemum salicifolium,* *Medicago* spp., *Trifolium* spp., *Trigonella* spp., *Pterocephalus kurdicus, Rindera lanata* and *Zoegea crinita*.

These woodlands are sometimes intermixed with scattered trees of *Juniperus excelsa* in the upper parts, but compared to the *Juniperus* woodlands of the eastern

Fig. 6.7 *Quercus* woodlands of the Zagros. (**a**) northern Zagros (Shahu Mts.); (**b**) central Zagros (Oshtorankuh Mts.); (**c**) southern Zagros (Dena Mts.; photos JN)

Alborz, these stands are not well developed (or already destroyed) and contain just sparse communities of this tree.

6.6.2 Amygdalus-Pistacia *Shrublands*

This vegetation type is a common stand in foothills of the southern Zagros (Fig. 6.8a), especially at lower (marginal) zone of *Quercus* woodlands. The annual precipitation of this stand is less than *Quercus* woodlands and higher than montane steppe shrublands (Djamali et al. 2011). The main elements of this unit are *Amygdalus scoparia* (Fig. 6.8a) and *Pistacia atlantica* (Fig. 6.8a) associated with *Amygdalus eburnea, A. kotschyi, A. lycioides, Pistacia khinjuk* and *Acer monspessulanum*. Based on site condition, there are different compositions of dominant taxa and in some places it intermixes with *Quercus* woodlands and at higher altitudes it penetrates into the *Juniperus* woodlands. Frey et al. (1999) named this vegetation type *Amygdalus-Pistacia* but Zohary (1973) merged this unit with *Juniperus* woodlands under the extensive community type of *Juniperus-Pistacia-Amygdalus* scrub. Some dominant underground species of these habitats are *Acantholimon scorpius, Acanthophyllum bracteatum, Artemisia aucheri, Astragalus fasciculifolius, Convolvulus acanthocladus, C. spinosus, Cotoneaster nummularioides, Ephedra intermedia, Eryngium billardieri, Oryzopsis holciformis, Otostegia persica, Phlomis olivieri, Pteropyrum aucheri, Pycnocycla nodiflora, Salvia santolinifolia* and *Scorzonera tortuosissima.*

6.6.3 Montane Steppe Shrublands

In the Zagros mountain range, just as in other Iranian mountain ranges, montane steppe shrublands are common vegetation types in many foothills and in the montane zone, especially in the vast areas in the eastern part of this mountain range. The governing bioclimatic regime is Mediterranean xeric-continental, characterized by a longer summer drought and relatively low total precipitation values (ca. 250 to 350 mm/year) compared to the *Quercus* and *Amygdalus-Pistacia* shrublands (Djamali et al. 2011). In our opinion this vegetation type can be classified in the class *Astragalo-Brometea* (Quezel 1973) described from Anatolia. Based on site conditions, stands show different species compositions and in some places they mix *Amygdalus-Pistacia* shrublands. The shrubs like *Amygdalus, Cotoneaster* and *Crataegus* usually present in this vegetation type but more scarce than the shrub density in the *Amygdalus-Pistacia* shrublands. *Astragalus microcephalus* (Fig. 6.8b) is usually the most dominant species in the communities.

This stand in the eastern most parts of the Zagros is meanly dominated by *Stipa-Artemisia* steppes (Fig. 6.8c). It is a transitional vegetation type from semi-desert to montane steppe shrublands. The most dominant species throughout this region are

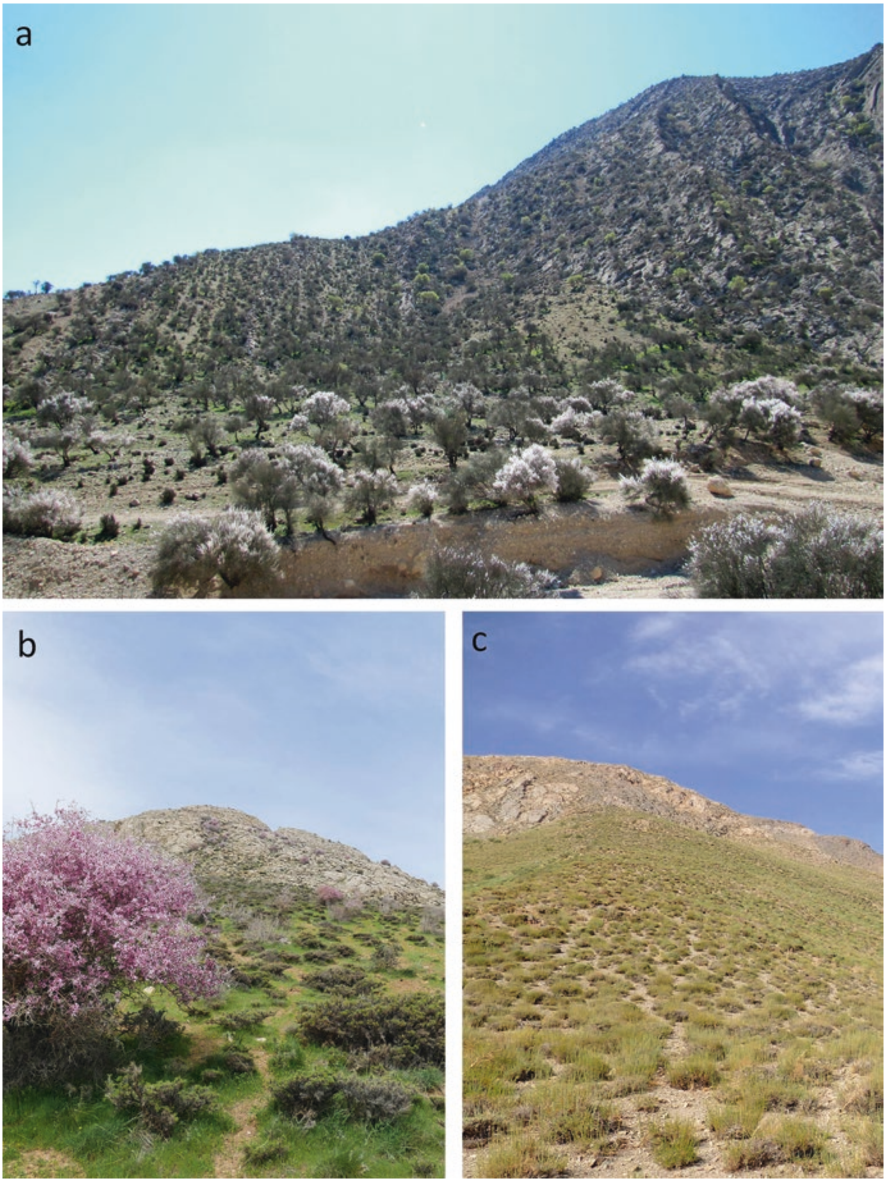

Fig. 6.8 (**a**) *Amygdalus-Pistacia* shrublands (*Amygdalus scoparia* and *Pistacia atlantica*; southern Zagros, Fars Province, near Kavar, 1800 m a.s.l.; photo A. Ghorbanalizadeh); (**b**) Montane steppe shrublands (*Amygdalus lycioides, Astragalus microcephalus* (northern Zagros, near Kermanshah, 2200 m a.s.l.; photo JN); (**c**) *Stipa-Artemisia* steppes (*Artemisia aucheri*; southern Zagros, Bel Mts., 3000 m a.s.l.; photo JN)

Stipa arabica and *Artemisia aucheri* (Fig. 6.8c). Some other dominant species are *Acantholimon flexuosum, Aegilops* spp., *Ajuga chamaecistus, Astragalus fasciculifolius, Centaurea virgata, Convolvulus acanthocladus, C. spinosus, Dendrostellera lessertii, Ebenus stellata, Erigeron bungei, Euphorbia heteradena, Gundelia tehranica, Hertia angustifolia, H. intermedia, Iris songarica, Kochia prostrata, Melica persica, Noaea mucronata, Phlomis persica, Pteropyrum aucheri, Scariola orientalis, Stachys inflata, Taeniatherum crinitum* and *Teucrium polium.* Most of these species also occur in the other mountains of the Irano-Anatolian Plateau.

6.6.4 Wetlands

The unbroken range of the Zagros, from the north-eastern Iraq to the south of Iran, with relatively high mountain peaks, receives considerable amounts of precipitation that in some places reach to more than 1500 mm/year (Fig. 6.1). Several wide or narrow rivers flow down from the Zagros to different lakes or to the Persian Gulf. Important rivers with their main resources in the Zagros create fresh water of lakes, like the Zaribar, Gahar, Gavkhuni, Bakhtegan, Tashk and the Maharlu. The lakes Bakhtegan, Maharlu, Tashk and Gavkhuni are almost completely dried up in recent years, but they still harbor some local endemic elements, e.g. *Frankenia persica, Salicornia perspolitana, S. persica* and *S iranica*. The hygrophilous vegetation of rivers and fresh water lakes in the Zagros is not well known but some characteristic taxa are *Barbarea plantaginea*, *Calamagrostis pseudophragmites, Carex* spp., *Cyperus* spp., *Dactylorhiza umbrosa, Eleocharis* spp., *Epipactis palustris, E. veratrifolia*, *Glyceria plicata, Juncus* spp., *Lythrum salicaria, L. hyssopifolium, Nasturtium officinale, Orchis palustris, Pedicularis sibthorpii, Phragmites* spp., *Potamogeton* spp., *Primula gaubaeana, Ranunculus kotschyi, Salix* spp., *Stachys spectabilis*, *Swertia latifolia*, *Tamarix* spp., *Typha* spp., *Trifolium* spp., *Triglochin palustris* and *Veronica anagallis-aquatica*.

6.6.5 Chasmophytic Habitats

Vast rocky habitats of different substrates in the Zagros have provided suitable environments for diversification and occurrence of diverse chasmophytic plants (Fig. 6.9). Some characteristic species of these habitats, which are widely distributed in the Irano-Anatolian high mountains, are *Arabis caucasica, Asplenium ruta-muraria, Aubrieta parviflora, Corydalis rupestris, Cystopteris fragilis, Dielsiocharis kotschyi, Rosularia elymaitica, Scrophularia variegata, Tanacetum kotschyi* and *Umbilicus intermedius.* These vegetation types in the Zagros, similar to the Alborz, can be classified in the class *Asplenietea rupestris* (Klein 2001). However, there are many taxa which are restricted to the Zagros range. One of the most important genera of these habitats is *Dionysia,* with more than 80% of its species in the Zagros are

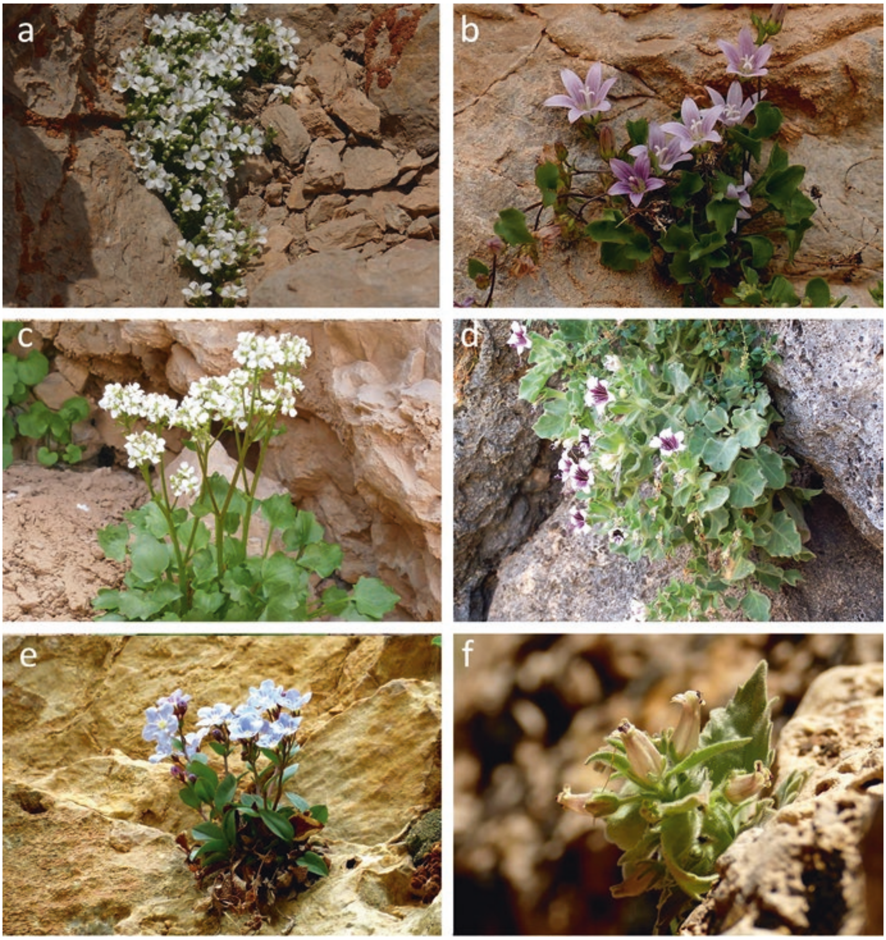

Fig. 6.9 Chasmophytic habitats of the Zagors. (**a**) *Arenaria minutissima* (Kelar Mt., 3200 m a.s.l.; photo JN); (**b**) *Campanula acutiloba* (Oshtorankuh Mts., 3000 m a.s.l.; photo AT); (**c**) *Graellsia saxifragifolia* (Dena Mts., 3800 m a.s.l.; photo JN); (**d**) *Hyoscyamus tenuicaulis* (near Persepolis, 1700 m a.s.l.; photo JN); (**e**) *Omphalodes luciliae* subsp. *kurdica* (Zardkuh Mts., 2700 m a.s.l.; photo AT); (**f**) S*crophularia denaensis* (Margun waterfall, 2400 m a.s.l.; photo JN)

endemic to this range (see section 6.5). Some other chasmophytic species are *Ajuga austroiranica, Arenaria minutissima* (Fig. 6.9a)*, Campanula acutiloba* (Fig. 6.9b), *C. candida, C. incanescens, C. luristanica, Cerasus brachypetala, Draba aucheri, Graellsia saxifragifolia* (Fig. 6.9c), *Hyoscyamus tenuicaulis* (Fig. 6.9d), *Micromeria persica*, *Omphalodes luciliae* subsp. *kurdica* (Fig. 6.9e)*, Pentanema pulicariiforme, Phagnalon nitidum, Potentilla lignosa, Scrophularia crassiuscula, S. denaensis* (Fig. 6.9f)*, Silene elymaitica, Stachys benthamiana, Umbilicus tropaeolifolius* and *Viola pachyrhiza.*

6.6.6 Subalpine Habitats

Subalpine tall herbs and umbelliferous vegetation types in the Zagros, as in the Alborz, cover steep slopes in the subalpine zone from ca. 2500 to 3500 m a.s.l. (Fig. 6.10). Usually this zone comprises the ecotone between the *Quercus* woodlands and the high alpine zone. The vegetation is highly dominated by tall herbs, mainly from the Apiaceae family, which mostly belong to genera *Ferula*, *Ferulago* and *Prangos*. Some of the dominant species of these vegetation types in the Zagros are *Chaerophyllum macropodum, Dorema aucheri, Ferula gummosa, F. ovina* (Fig. 6.10a)*, Ferulago angulata* (Fig. 6.10b)*, Iris lycotis, Helichrysum oligocephalum, Hypericum scabrum, Phlomis olivieri, Prangos uloptera* (Fig. 6.10a, c), *Silene chlorifolia* and *Smyrnium cordifolium.* The physiognomy, ecology and species composition of this vegetation type is very similar to the equivalent stand in the Alborz and all can be classified in the provisional class *Prangetea ulopterae* described by Klein (1988) for the central Alborz.

Thorn-cushion communities usually occupy the windswept slopes of subalpine zone. This is a common feature in the entire Irano-Anatolian highlands. In subalpine zone of the central Zagros, with high annual precipitation (ca. 1000 mm) and deep snow cover during the winter, the plant communities are often strongly dominated by a large thorn-cushion species i.e. *Astragalus brachycalyx* (Figs. 6.11a, 6.15c). Some other frequent species accompanying *Astragalus brachycalyx* are *Acantholimon erinaceum, A. scabrellum*, *Agropyron tauri, A. intermedium, Allium hirtifolium, Astragalus cephalanthus, A. gossypinus, A. myriacanthus, A. susianus, Biebersteinia multifida, Bromus tomentellus, Centaurea aucheri, C. gaubae, Cirsium lappaceum, Cousinia bachtiarica, C. cylindracea, Daphne mucronata* (Fig. 6.11a)*, Dianthus crinitus, Euphorbia decipiens, Fibigia macrocarpa*, *Fritillaria persica, Helichrysum oligocephalum*, *Onosma microcarpa, Phlomis bruguieri, Scutellaria multicaulis, Stachys acerosa*, *S. pilifera* and *Tulipa systola* (Fig. 6.11b). This zone also harbors diverse showy, bulbous plants. In some stands *Fritillaria imperialis* is very dominant and makes vast fields of red flowering *Fritillaria* at the end of April and early May (Fig. 6.11c). It occurs from southeastern Turkey all along the Zagros to the southeastern limit of this mountain range. It does not exist in the Yazd-Kerman massifs and the Makran mountains, but after a long gap is present again in the southwestern Hindu Kush mountains.

6.6.7 Alpine Zone

The alpine zone of the Zagros lies above 3000–3500 m a.s.l. depending on the latitude and the aspect (slope direction) of the area. A total of 482 vascular plant taxa from the alpine zone of the Zagros (subalpine, alpine, subnival species) are recorded, of which 262 taxa (54%) are endemic of this mountain range (Noroozi et al. 2016). These species belong to only 33 families and 159 genera. The richest families of this

Fig. 6.10 Subalpine tall herbs and umbelliferous vegetation types. (**a**) *Ferula* cf. *ovina, Prangos uloptera* (Zardkuh Mts., 2700 m a.s.l.); (**b**) *Ferulago angulata* (Dena Mts., 3400 m a.s.l.); (**c**) *Prangos uloptera* (Shahu Mts., 2700 m a.s.l.; photos JN)

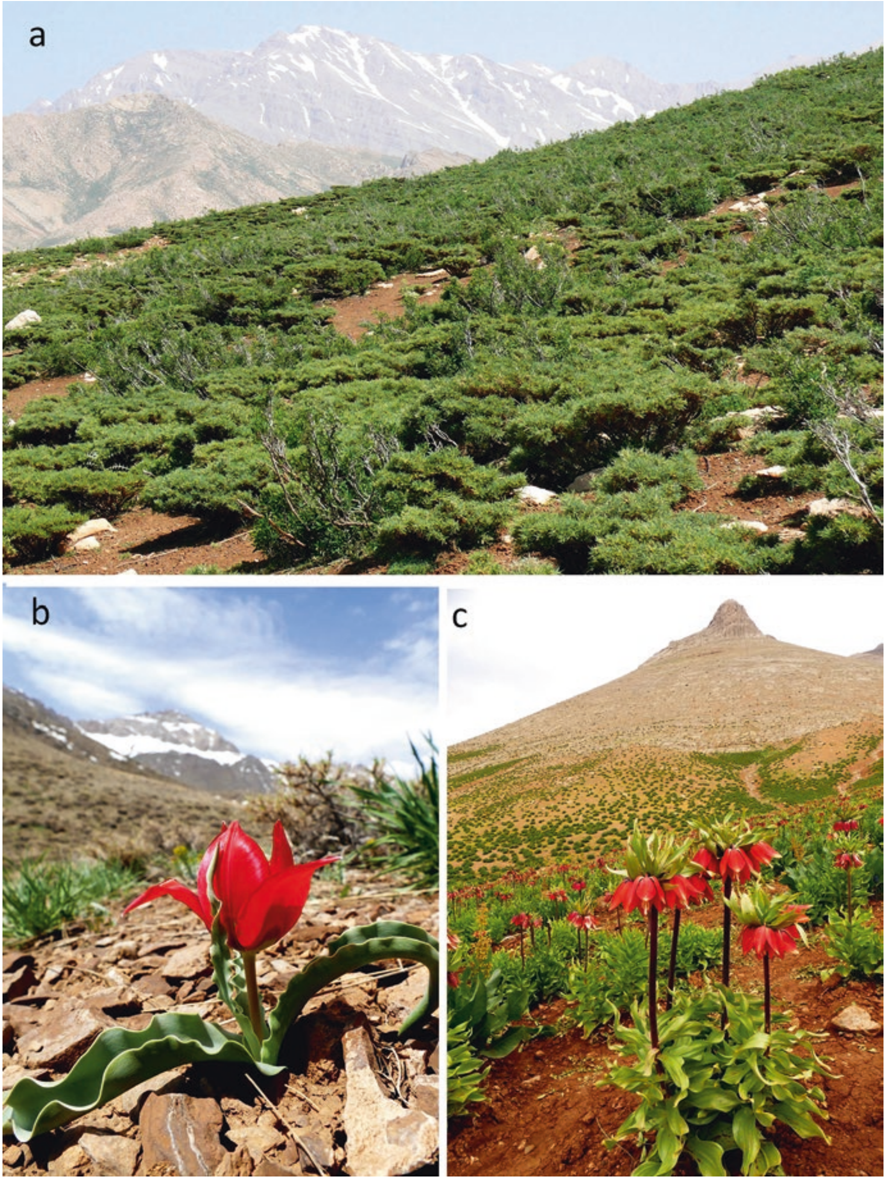

Fig. 6.11 Thorn-cushion communities of the Zagros. (**a**) *Astragalus brachycalyx* and *Daphne mucronata*; (**b**) *Tulipa systola*; (**c**) *Fritillaria imperialis* (all photos from central Zagros, Zardkuh Mts., 2500–3000 m a.s.l.; photos JN)

zone in the Zagros are Asteraceae (71 taxa), Fabaceae (54), Lamiaceae (41), Caryophyllaceae (39), Brassicaceae (38), Apiaceae (35), Scrophulariaceae (24), Primulaceae (21), Rosaceae (20), Poaceae (19) and Plumbaginceae (17). The richest genera are *Astragalus* (Fabaceae; 41 taxa), *Nepeta* (Lamiaceae; 21), *Dionysia* (Primulaceae; 20), *Acantholimon* (Plumbagianceae; 17), *Silene* (Caryophyllaceae; 14), *Cousinia* (Asteraceae; 12), *Ranunculus* (Ranunculaceae; 11), *Potentilla* (Rosaceae; 10), *Allium* (Alliaceae; 9) and *Veronica* (Scrophulariaceae; 9).

Compared to the Alborz, the number of alpine species is less in the Zagros range but the number of alpine endemics is twice larger than in the Alborz, and the rate of endemism in the Zagros alpine zone is much higher (27% in the Alborz and 54% in the Zagros; Noroozi et al. 2016). The Zagros is a huge mountain range and the area size is almost five times more than the Alborz. But the alpine zone of the Alborz is remarkable and even bigger than the alpine zone of the Zagros, and they are mostly concentrated to the central Alborz where there is a high connectivity. The alpine zone of Zagros is highly isolated and occurs scattered from north to south. Therefore, despite the low number of alpine species in the Zagros, most of them are restricted to local, isolated alpine habitats, and this increase the rate of endemism in this zone.

As mentioned, the vegetation of the Zagros, especially that in the higher elevations, is little known. Our knowledge about the biodiversity and ecology of these habitats are based on floristic studies and our personal observations.

Thorn-cushion grasslands cover large areas of the alpine habitats in the Zagros (similar to the Alborz), and the dominant species usually belong to the compact tragacanthic species of *Astragalus*, *Acantholimon* and *Onobrychis cornuta* (Fig. 6.12). Some characteristic species of these vegetation types are *Acantholimon brachystachyum, A. bromifolium, A. erinaceum, A. scabrellum, A. tomentellum, Acanthophyllum caespitosum, Arenaria persica, Astragalus eriosphaerus* (Fig. 6.12a), *A. leucargyreus* (Fig. 6.12b), *Bromus tomentosus, Cousinia lasiolepis* (Fig. 6.12c), *C. multiloba, Festuca ovina, Helichrysum psychrophilum, Poa araratica, Scutellaria multicaulis, Silene goniocaula* and *Stachys acerosa.*

The snowbed communities are dominated by rosette species and small herbs, in correspondence with their short growing season. *Catabrosella parviflora, Piptatherum laterale, Plantago atrata, Polygonum serpyllaceum* and *Ranunculus elymaiticus* (Fig. 6.13) are the most dominant species of the alpine snowbed communities.

6.6.8 Subnival Zone

The subnival zone in the Zagros is limited in surface area-size and occurs scattered, mainly at the high elevations of the Dena, Zardkuh and Oshtorankuh mountains, where the elevation exceeds 4000 m a.s.l. This zone lies usually above 3800–4000 m a.s.l. depending on aspect and latitude of the mountain slope. At these elevations, the ground is usually covered with screes and rocks and most of the species can grow on both habitats. The vegetation types of these habitats can be

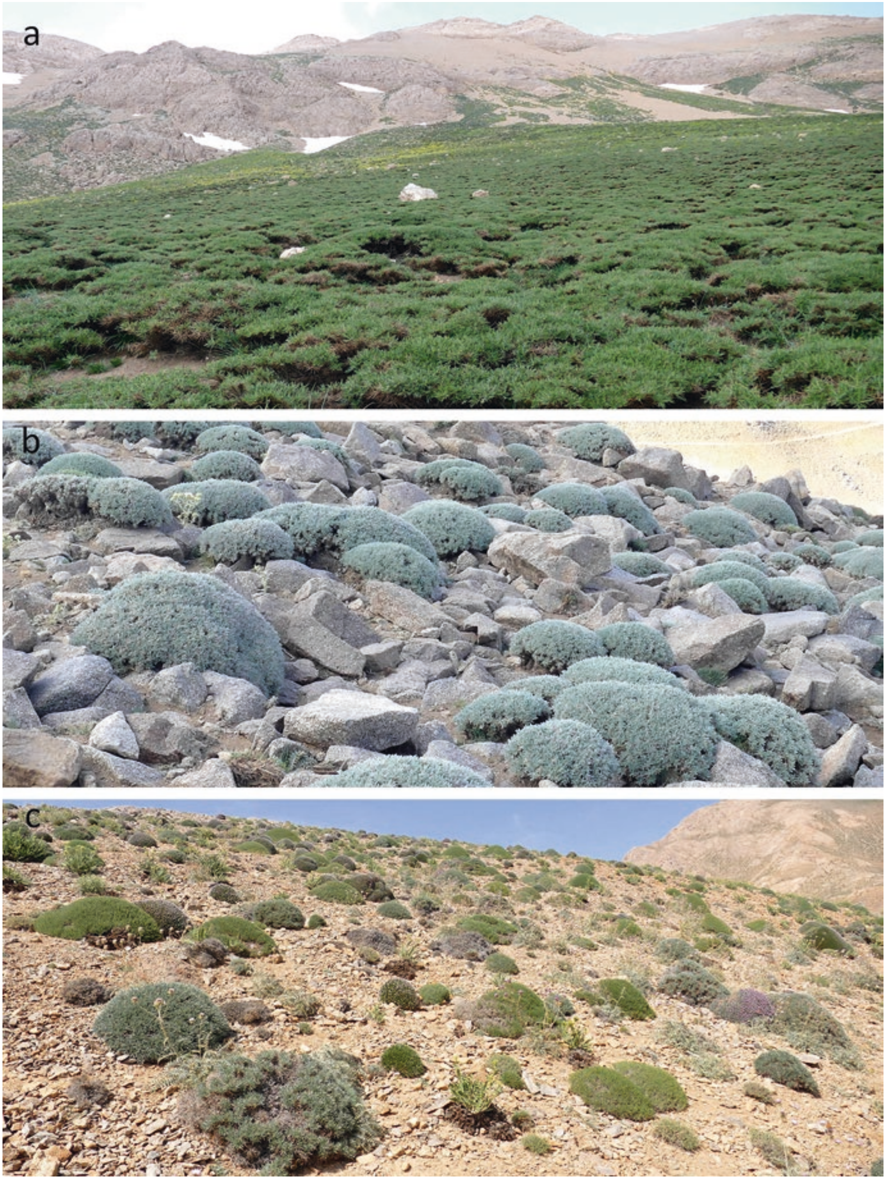

Fig. 6.12 Alpine thorn-cushion grasslands. (**a**) *Astragalus murinus* and *A.* cf. *eriosphaerus* (Dena Mts., 3800 m a.s.l.); (**b**) *Astragalus leucargyreus* (Alvand Mts., 3500 m a.s.l.); (**c**) *Onobrychis cornuta*, *Cousinia lasiolepis*, *Acantholimon* sp., *Astragalus* sp. (Bel Mts., 3800 m a.s.l.; photos JN)

Fig. 6.13 High alpine snowbed communities are mostly dominated by *Ranunculus* species (*Ranunculus elymaiticus,* Dena Mts., 3750 m a.s.l.; photo JN)

classified in the *Didymophyso aucheri-Dracocephaletea aucheri* class and the *Didymophysetalia aucheri* order (Noroozi et al. 2014). *Elymus longiaristatus, Euphorbia aucheri* (Fig. 6.14a)*, Physoptychis gnaphalodes* and *Ziziphora clinopodioides*, which are character species of the class (Noroozi et al. 2014), are common

Fig. 6.14 Subnival zone. (**a**) *Euphorbia aucheri*; (**b**) *Erigeron daenensis*; (**c**) *Silene daenensis* and *Nepeta lasiocephala* (all photos from Dena Mts., 4000–4400 m a.s.l.; photos JN)

in these habitats. Although *Didymophysa aucheri* (one of the most important character species of subnival zones of the Iranian Plateau) occurs widely spread in the entire Zagros, it is rather rare and less common in the Zagros subnival communities compared to those in the Alborz, Sahand and Sabalan mountains. Some of the

Zagros and Zagros/Yazd-Kerman elements which are dominant in these habitats are *Erigeron daenensis* (Fig. 6.14b), *Nepeta lasiocephala* (Fig. 6.14c), *Silene daenensis* (Fig. 6.14c), *S. persica, Stachys obtusicrena* and *Zerdana anchonioides.* One of the monotypic genera of these habitats which is restricted the Zagros and Yazd-Kerman massifs is *Zerdana.* It is a rare plant which only grows on scree and sometimes on rock grounds in the subnival zone. The rate of endemism in the subnival zone of the Zagros mountains is very high due to their highly isolated situation (Noroozi et al. 2011, 2018).

6.7 Conservation

Archeological studies in the Zagros reveal over 2200 years of cultivation of plants (Riehl et al. 2013). This region is one of the centres of plant and animal domestications in the world (Zeder and Hesse 2000; Riehl et al. 2013). The first domestication of goats (*Capra hircus*) was documented for the highlands of the Zagros at 10,000 years ago (Zeder and Hesse 2000). This and similar evidence show that this mountain range has a long history of anthropogenic activities. Currently, overgrazing is one of the main factors threatening the flora and vegetation types of this mountain range, as in other parts of Iran. Trampling by crowded herds of sheep and goats has been destroying the herb layer in many places and left the soil prone to erosion. The dominance of poisonous or spiny plants in the most of vegetation types is a result of the high pressure of overgrazing (Fig. 6.15). Besides, charcoal burning and clear cutting of *Quercus* forests in order to expand crop fields have extensively destroyed some natural landscapes. Uncontrolled wildfires from natural or human-induced causes also burn thousands of acres of land each year. Irregular dam construction is another source of threat that has had a great impact on the river and wetland systems and consequently their plant diversity in different parts of the Zagros (Manouchehri and Mahmoodian 2002; Fuladavand and Sayyad 2015).

The significant plant diversity of the Zagros, especially the occurrence of high numbers of endemic and narrowly distributed species (Noroozi et al. 2019b), asks for a strong conservation policy. Figure 6.16 shows the nature reserves of the Zagros. Despite the presence of a high number of nature reserves in this mountain range, there is a big conservation gap between the biodiversity hotspots and that of nature reserves (Noroozi et al. 2019a). It means that there is a poor overlap between the location of the biodiversity hotspots and the nature reserves. Therefore, we highly recommend reducing the conservation gaps in the Zagros by increasing the protected areas in the recognized biodiversity hotspots.

Fig. 6.15 Overgrazing impact on the vegetation types of the Zagros. (**a**) *Cirsium* cf. *lappaceum*, *Cousinia elwendensis* and *Euphorbia cheiradenia*; (**b**) *Euphorbia cheiradenia* (both photos from Alvand Mts., 3300–3400 m a.s.l.); (**c**) *Astragalus brachycalyx, Cirsium lappaceum* (Zardkuh Mts., 2600 m a.s.l.; photos JN)

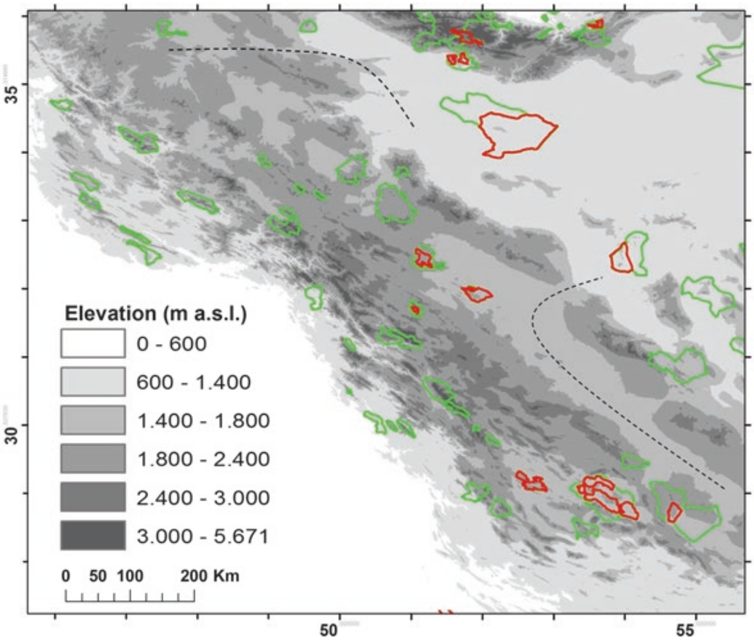

Fig. 6.16 Nature reserves of the Zagros mountain range (Green lines: Protected Areas; Red lines: National Parks)

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Chapter 7
The Anatolian High-Mountain Ranges – Plant Diversity Between Two Seas

Gerald Parolly

Abstract This contribution provides a survey on the high-mountain vegetation of Anatolia, Turkey, covering the West Anatolian Mts., the Taurus mountain system, the Inner Anatolian volcanoes, the East Anatolian highlands and the Black Sea Mts. Due to its location between the Black Sea and the Mediterranean Sea, the intersection of three phytogeographical regions, a highly varied geologic and climatic setting in addition to a dramatic geological past, the plant life of the different Anatolian mountains systems and isolated peaks is amazingly diverse and very rich in endemics. The chapter introduces all important high-mountain ranges, their zonation, major ecosystems, key vegetation types and floristic inventories. Based on a thorough phytogeographic analysis of the high-mountain flora and an evaluation of a wide range of floristic and phylogenetic studies, the diversity patterns of the Anatolian mountain systems and their floristic links to the adjacent areas are reviewed and mapped.

Abbreviations

IPA	Important Plant Area (see Özhatay et al. 2005)
KBA	Key Biodiversity Area (see Eken et al. 2006)
Mt.	Mount (Turkish: Dağı, −dağ)
Mts.	Mountains (Dağları, −dağlar)
NP	National Park
vs.	versus

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7.1 Introduction

A glance at a physiographical map reveals Turkey's mountainous character, with a median elevation of more than 1100 m and only few narrow strips of lowland along the coasts of the Black and Mediterranean Sea. Rising from all four directions, mid-elevational mountains and high-mountains encircle the Anatolian peninsula (Fig. 7.1). Two very different mountain systems, each relatively narrow but more than 1000 km long, line its coasts: the Black Sea Mts. (Turkish: Karadeniz Dağları; North Anatolian Mts./Kuzey Anadolu Dağları) in the north and the Taurus Mts. (Turkish: Toroslar) in the south. In East Anatolia, the two mountain systems converge into rugged highlands, exceeding 1500 m in median elevation, which are flanked by the highest mountain chains of the country. The western part of this mountainous transverse functions as a biogeographically highly significant floristic break, the so-called 'Anatolian Diagonal' (Davis 1965–1985, 1971; Ekim and Güner 1986, 2014; Fig. 7.2). In addition to the Taurus and the Black Sea Mts. as part of the Alpide–Himalayan folded system, the central and eastern parts of Anatolia are dotted by isolated volcanic cones piled up over vast steppe territories.

With some 11,800 subgeneric taxa (species and subspecies) of native vascular plants, and approximately one third of them being endemics, Turkey ranks as richest

Fig. 7.1 Position of the major mountain ranges and massifs and of three selected metereological stations in Anatolia [**1** Kaz Dağı; **2** Uludağ; **3** Köroğlu Dağları; **4** Ilgaz Dağları; **5** Isfendiyar Dağları (Küre Dağlar); **6** Giresun Dağları; **7** Gümüşhane Dağları; **8** Rize Dağları (s. str.); **9** Çoruh Vadisi; **10** Kaçkar Dağları; **11** Yalnızçam Dağları; **12** Bozdağlar; **13** Murat Dağı; **14** Sandras Dağı; **15** Baba Dağı; **16** Honaz Dağı; **17** Akdağlar (Gömbe Akdağ and Yumru Dağı); **18** Beydağları (Kızlar sivrisi); **19** Beydağları (Tahtalı Dağ)ı; **20** Barla Dağı; **21** Davras Dağı; **22** Bozburun Dağı; **23** Dedegöl Dağları; **24** Sultan Dağları; **25** Geyik Dağları; **26** Taşeli Platosu; **27** Oyuklu Dağı; **28** Bolkar Dağları; **29** Posantı Dağları; **30** Aladağlar; **31** Hasan Dağı; **32** Melendiz Dağı; **33** Erciyes Dağı; **34** Tahtalı Dağları; **35** Nur Dağları (Amanos Dağları); **36** Binboğa Dağları; **37** Berit Dağı; **38** Engizek Dağları; **39** Ahır Dağı; **40** Tecer Dağları; **41** Malatya Dağları; **42** Munzur Dağları; **43** Esence (Keşiş) Dağları; **44** Palandöken Dağları; **45** Bingöl Dağları; **46** Bitlis Güneyi Dağları; **47** Nemrut Dağı; **48** Süphan Dağı; **49–53** Hakkâri-Taurus; **49** Tanin Tanin Dağları; **50** Artos Dağı; **51** Buzul (Cilo) Dağları; **52** Ikiyaka (Sat) Dağları; **53** Mordağlar; **54** İspiriz Dağları and Van Doğusu Dağları; **55** Erek Dağı; **56** Tendürük Dağı; **57** Ağrı Dağı; **58** Pirreşit Dağı; **59** Allahuekber Dağları. – **A** Muğla; **B** Rize; **C** Kars]

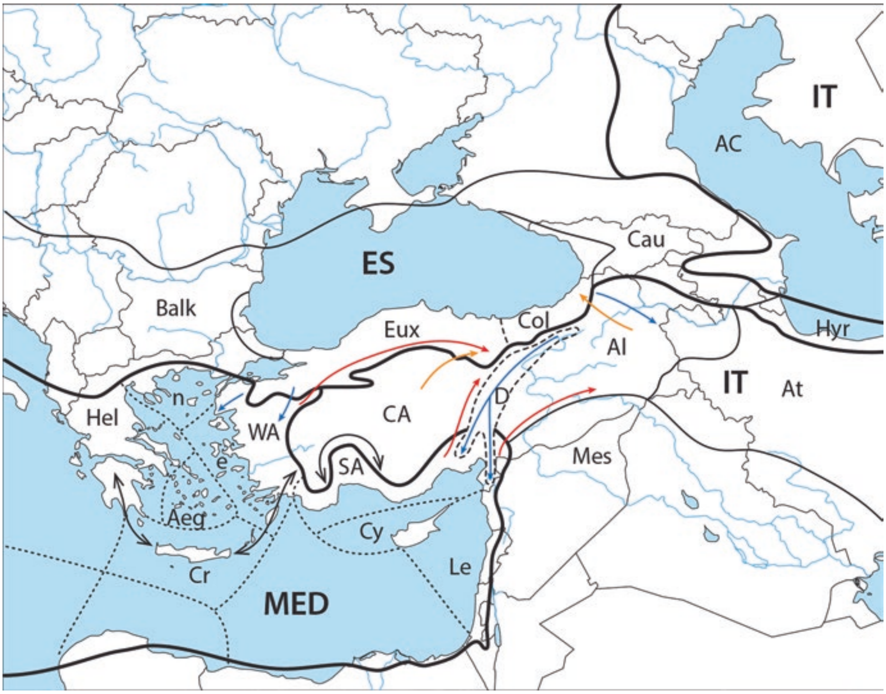

Fig. 7.2 Biogeographical setting of Anatolia (based on Meusel et al. 1965 and Davis 1971; after Parolly 2004, altered) and important floristic links [**ES** Euro-Siberian Region: **Balk** Balkan Province; **Eux** Euxine Province, with Euxine Sector and **Col** Colchic Sector; **Cau** Caucasian Province. — **Med** Mediterranean Region/East Mediterranean Subregion: **Hel** Hellenic Province, **Aeg** Aegean Subprovinve (**e** eastern, **n** northern Aegean), **Cr** Cretean Subprovince; **SA** South Anatolian Province, **Cy** Cyprian Subprovince, **Le** Lebanon Subprovince, **Ta** Tauric Subprovince (for its subdivision, see Fig. 7.4); **WA** West Anatolian Province. — **IT** Irano-Turanian Region/ Irano-Anatolian Subregion: **AI** Armeno-Iranian Province, **At** Atropatenian Subprovince; **CA** Central Anatolian Province; **Mes** Mesopotamian Province. – **D** Anatolian Diagonal]. – Plant migrations and irradiations of Euro-Siberian elements (blue arrows), Mediterranean elements (red arrows), Irano-Turanian elements (orange arrows), endemics (via Arc of Isparta) and floristic links to Greece via Aegaean Arc (black arrows)

among the South-west Asian countries in terms of phytodiversity (Davis 1965–1985; Davis et al. 1988; Güner et al. 2000, 2012). Major parts of Turkey's surface (ca. 80%) contribute to the 35 global biodiversity hotspots (Mittermeier et al. 2011) by forming part of the hotspots of the Mediterranean Basin, the Caucasus and the Irano-Turanian areas (Médail and Quézel 1999; Myers et al. 2000). The main reasons behind the evolution and persistence of this diversity are traced in a variety of climates (Fig. 7.3), topographical and geological diversity and steep altitudinal gradients from sea-level to above 5000 m a.s.l. In addition, Turkey lies at the junction of three major phytochoria (phytogeographic regions; Davis 1971; Zohary 1973; Ekim and Güner 2000; Parolly 2004; Güner and Ekim 2014; Fig. 7.2). The Anatolian peninsula has a convolute geological and floristic past, served as passage-way during many historical periods (Davis 1971; Zohary 1973; Ekim and Güner 2000,

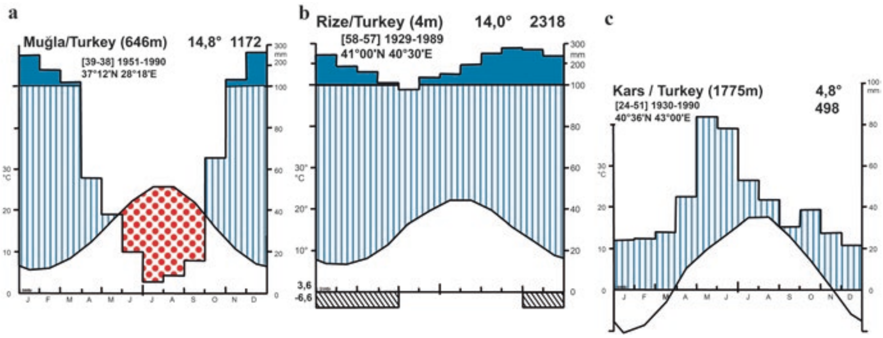

Fig. 7.3 Climatic diagrams of selected stations in Anatolia reflecting Mediterranean (**a**), oceanic Black Sea (**b**) and continental (**c**) climate types. For the position of the stations, see Fig. 7.1

2014) and offered Pleistocene refugia for Tertiary floras (Davis 1971; Thompson 2005; Médail and Diadema 2009; Korotkova et al. 2018). Much of Turkey's outstanding plant diversity is linked to mountain habitats. It thus would be hard to overemphasize the importance of the Anatolian mountains by serving as climatic, geologic and biogeographic divide, by providing substrate specific habitats for plants, as migration route or dispersal barrier and in general as a trigger for plant evolution for the plant life of the region.

State of Knowledge – In contrast to the situation in e.g. forest and steppe ecosystems, there is almost no applied socioeconomic interest promoting the study of high-mountain ecosystems beyond the level of pure scientific aspects, thus the asylvatic mountain ecosystems of Turkey are still relatively poorly understood. Of course, there are many local studies dealing with the flora and vegetation of a single massif or peak, but often without records from the highest elevations (for selected references, see below, Parolly 2004 and Güner and Ekim 2014) and mostly providing a florula and a few tens of phytosociological relevés mainly from the lower belts. In contrast, there are very few approaches to synthesize consistently the scattered vegetation data according to a standardized method. Surveys of larger sections of mountain ranges addressing both the vegetation and flora have been written e.g. by Schwarz (1936: West Anatolian Mts.), Kürschner (1984: Central Taurus and Inner Anatolian volcanoes; 1986a, b: thorn-cushion vegetation of the Taurus and the Levant), Öztürk et al. (1991: Mediterranean Anatolia), Parolly (1995, 1998: scree vegetation of the Western and Central Taurus), Vural (1996: high-mountain vegetation of the Rize Dağları), Hein et al. (1998: rock vegetation of the Western and Central Taurus), Kürschner et al. (1998: chionophytic vegetation of the Western and Central Taurus), Eren (2006: mountain vegetation of the Western Taurus) and Hamzaoğlu (2006: mountain steppe and thorn-cushion vegetation of East Anatolia). The unpublished study of Gemici et al. (1994) on the high-mountain vegetation of West and South Anatolia has been circulated with much influence among the Turkish scientific community.

A first phytosociological survey of the Anatolian high-mountain vegetation – at the same time a critical gap analysis – was given by the author (Parolly 2004), 10 years later followed by an expanded and actualized account (Ketenoğlu et al.

Fig. 7.4 Biogeographic subdivision of the Anatolian mountain ranges [**1** Black Sea Mts., **a** Western Euxine Sector, **b** Central Euxine Sector, **c** Colchic Sector; **2** West Anatolian Mts., **a** Kaz Dağı, **b** Uludağ, **c** Murat Dağı]; **3–7** Taurus range: **3** Western Taurus (Lycian Sector), **a–b** Lydian Subsector, **a** Bozdağlar range, **b** Honaz Dağı–Baba Dağı range, **c** Lycian Subsector; **4** Central Taurus, **a** Pisidian-Isaurian Sector, **a1** Pisidian Subsector, **a2** Isaurian Subsector, **b** Cilician Sector; **5** Sector of the Inner Anatolian volcanoes; **6** Amanos Sector; **7** Eastern Taurus, **a** western section (Cataonian Sector), **b** central section/Sector of the Anatolian Diagonal, **c** Hakkâri section; **8** East Anatolian highlands, **a** Erzurum-Kars area, **b** Yukarı Murat-Van area]

2014) in the marvellous introductory volume to the 'Illustrated Flora of Turkey' (Güner and Ekim 2014). Today, knowledge about the high-mountain flora and vegetation still concentrates in the western half of Turkey. There are no special studies dealing with some vegetation units of the high-mountain vegetation of Eastern Anatolia at all, and our knowledge on alpine and subnival mat-forming cushion vegetation or the vegetation on scree, rocks or of snow-beds remains extraordinary poor.

Goals and Concepts The present contribution gives a concise survey on the high-mountain plant life of Anatolia with a focus on the distribution patterns of its flora and vegetation. Distributional and evolutionary aspects are addressed within the frame of the phytogeographic setting of Turkey (Fig. 7.2) as well as the subdivision of the Anatolian mountain ranges (Fig. 7.4), which summarizes the conclusions presented.

The major mountain ranges are introduced in a biogeographical context and all main mountains mentioned in the text are mapped (Fig. 7.1). Where appropriate, this introduction adds additional facts on the topography, geology and climate in order to better understand the factors underlying the distribution patterns, because space was limited in the introductory chapters on the geology and climate of Anatolia.

The geographical focus will necessarily be on the coastal part of the Taurus range, reflecting the state of knowledge. The term 'high-mountain' is taken in a strict sense: the contribution lays the stress on the flora and vegetation above the tree-line, but also provides some relevant information about the respective mountain forests in order to draft a more comprehensive picture. For convenience, I distinguish Caucasus-type from Taurus-type mountain ranges and ecosystems and group biogeographically the Anatolian mountain ranges into: (1) the Black Sea Mts. and their outliers (Caucasus-type mountain range; Fig. 7.4: 1–2); (2) the wider Taurus Mts. range and their outliers (Taurus-type mountain ranges; Fig. 7.4: 3–7), including the Taurus Mts. proper, the Inner Anatolian volcanoes, the Nur Dağları (Amanos Mts.) plus the mountains forming the Anatolian Diagonal; and (3) the mountains of the East Anatolian highlands (Fig. 7.4: 8), including the high volcanoes (mostly Taurus-type mountain ranges). This approach structures the main paragraphs of the paper as well.

As far as the flora is concerned, the few existing phylogenetic and phylogeographic studies devoted to Anatolian mountain plants have been considered. It goes without saying that in view of Anatolia's enormous plant diversity only very few of the many local endemics and other remarkable species of the different mountain ranges could be mentioned in the text. However, since many mountains represent Important Plant Areas or Key Biodiversity Areas, reference can often be made to Özhatay et al. (2005) or Eken et al. (2006), where area-based lists of selected rare species are offered. The naming of the species follows largely Güner et al. (2012), with the exception of the following taxa (references to the taxonomic backbones in brackets): *Anemonastrum*, Asteraceae, *Lomelosia*, *Noccaea*, *Odontarrhena* and pteridophytes (The Euro+Med PlantBase [http://ww2.bgbm.org/EuroPlusMed/query.asp]; Caryophyllales (Dillenberger and Kadereit 2014; Hernández-Ledesma et al. 2015; Madhani et al. 2018), *Lamium* (Mill 1982), *Minuartiella dianthifolia* (Eren et al. 2004) and *Scilla* s.l. (Speta 1981).

The account on the high-mountain vegetation deals with the zonation, the main habitat types, their site-ecology and species inventories of the different areas, without focusing too much on the syntaxa involved. Nevertheless, the major syntaxa (alliance to class-level), where known, are given in brackets as guideline for readers with an interest in phytosociology. For detailed syntaxonomic accounts, reference can be made to Parolly (2004) and Ketenoğlu et al. (2014).

7.2 Geology

Anatolia's geology is very complex (Avcı 2014) by comprising a mosaic of several terranes amalgated during the Alpide orogeny (Okay 2008). Structurally, the Anatolian peninsula is comparable to tectonic units in the Balkans and the Caucasus, as well as those in the eastern Alps (Schiechtl et al. 1965; Okay 2008). Turkey consists of three main tectonic units: the Pontides, the Anatolides-Taurides and the Arabian Platform in the South-east (Okay 2008; Avcı 2014).

Anatolia is bordered by two prominent folded mountain ranges belonging to different main tectonic units: the Pontides in the north and the Anatolides-Taurides in the south. They converge in a highland in East Anatolia to culminate along the borders with Armenia, Iran and Iraq (Güldalı 1979; Avcı 2014). The Pontides and the Anatolides-Taurides wedge a central massif composed of uplifted blocks and downfolded troughs, covered by recent deposits and appearing as a rugged plateau (Avcı and Avcı 2014a). All major tectonic units, once surrounded by oceans, are now separated by sutures, which mark the tectonic lines or zones along which these oceans have disappeared. The remnants of the oceans, represented by ophiolite and accretionary complexes, occur widespread throughout Anatolia (Okay 2008). The Pontides and the Anatolides-Taurides evolved independently during the Phanerozoic and they were first brought together in the Tertiary (Şenel 1991; Okay 2008).

The Black Sea Mts. extend for over 1000 km with an average width of 110–160 km (Güldalı 1979) and were folded and thrusts faulted during the Alpide orogeny but not metamorphosed (Okay 2008). Along the latitudinal fault system a series of low, long troughs have been formed. Volcanic areas with elevated lava cones are included. The regularity of the West-East ranges is very often upset by cross-faulting and gorges, in which the major rivers such as the Sakarya, Kizil Irmak, Yeşil Irmak and Çoruh Nehri cut their way through the mountains into the Black Sea and turn the mountain range into a rough terrain with horsts and blocks (Zohary 1973; Avcı and Avcı 2014a).

The subunits composing the Pontides, namely the Strandja, Istanbul and Sakarya terranes, show markedly different geological evolutions and have Laurasian affinities. They conserve evidence of Variscan (Carboniferous) and Cimmeride (Triassic) orogenies and are linked to the tectonic units of e.g. the Rhodope Mts. (Schiechtl et al. 1965). The Pontides are located north of the northern branch of the Neo-Tethys. The closure of this ocean resulted in the İzmir-Ankara-Erzincan suture, which marks the boundary between the Pontides and the Anatolides-Taurides (Okay 2008). The region's rock structure is diverse and includes sedimentary, volcanic, granitoid, alluvial, metamorphic/ophiolitic and other rock types. Non-limestone areas prevail (Avcı and Avcı 2014a). The intrusive core of the eastern Black Sea Mts., consisting of granite, gneiss, granodiorite to diorite, and locally serpentine, is overlying soft tuff, basalt, dacite and andesitic volcanic rock or, at a few places, Cretaceous flysch (Schiechtl et al. 1965).

The Anatolides-Taurides show Gondwana affinities, but were separated from the main mass of Gondwana by the southern branch of the Neo-Tethys. In contrast to the Pontic terranes, the Anatolide-Tauride terrane has not been affected by the Variscan and Cimmeride deformation and metamorphism, but was strongly shaped by the Alpide orogeny. It was part of the Arabian Platform and hence Gondwana until the Triassic and was reassembled with the Arabian Platform in the Miocene. The Anatolide-Tauride terrane is subdivided into several zones mainly on the basis of type and age of Alpide metamorphism. Southeast Anatolia forms the northernmost extension of the Arabian Platform and shares many common stratigraphic features with the Anatolide-Tauride terrane (Okay 2008). East Anatolia, as defined here (Fig. 7.4: 8), is essentially covered by volcanic rock, while the neighbouring zones are made up by a mixture of volcanic and sedimentary rocks (Güldalı 1979).

The Taurus Mts. rise steeply from the Aegean Sea and extend over 2000 km to the Iranian border in the east, where they continue into the Zagros Mts. The Taurus Mts. are on average 50–100 km wide. They border on the Mediterranean Sea, delimit Inner Anatolia in the south and in the east and meet the Pontides near Erzincan. The Taurus Mts. form an anticlinal system consisting of series of folded arches frequently broken and much distorted. Geologically, the Toroslar is largely composed of sedimentary rocks, deposited in the former Tethys Sea (Güldalı 1979). Today, owing to the rapid orogenesis during the (late) Tertiary, mainly Mesozoic sediments form the impressive alpine, glacially ice-sculptured scenery of the Taurus. In the eastern Central Taurus, in particular Cretaceous layers exceed 2000 m a.s.l. and are uplifted to altitudes of 3500 m a.s.l. or more. The rock is predominantly a hard limestone, but locally with substantial outcrops of ultramafic rock in lower and mid-elevations. Mica schist (e.g. Baba Dağı) and orthogneiss (Bozdağ) make up single massifs in the West. The Sultan Dağları are composed essentially of strongly tectonised Lower Paleozoic formations (Brunn et al. 1971). In some parts of the Anti-Taurus lava sheets have covered the sedimentary ridges. Where limestone and dolomites prevail, extensive territories are subjected to karstic processes (Güldalı 1979), providing particular sites for plant life (e.g. dolines). Further details on the geology and landscapes are given below, when introducing the different mountain ranges (see Sects. 7.4 and 7.6).

7.3 Climate

A minimum of four major climate types occur in Anatolia (Mayer and Aksoy 1986; Kürschner et al. 1997; Avcı and Avcı 2014b): Oceanic Black Sea climate (Euxine beech-fir climate), Mediterranean climate (Mediterranean sclerophyllous wood climate), Inner Anatolian climate (continental steppe climate) and an extremely continental East Anatolian climate (continental high-mountain steppe and steppe forest climate).

Typical of the humid, warm-temperate Black Sea climate are high precipitation rates throughout the year, the absence of a dry season, mild winters (mean monthly minimum of the coldest month not below 0 °C, absolute minima not below −10 °C) and not too hot summers. The partly very high precipitation rates (>2000 mm/a) results from relief rainfall of increasingly water-saturated air masses coming across the Black Sea (Kürschner et al. 1997).

The Mediterranean climate zone extends in various subtypes along the Anatolian West and South coast. The climate is marked by relatively high precipitation rates in winter and spring (600–1000 mm/a, in the highest altitudes of the Taurus Mts. locally >2000 mm/a), mild winters (temperature minima not below −10 °C) and very hot summers. A pronounced summer drought furthers the occurrence of sclerophyllous woodland (Kürschner et al. 1997).

Inner Anatolia features a distinctly continental temperature regime with very cold winters (mean monthly minima of the coldest months below 0 °C, absolute minima below −25 °C), hot summers and relatively low precipitation rates

(300–500 mm/a). Rainfall is mainly in winter and especially in spring and is only in higher elevations sufficient to allow tree growth. Summer drought lasts from early June to mid-October (Kürschner et al. 1997; Avcı and Avcı 2014a).

Extremely rough and very cold winters (with temperature minima to −40 °C) with a thick snow cover, rainy springs (annual precipitation 400–600 mm/a) and hot, dry summers characterize the continental East Anatolian climate. Temperatures below 0 °C can occur in 9–11 months of the year and at 4 months even the mean minimal temperature is below 0 °C. Due to the high altitudes the continental character is intensified by high irradiation and considerable differences in day/night temperatures (Kürschner et al. 1997).

Situated in a transitional zone between more humid climates and the Inner Anatolian steppe climate, the Black Sea Mts. and the Taurus Mts. range are both influenced by adjacent climatic types. Especially in respect to precipitation, their main ridges form a strong barrier (Luvs-lee effect) between the sea-facing and the steppe-facing slopes of the mountain chains. The coastal slopes of both mountain systems are characterized by at least a distinct or a permanent perhumid period (winter rains in the Taurus), few frosts and warm summers. Most of the southern incline of the Black Sea Mts. and the northern incline of the Taurus Mts. are influenced by the climate of the arid, summer-hot (summer depression) and winter-cold and snowy steppe region. In summer, air temperature in the alpine belt can drop down from +30 °C in the early afternoon to well below zero at night. The alpine and subnival landscape bears the stamp of that resulting in an intensive thermic weathering, expressed in enormous talus slopes of scree and a rugged and steep mountain profile (Parolly 1998).

In phytoclimatical respects, the Inner Anatolian steppe climates and parts of the East Anatolian climates are included into a very broadly defined Mediterranean climate (Akman and Ketenoğlu 1986; Kurt 2014), accepting only Mediterranean ranges (e.g. the climatic diagram of Muğla, Fig. 7.3a; note that the positions of the meteorological stations are indicated in Fig. 7.1), a oceanic zone along the Black Sea (e.g. Rize, Fig. 7.3b) and continental areas north of Ankara and in northern East Anatolia (e.g. Kars, Fig. 7.3c). Somewhat simplifying, the high altitudes of the Black Sea Mts. and the Taurus Mts. share in bioclimatic respects cold to very cold variants of a subhumid (to rarely humid) Mediterranean climate (Kürschner 1984; Akman and Ketenoğlu 1986). In East Anatolia extremely cold to glacial variants of semi-arid Mediterranean climates prevail with the exception of the continental range around Erzurum, Kars, Adahan, Posof and Sarikamiş (Akman and Ketenoğlu 1986; Kurt 2014). García-Lopez (2001) characterizes the climate of the high altitudes of the coastal Taurus as Boreo-mediterranean (*Cedrus-Abies* climax belt) or as Boreo-steppic to Arctiocoid/alpinoid (alpine-subnival elevations).

7.4 Flora and Phytogeography

7.4.1 General Phytogeographical Setting and Main Subdivision of the Turkish Mountain Ranges

Turkey is the meeting-place of the Euro-Siberian, the Mediterranean and the Irano-Turanian Region (Davis 1965, 1971; Takhtajan 1986). The extension of the mountain ranges shapes distribution of the phytogeographical regions (Fig. 7.2). The phytogeographical subdivision of Anatolia in view of its mountain flora and vegetation is shown in Fig. 7.4.

The Euro-Siberian territory covers most of North Anatolia, following the Black Sea Mts. from east to west to the mid-mountain range of the Istanca Dağları in Turkey-in-Europe. Mesophytic deciduous forest prevails in lower and mid-mountain elevations under mostly humid conditions, especially in the east, with considerable proportions of evergreen species added. The southern macroslope of the Black Sea Mts. borders on the Irano-Turanian steppe ranges; hence, the influence of the latter element can be locally prominent especially on south-exposed slopes. Small Mediterranean exclaves, mostly sclerophyllous scrub or pine forest, are a feature of the lowland coastal face of the Black Sea Mts. Exclaves of Euxine flora and vegetation occur in western and southern Anatolia (e.g. Kaz Dağı, Amanos range).

The Mediterranean parts are confined to the areas of western and southern Anatolia adjacent to the Mediterranean Sea. At many places, the dense evergreen forest has been degraded to sclerophyllous scrub vegetation or pine forest. In western Anatolia, where the Inner Anatolian plateau falls gently to sea-level and terminates in a series of promontories facing some of the East Aegean Islands, the Mediterranean flora and vegetation covers a fairly wide zone and reaches (100–)200–300(−350) km inland to merge gradually into the Irano-Turanian steppe vegetation of Inner Anatolia. The western Anatolian mountain ranges are low, fairly isolated and marked by a diverse orogeny and geology. In southern Anatolia (including south-western Anatolia) the steep slopes of the Taurus chain confine larger coastal plains to areas around Antalya and Adana and Mediterranean vegetation proper to its lower parts. The main ridge of the Taurus Mts. separates an oro-Mediterranean flora on the humid southern incline and along the river valleys from the semi-arid northern macroslope with a flora displaying an increasing number of Irano-Turanian elements along the lower slopes. It is mainly the mountain flora of the different mountain groups which allows dividing the Mediterranean parts into several sectors, because the lower parts along the coast line show a rather uniform appearance in terms of their flora and vegetation.

The Irano-Turanian Region is the largest in Turkey and mainly confined to Inner and Eastern Anatolia. The flora is particularly rich and composes vegetation types, in which dwarf-shrubland with substantial proportions of hemicryptophytes and annual species prevail. A great number of species-rich genera with a complex evolution are important edificators of these units, including *Acantholimon*, *Astragalus*, *Artemisia*, *Bromopsis*, *Limonium*, *Gypsophila*, *Quercus* and *Stipa* (Zohary 1973;

Ekim and Güner 2000). For a concise survey on the steppe flora and vegetation, see Kürschner and Parolly (2012). The Irano-Turanian territories stretch along the northern incline of the Taurus range and along the southern incline of the Black Sea Mts., respectively, to find their upper altitudinal limitation with increasing precipitation, while the Inner Anatolian volcanoes and the high-mountains of the east rise over Irano-Turanian steppes.

7.4.2 Turkey Forms Part of Two Mountain Systems

The floristic links between the Mediterranean and Irano-Turanian territories are much closer than between the flora of either of these regions and the Euro-Siberian Region (Davis 1971; Ekim and Güner 2000). Especially in the eastern parts of the Black Sea Mts. the high-mountain flora is strongly connected with that of the Caucasus and shows – with the notable exception of the driest places that support small exclaves of Irano-Turanian steppe-like vegetation – little resemblance and floristic links with most of Turkey. It appears thus appropriate to group all mountain ranges into two mountain systems, one comprising the vast majority of the high-mountains in West, South, South-east and East Anatolia, and one the high-mountains along the coast of the Black Sea.

7.4.2.1 The Tauric System

In earlier papers (Parolly 2004, 2015) the concept of the 'Tauric System' was introduced to geobotanically characterize the flora and vegetation of all mountain territories between mainland Greece and western Iran, with the Taurus Mts. in their core. Down to province-level, the subdivision of the Tauric System (Fig. 7.2) accords largely with the phytogeographical concepts of Meusel et al. (1965) and Takhtajan (1986). By incorporating additional distribution data from plants and vegetation units of the mountain ranges, a finer chorological classification (Parolly 2004) could be established (Fig. 7.4).

The Tauric System represents the south-eastern continuation of the Alpic System (Ozenda 1988) and corresponds in its extension to the tectonic units of the Hellenides, Taurides and small fractions of the Iranides. Within its range, the mountain ecosystems enjoy a relatively similar macro-climate expressed by a similar zonation (semi-arid zonation; Mediterranean type high-mountain zonation and climate) and they support common major syntaxa (mainly at ordinal-level to class-level) composed by species derived from a common Old Mediterranean (Mesogean) floristic stock. Overall, the different parts of the Tauric System share a similar floro-genetic and geological past. In floro-genetic respects, it is the westernmost mountain system that belongs to the Mesogean Sub-realm in the sense of Quézel (1973), Takhtajan (1986) and Zohary (1973).

A prime characteristic of the Tauric System are the coniferous forests of the montane belt complex (Fig. 7.5b, i), which are consistently composed of *Pinus brutia*, *P. nigra* subsp. *nigra* var. *caramanica*, *Juniperus excelsa* and further juniper species, *Cupressus sempervirens*, *Cedrus libani* s.l. and Mediterranean firs (with *Abies cilicica* and *A. cephalonica* as the most important species; Parolly 2004). Another significant feature is the structurally and phytosociologically consistent character of the tree-less high-mountain vegetation by displaying, xerophytic grasslands and other steppe-like vegetation dominated by thorn-cushions and dwarf-shrubs. This thorn-cushion vegetation of the wider subalpine belt is particular of the mountains of the Tauric System (and of the mountain ranges east of it). Within the Tauric System, xerophytic high-mountain grasslands and dwarf-shrub and thorn-cushion vegetation (Daphno-Festucetales super-class) make up the zonal vegetation of the land above the trees (Parolly 2004). In the core part of the Tauric System, including the wider Taurus range, Cyprus and the Lebanon Mts., this vegetation on alkaline, ultramafic or schistose soils is grouped into a single order (Astragalo-Brometalia) whose distribution perfectly matches the range of the *Cedrus-Abies* forests (Querco-Cedretalia libani).

A particular feature of the Tauric System is that it includes mountain ranges, which stretch along the boundaries of two major phytochoria, mostly Mediterranean and Irano-Turanian territories. The flora and vegetation thus harbours and integrates elements of the neighbouring regions. This transitional biogeographical position contributes much to the plant diversity and the high speciation potential of the range (Davis 1971; Parolly 2004; Parolly et al. 2010). The phytodiversity within the Tauric System is amazingly high with more than 6000 taxa in Turkey alone and estimated 7000–7500 taxa in all of the Tauric System.

7.4.2.2 The Caucasic System

The mountain ranges of the Greater and Lesser Caucasus, its western range extension along the Black Sea towards coastal Bulgaria, as well as the Talysh Mts. at the south-western edge of the Caspian Sea, form a huge eco-geographical unit, for which I introduce here the term ‘Caucasic System’. Its features are briefly outlined in the following and based on the criteria used for defining the Alpic System (Ozenda 1988) and the Tauric System (see above).

The Caucasic System is the eastern continuation of the Alpic System, on a tectonic setting that corresponds to the Pontides and the southern margin of the Eurasian plate. The mountain ecosystems of the Caucasic System enjoy a relatively similar oceanic macro-climate revealed by a similar zonation of the vegetation (humid Pontic zonation sensu Kürschner 1982, 1984; Mayer and Aksoy 1986). They develop common major vegetation types (classified in high-ranked syntaxa of Eurasian or Euro-Siberian character), which are dominated by species derived from the Euro-Siberian or sometimes the relictual Arcto-Tertiary floristic stock. Many of these typical syntaxa do not occur in the mountains of the Tauric System or occur in fragmentary stands confined to Euxine outposts only. Many of these ecosystems are

Fig. 7.5 Typical landscapes, habitats and selected plants of the Taurus range and western Anatolia. (**a**) Lycian Taurus, open thorn-cushion vegetation (Akdağlar with Yeşil Göl, in the background Yumru Dağı, 2200 m a.s.l.); (**b**) *Abies cilicica* subsp. *cilicica* forest in the eastern Central Taurus (Emli Vadisi, Aladağlar, 1800 m a.s.l.); (**c**) *Vavilovia formosa* (Aktepe, Beydağları); (**d**) *Noccaea oppositifolia* (Medetsiz, Bolkar Dağları); (**e**) *Pelargonium endlicherianum* (Maden Deresı, Bolkar Dağları); (**f**) *Hypericum kazdaghense* (Kaz Dağı); (**g**) Hasan Dağı; (**h**) open dwarf-shrub vegetation and doline with snow-bed turf (Yumru Dağı, 2300 m a.s.l.); (**i**) coniferous forest with *Pinus nigra* var. *caramanica* and ultramafic summit (Çiçek Baba Tepesi, Sandras Dağı, 1700–2294 m a.s.l.); (**j**) *Omphalodes luciliae* subsp. *luciliae* on vertical rock (Davras Dağı); (**k**) *Papaver pilosum* subsp. *pilosum* (Sultan Dağları); (**l**) thorn-cushion vegetation dominated by *Onobrychis cornuta* (Bakırlı Dağı, Beydağları, 2350 m a.s.l.)

enriched substantially by Mesogean elements (more Mediterranean infiltrations in the western half of Anatolia, increasing numbers of Irano-Turanian taxa towards the east) from the adjacent floristic realms (Fig. 7.2).

Other key characteristics of the Caucasic System include: a fairly uniformly composed alpine belt with a largely Euxine, Euro-Siberian and Eurasian flora and many floristic links to the 'northern' mountain areas between the Alps and the Himalayas (Kadereit et al. 2008); the lack of a distinct subalpine thorn-cushion belt (although there are patchy stands of thorn-cushion vegetation in dry valleys at the steppe side of the mountains) and a comparatively homogeneous montane vegetation with extensive beech forests (*Fagus orientalis*) and associated *Abies nordmanniana* s.l. and *Picea orientalis* (Quézel 1986; Rhododendro-Fagetalia orientalis; Fig. 7.6g). At drier places and often also forming pure stands, *Pinus sylvestris* var. *hamata* (incl. *P. kochiana* and *P. sosnowskyi*) mixes in. These forests mark the core part of the Caucasic System.

Another peculiarity of the Caucasic System is the (geographically structured) heterogeneity of the subalpine belt, comprising a tree-line of *Fagus orientalis* (mainly in the west) or of 'krummholz' composed by *Betula* spp., *Sorbus aucuparia* agg. and *Salix caprea* (in the more continental parts). Such vegetation is normally intertwined with outposts of montane forest, tall forb vegetation and/or ericaceous scrub (Fig. 7.6h). The latter vegetation can dominate vast ranges of the subalpine belt. Xerophytic dwarf-shrub vegetation of Mesogean origin contributes only in the Mediterranean-influenced western part to the zonal vegetation of the subalpine and alpine belt of the Black Sea Mts. (Akman et al. 1983; Parolly 2004).

The phytodiversity within the Caucasic System may include up to 4000 taxa in Turkey and 5500 taxa in all of the system (excluding all typical Irano-Turanian taxa; estimations based on Davis 1965–1985). As with the Tauric System, the Caucasic System includes mountain ranges, which stretch along the boundaries of two major phytochoria, here Euro-Siberian (Euxine) vs. Irano-Turanian (Inner Anatolian) territories. For a subdivision of the Caucasic System, see Sect. 7.4.3.3 and Fig. 7.4.

7.4.3 The Anatolian Black Sea Mountains and Their Outliers

7.4.3.1 Phytogeographical Nature of the Mountain Range

The Black Sea mountain range in Turkey is the western extension of the Caucasic System. In the west, it tapers into the Istanca Dağları in Turkey-in-Europe, while it merges into the Caucasus proper in the east. It includes all mountains lining the Black Sea coast in one or two chains. In the western half, the mountains only exceptionally reach alpine elevations and are often isolated massifs; in the east, massive and continuous mountain fronts prevail, which culminate in the Doğu Karadeniz Dağları near the Georgian border.

Phytogeographically, all of the territory belongs to the Euxine Province of the Euro-Siberian Region (Davis 1971; Takhtajan 1986). By focussing on the climax

Fig. 7.6 Typical landscapes, habitats and selected plants of East Anatolia and the Black Sea range. (**a**) extensive lava sheet from a recent eruption in the East Anatolian highlands (Tendürük Dağı); (**b**) *Veronica gentianoides* (Ilgaz Dağları); (**c**) *Fritillaria kurdica* (İspiriz Dağları); (**d**) *Lathyrus roseus* (Kaçkar Dağları); (**e**) *Campanula aucheri* (Ovit Dağı, eastern Black Sea Mts.); (**f**) fringe of forb vegetation along a creek and hay meadows (Kaçkar Dağları above Olgunlar, ca. 2300 m a.s.l.); (**g**) montane pasture, *Abies nordmanniana–Picea orientalis* forest in the background and *Rhododendron luteum* in the front (Camili area, Black Sea Mts.); (**h**) *Rhodendron caucasicum* scrub, *Betula litwinowii* and *Salix caprea* (Kaçkar Dağları); (**i**) *Aconitum nasutum* (near Artvin)

vegetation alone, the Euxine area could be seen as part of the Euxine-Caucasian-Hyrcanian temperate forest province (e.g. Kürschner et al. 2012). There is a gradual, but noticeable shift of floristic elements along the axis of the Black Sea Mts. The floristic affinities to the Caucasus proper are best developed in the eastern part (see also below). In return, there are notable infiltrations of the East Mediterranean flora especially in the west, while the influence of the Irano-Turanian floras is visible all along the southern macroslope of the Black Sea Mts. The Anatolian Diagonal separates the latter into a Central Anatolian (Irano-Anatolian sensu Zohary 1973) part west of it and an Armeno-Iranian (Irano-Armenian sensu Zohary 1973) part in the east. Most of the Euxine province below the tree-line is covered with forest or by scrub where the forest has been destroyed. The lower slopes are mainly occupied by woody deciduous tree species, often associated with evergreen shrubs such as *Buxus sempervirens*, *Ilex colchica* and *Rhododendron ponticum*, but in the higher parts conifers increase or even predominate. The forest ecosystems are marked by *Fagus orientalis* and *Abies nordmanniana* s.l. (and in the east) by *Picea orientalis* (Louis 1939; Davis 1971; Quézel 1986). In contrast with the Taurus range, moist mountain forests are often found in high valley bottoms or on sheltered slopes.

The Black Sea Mts. are floristically well known for its glacial refugia, supporting a great diversity of relict species, mainly of the Arcto-Tertiary floristic stock whose flora once covered a large part of temperate Eurasia. Most of these species are centred in the eastern part of the range and in lower altitudes. Examples and floristic links are given below. A few exclaves of the Black Sea flora and vegetation, scattered on the higher mountains of north-western Anatolia (Fig. 7.4: 2) in an otherwise Mediterranean surrounding, are addressed here in this chapter.

7.4.3.2 Important Floristic Components and Floristic Affinities

An analysis of the taxonomic inventory of the high-mountain flora (including the upper forest belt) quickly reveals its overall similarity with other Euro-Siberian (‘northern’) mountain areas such as the Alps and the mountains of the inner Balkan Peninsula. Examples of significant genera and sections, given in systematic order, may underpin this: *Fritillaria*, *Gagea, Colchicum* (Liliales); *Allium*; *Galanthus*; *Scilla* s.l.; *Crocus*, *Iris*; *Dactylorhiza* (Asparagales); *Alopecurus*, *Carex*, *Festuca*, *Koeleria, Phleum*, *Sesleria* (Poales); *Papaver*, *Corydalis*; *Aconitum*; *Anemone*, *Anemonastrum*, *Delphinium, Pulsatilla*, *Ranunculus* (Ranunculales); *Paeonia*, *Ribes*; *Saxifraga*; *Hylotelephium*, *Phedimus*, *Prometheum*, *Rosularia*, *Sedum*, *Sempervivum* (Saxifragales); *Astragalus* sect. *Erophaca*, sect. *Hypoglottis*, etc., *Coronilla, Lathyrus, Oxytropis*, *Trifolium*, *Vicia*; *Polygala* (Fabales); *Achillea, Potentilla* s.l.; *Oreoherzogia* (Rosales); *Betula* (Fagales); *Euphorbia*; *Salix*; *Viola*; *Linum*; *Hypericum* (Malpighiales); *Geranium* (Geraniales); *Epilobium* (Myrtales); *Daphne*; *Helianthemum* (Malvales); *Arabis*, *Cardamine*, *Draba*, *Erysimum*, *Hesperis*, *Noccaea* s.l., *Odontarrhena* (Brassicaceae); *Bistorta*; *Atocion*; *Cerastium*, *Dianthus*, *Eremogone*, *Gypsophila*, *Pseudocherleria*, *Sabulina*, *Silene* (Caryophyllales); *Androsace*, *Primula*; *Bruckenthalia*, *Epigaea*, *Rhododendron*, *Vaccinium* (Ericales); *Asperula*, *Galium* (Rubiaceae); *Gentiana*, *Gentianopsis*, *Swertia* (Gentianaceae); *Onosma*, *Myosotis* (Boraginaceae); *Linaria*, *Plantago*, *Veronica* (Plantaginaceae); *Scrophularia*, *Verbascum* (Scrophulariaceae); *Betonica, Dracocephalum, Lamium, Nepeta, Scutellaria, Stachys, Teucrium, Thymus* (Lamiaceae); *Pedicularis*, *Rhynchocorys* (Orobanchaceae); *Asyneuma*, *Campanula* sect. *Latilimbus*, sect. *Scapiflorae*, sect. *Sibiricae* and sect. *Symphyandriformes*, *Gadellia* (Campanulaceae); *Achillea*, *Centaurea*, *Cirsium*, *Cota*, *Crepis, Cyanus*, *Helichrysum, Hieracium*, *Jurinea*, *Lactuca* s.l., *Podospermum*, *Psephellus*, *Scorzonera*, *Senecio* s.l., *Tanacetum* s.l., *Taraxacum* (Asteraceae); *Astrantia*, *Eryngium*, *Heracleum, Ferulago*, *Pastinaca*, *Pimpinella* s.l., *Seseli* (Apiaceae); *Cephalaria, Lomelosia*, *Scabiosa* and *Valeriana* (*Caprifoliaceae*).

Euro-Siberian–Balkan affinities are expressed for example by the monotypic spike heath *Bruckenthalia spiculifolia*, which grows scattered in acidophytic mountain scrub of the eastern Carpathians, the Dinarids, northern Greece and the Black Sea Mts. (Stevens 1978). There is a molecular study which supports links to the mountains of South-western Europe and the Balkan Peninsula in *Lilium* sect. *Liriotypus.* The North Anatolian *L. ciliatum* and *L. akkusianum* were found sister to the European species of the *L. carniolicum* group. They together form a lineage sister to the North Anatolian-Caucasian *L. monadelphum* group and to *L. ponticum* (İkinci et al. 2006).

Glimpses on the distribution patterns of Arcto-Tertiary species reveal further interesting floristic links. Nearly 70 different pteridophytes occur under the suitable humid conditions of the eastern Black Sea range alone, and 28 are apparently found nowhere else in Turkey. Some of these, including *Dryopteris aemula* and *Hymenophyllum tunbrigense*, are Atlantic species which survived in the Colchic refuge (extending to Georgia) far abroad from their main centre of distribution (Mill 1994d). *Hypericum bupleuroides* is said to have its nearest allies in East Asia (Davis 1971). *Epigaea gaultheroides* is endemic to Adjara and North-east Anatolia (Manvelidze et al. 2009; Fischer et al. 2018). The two other species in the genus grow in the Sino-Japanese Region and eastern North America – a Tertiary relict distribution (Davis 1971). *Rhodothamnus* is a bitypic genus, with *R. chamaecistus* in the eastern Alps and *R. sessilifolius* localized in the eastern part of the Black Sea Mts. (Davis 1971).

There are also old connections within the Mesogean floristic stock, especially in the Irano-Turanian element; e.g. *Cynoglossum imeretinum* has its nearest relatives in Afghanistan and the Himalaya (Mill 1994d).

Regional affinities are shown by the occurrence of Caucasian elements such as *Gadellia* (*G. lactiflora*) and *Kemulariella* (occurring in North-east Anatolia with *K. caucasica*), both endemic to wider Caucasia (Davis 1965–1985). By contrast, *Paederotella* (with 1–3 species and *P. pontica* [= *Veronica ruprechtii*] in North-east Anatolia), mostly accepted in Caucasian and Turkish floras, showed a position within *Veronica* subgen. *Stenocarpon* in a molecular analyses of both nuclear ribosomal and plastid DNA (Albach et al. 2004a, b; Albach 2006) and by this its wide Eurasian affinities. However, its next relatives remain unknown. *Kartalinia acaulis* (*Psoralea acaulis*; earlier placed in the monotypic subgenus *P.* subgen. *Christevenia*) holds an isolated position in the tribe *Psoraleeae* and represents a monotypic and isolated genus with a narrow distribution in the eastern Black Sea Mts. and Georgia (Brullo et al. 2018; Fischer et al. 2018).

7.4.3.3 Phytogeographic Subdivision and Peculiarities of the Different Sections (Fig. 7.4: 1)

The Black Sea Mts. are biogeographically divided into three sections (which can also be taken as formal chorononic sectors), with little dispute about their delimitation: The western section reaches from the promontories west of Bolu to the Murat river valley near Samsun. The central section extends between the mountains around Amasya (e.g. Amasya Akdağı) south-east of Samsun and the Melet river near Ordu, while the eastern section comprises the mountains east of it, i.e. the area between the Giresun Dağları and the Georgian border. This subdivision is largely based on the intensively studied forest vegetation (Quézel et al. 1980; Quézel 1986; Akman 1995) and perfectly congruent with the three parts of the Karadeniz Bölgesi (Black Sea region) of the Turkish ecoregion classification (Güner et al. 2012; Ekim and Güner 2014), distinguishing a Batı Karadeniz Bölümü (Western Black Sea Section) from an Orta Karadeniz Bölümü (Central Black Sea Section) and a Doğu Karadeniz Bölümü (Eastern Black Sea Section). The deepest phytogeographic divide is between the eastern and central part, which is also reflected by the formal recognition of the eastern part as Colchic Sector, while the two more western parts could be named central and western Euxine Sector.

Western and Central Euxine Sector (Fig. 7.4: 1a–b) Here, the Black Sea Mts. are often only mid-range mountains (as the Abant Dağları, 1784 m a.s.l.), and only a few mountains have a natural tree-line, including the Köroğlu Dağları (Köroğlu Tepe, 2399 m a.s.l.) and Ilgaz Dağları (2587 m a.s.l.). Another mountain range with at least secondary areas of high-mountain steppe lies in the Küre Dağları (Isfendiyar Dağları, 2019 m a.s.l.). The northern incline is under the influence of an oceanic climate and – as long as the vegetation is not degraded – densely forested. The high-mountain flora comprises a mixture of mesophytic Euxine species and elements of xerophytic dwarf-shrub vegetation at drier places, which also occurs in western Anatolia and which develops under a semi-arid and less rainy cold type of the Mediterranean climate (Akman et al. 1983). Typical high-mountain species are *Androsace villosa*, *Anthyllis vulneraria* subsp. *variegata*, *Aster alpinus*, *Astragalus microcephalus*, *Bromopsis tomentella*, *Hypericum linarioides*, *Jasione supina* subsp. *pontica*, *Juniperus communis*, *Pedicularis comosa* subsp. *sibthorpii*, *Potentilla crantzii*, *Thymus praecox* subsp. *skorpilii* and *Veronica gentianoides* (Akman et al. 1983).

The present knowledge about high-mountain plants does not allow distinguishing between a western and central Euxine section. Overall, the phytodiversity of the area is relatively low; nevertheless these massifs still harbour between 70 and 80 endemics (Özhatay et al. 2005). There are a number of endemics which single out particular massifs or outline the whole mountain range (as e.g. *Dactylorhiza* *nieschalkiorum*). Examples (Eken et al. 2006) of more localized taxa include *Crocus abantensis*, *Ornithogalum pascheanum* (in the mountain meadows of Abant Dağları), *Astragalus kastamonuensis*, *Delphinium ilgazicum* (also on İlgaz Dağları), *Erodium birandianum*, *Prangos denticulata* (Küre Dağları), *Arum elongatum* subsp. *alpinariae*, *Cirsium boluense, Jasione supina* subsp. *akmanii* (Köroğlu Dağları), *Asyneuma ilgazensis*, *Astragalus panduratus* and *Dactylorhiza ilgazica* (Ilgaz Dağları). None of them is confined to areas above the tree-line.

Colchic Sector (Fig. 7.4: 1c) The range between the Giresun Dağları (3107 m a.s.l.) and Doğu Karadeniz Dağları has many peaks above 3000 m a.s.l. and reaches its highest point at Kaçkar Dağı (3932 m a.s.l.). The eastern part of this range with its impressive high-mountain scenery is sometimes called the 'Pontic Alps' in old literature. Vural (1996) applies the name Rize Dağları for this mountain complex, comprising the mountains between the coastal towns of Of and Findikli. Other important mountain ranges of the Colchic Sector (Fig. 7.1) include the Gümüşhane Dağları (3286 m a.s.l.) and somewhat further inland the Çimen Dağları (2710 m a.s.l.), the mountains around the dry Çoruh Vadisi (2500 m a.s.l.), the Yalnızçam Dağları (3050 m a.s.l.) south-east of Artvin and the Karçak Dağları (Artvin, 3428 m a.s.l.). These eastern mountain ranges more or less form the boundary between North-east Anatolia and the East Anatolian high plateau.

Most of the rock is igneous, but many of the jagged peaks are granite and there are outcrops of granodiorite. Signs of the past glaciations are obvious everywhere, with cirques, more than 100 high-alpine lakes and a few extant small glaciers. The mountains fall steeply to both sides. To the north many torrents and streams flow in deep south-north gorges; to the south the Çoruh, the region's major river, drains the territory parallel to the main chain, occupying a fault line (Mill 1994d). The river cuts deeply through the mountains near Artvin before emptying its waters into the Black Sea south-west of Batumi in Georgia.

Overall, and especially in the forest zone, there is much affinity with the flora and vegetation of the Hyrcanian range (Zohary 1973; Mill 1994d; Kürschner et al. 2012). The flora of the Colchic Sector is rich and contains a total of 3210 native or naturalized vascular plant taxa, of which 465 are endemic to Turkey and more than 160 are only known from North-east Anatolia (Mill 1994d; Güner et al. 2012; Terzioğlu et al. 2015). Centres of endemism include the Cimil region, the Çoruh valley and the mountains around Artvin (Mill 1994d; Eminağaoğlu and Kutbay 2006; Eminağaoğlu et al. 2007; Manvelidze et al. 2009). Taxa endemic to the Colchic Sector include e. g. numerous species of *Alchemilla* and *Hieracium*, several of *Centaurea* and *Lilium* sect. *Liriotypus*, *Crocus aerius*, *Lamium tschorochense*, *Papaver lateritium*, *Ranunculus tempskyanus* (Mill 1994d; Güner et al. 2012) and all species of the monophyletic *Campanula* sect. *Symphyandriformes* (*C. betulifolia*, *C. choruhensis*, *C. seraglio*, *C. troegerae*; Mansion et al. 2012). The flora of Georgia beyond the Turkish border (Autonomous Republic of Adjara) continues to be rich in endemics. Depending on source and species concepts, 130–180 endemic species are known to occur in this transboundary area, including at least 48 narrow endemics such as *Epigaea gaultherioides*, *Kartalinia acaulis* and *Scutellaria pontica* (Mill 1994d; for more examples, see Manvelidze et al. 2009).

There is a progressive decrease in Colchic species that are concentrated in the north-east and in the western Caucasus. This decrease becomes more sudden west of the Melet River (Davis 1971; Mill 1994d) and includes e.g. *Acer cappadocicum*, *Alnus glutinosa* subsp. *barbata*, *Betula medwediewii*, *Daphne glomerata*, *Diospyros lotus, Oreoherzogia imeretina*, *Osmanthus decorus*, *Picea orientalis, Quercus pontica*, *Rhododendron caucasicum*, *R. smirnowii*, *R. ungernii* and *Sorbus subfusca* among the woody and *Chamaesciadium acaule, Draba hispida, Geranium psilostemon, Hypericum bupleuroides, Lathyrus roseus, Lilium ponticum, Pachyphragma macrophyllum*, *Papaver lateritium* and *Primula megasaeifolia* among the herbaceous taxa (Ekim and Güner 2000; Terzioğlu et al. 2015). Many of these species are associated to the Arcto-Tertiary element (see below, e.g. Sects. 7.6.1 and 7.6.3.2). *Abies nordmanniana* s. str. predominates at many places in the mountain forests. The flora and vegetation above the tree-line is typical Caucasian in character, while the Irano-Turanian exclaves are of the Armeno-Iranian/East Anatolian/Caucasian type (see Sects. 7.4.5.2 and 7.4.5.3).

West Anatolian Exclaves (Fig. 7.4: 2) Mountains such as Kaz Dağı (1796 m a.s.l.; Fig. 7.4: 2a), Murat Dağı (2309 m a.s.l.; Fig. 7.4: 2c) and Uludağ (2543 m a.s.l.; Fig. 7.4: 2b) show a transitional character between the Caucasic and Tauric Systems by combining a Caucasus-type (European type sensu Quézel 1986) forest flora and vegetation, often dominated by Oriental beech and the western subspecies of Caucasian fir (*Abies nordmanniana* subsp. *equi-trojani*), with a Taurus-type high-mountain flora and vegetation (Parolly 2004). Their classification is arbitrary. They rise over Mediterranean landscapes belonging phytogeographically to the West Anatolian Province of the East Mediterranean Subregion (e.g. Parolly 2004). There are numerous floristics links towards Greece and the Balkans (e.g. Hein et al. 1998) and the asylvatic mountain flora is rich in local endemics which are vicariously linked to plant species from the wider Taurus range.

This holds especially true for Murat Dağı (Fig. 7.4: 2c), which is made up by metamorphic rock, including grandodiorite, marble and ultramafic complexes of regional greenschists; it lies at the north-eastern periphery of the Menderes Massif (Güldalı 1979). It combines features of the mountains of North-west Anatolia and the Lydian Sector of the Taurus. Strong links to the Taurus Mts. (e.g. *Ranunculus heterorhizus*) predominate and its endemics (*Allium huber-morathii*, *Astragalus gaeobotrys*, *Odontarrhena davisiana*, *Prometheum muratdaghense*, *Verbascum coronopifolium*) are allied to the species of the Taurus Mts. A proportion of the West Anatolian high-mountain element is shared with Kaz Dağı and Bozdağ (*"(Centaurea aphrodisea*, *Dianthus erinaceus*), while species such as *Centaurea olympica*, *Crenosciadium siifolium* and *Noccaea jaubertii* also grow on Uludağ and/or the northwest Anatolian Black Sea Mts. (Davis 1965–1985). A total of 116 endemic taxa have been recorded from Murat Dağı (Özhatay et al. 2005). For species lists from Kaz Dağı and Uludağ, see below (Sect. 7.6.1.5) and Efe et al. (2015) and Güleryüz (2000).

7.4.4 The Taurus Mountains and Their Outliers

7.4.4.1 Phytogeographical Nature of the Mountain Range

The Taurus Mts. (Turkish: Toroslar) represent the westernmost South-west Asian type of a high-mountain range with a semi-arid vegetation zonation. The Taurus Mts. and their outliers comprise all mountains along Anatolia's Mediterranean west and south coast (Western and Central Taurus) and their extension to the east (Eastern Taurus), as well as the mountains of the Anatolian Diagonal. From the very east, where the Taurus merges into the Zagros range, the available data on the flora and the vegetation are too poor to allow a subdivision or even the clear delimitation of the Taurus range (and the Tauric System) against the adjacent areas in phytogeographical respects. By contrast, the high-mountain flora and vegetation of the Inner Anatolian volcanoes is so similar to those of the Central Taurus that this area is treated here as an outlier of the Taurus Mts. rather than as a category of its own (as would be appropriate in geological, topographical and orographical respects).

Chorological studies on the mountain flora and vegetation (e.g. Kürschner 1982, 1984; Parolly 1995; Hein et al. 1998; Eren et al. 2004) reflect the phytogeographical position of the western half of the Taurus range at the intersection of two phytochoria, viz. the Mediterranean and Irano-Turanian regions, chiefly represented by East Mediterranean and Irano-Turanian elements. These chorotypes, partly as bi-regionals (East Mediterranean–Central Anatolian), predominate both in the flora and in most of the vegetation units, i.e. in all Mesogean units (Quézel 1973; Kürschner 1982; Hein et al. 1998) of the Taurus. Many endemics – the most diverse centres of endemism in Turkey are located in the Taurus range (Davis 1971; Ekim and Güner 1986, 2000; Ekim et al. 2000; Parolly 2004; Eren et al. 2004; Özhatay et al. 2005) – are of Mesogean origin, too.

In the coastal western half of the Taurus proper (Western and Central Taurus, Amanos Mts.), East Mediterranean chorotypes prevail. This influence becomes even more prominent, if one considers that the majority of the endemics are of East Mediterranean (montane) origin (cf. Davis 1965–1985; Davis et al. 1988; Güner et al. 2000). In the eastern half, along the Diagonal and on the Inner Anatolian volcanoes, Irano-Turanian elements gain dominance. Generally, the proportion of the Irano-Turanian element increases towards the east and with altitude (Quézel 1973; Kürschner 1982; Parolly 1995; Hein et al. 1998). In return, the Mediterranean influence sinks towards the east to reach in the Hakkâri-Taurus proportions of probably much less than 10% within the chorotype spectrum (Öztürk et al. 2015).

Although the majority of Irano-Turanian species is adapted to dry sites, it is interesting to note that not all are xerophytes. There is a remarkable number of mesophytic species with Irano-Turanian distribution or of Irano-Turanian origin growing at moist places (Kürschner et al. 1998; Parolly 2015). Typical examples include *Cirsium rhizocephalum*, *Inula acaulis*, *Primula auriculata*, *Taraxacum crepidiforme*, *Veronica biloba* and Gentianaceae such as *Gentianella holosteoides,* *Swertia longifolia* and members of the *Gentiana gelida*-clade (Davitashvili and Karrer 2006).

Chorotype spectra may provide some indications of ancient climates, migration routes and origin of different elements (Kürschner 1982). For historical reasons (migration along the Anatolian Diagonal during the Quaternary glaciations), a certain number of Euro-Siberian species (including Euxine taxa) are geographically concentrated in the eastern part of the Central Taurus (*Fagus orientalis* forest north of Karsantı, Pos forest; Kürschner 1982, 1984) and the Amanos Mts. (Fig. 7.2). Some taxa even penetrate further south to the Lebanon. They are edaphically restricted to more or less moist and often north-facing sites.

7.4.4.2 Important Floristic Components and Floristic Affinities

The western half of the Taurus Mts. is the area of *Abies isaurica*, *Cedrus libani* and (near streams) of *Alnus orientalis* (shared with western Anatolia and Cyprus and allied to the Hyrcanian *A. subcordata*) and displays the highest plant diversity of Turkey (Davis 1971). A rough guess of the species number of Taurus range may well exceed the 5000+ taxon line (based on a roughly calculated evaluation of the 'Flora of Turkey'; Davis 1965–1985; Davis et al. 1988; Güner et al. 2000).

The taxonomic inventory of the mountain flora (including the forest belt) of the Taurus is marked by an enormous number of often vicarious endemics concentrated in the speciose families Apiaceae, Asteraceae, Boraginaceae, Brassicaceae, Campanulaceae, Caryophyllaceae, Fabaceae, Lamiaceae, Ranunculaceae, Rubiaceae, Asparagaceae and Poaceae. Typical and species-rich genera and sections include (in systematic arrangement): *Fritillaria*, *Gagea*; *Colchicum* (Liliales); *Allium*; *Muscari* s.l., *Ornithogalum* s.l., *Scilla* s.l.; *Crocus, Iris* (Asparagales); *Alopecurus*, *Bromopsis, Carex* [at damp places], *Elymus, Elytrigia*, *Festuca, Koeleria, Sesleria, Stipa* (Poales); *Papaver*, *Corydalis*; *Delphinium, Ranunculus* (Ranunculales); *Saxifraga*; *Prometheum, Rosularia, Sedum* (Saxifragales); *Astragalus* sect. *Dasyphyllium*, sect. *Hololeuce*, sect. *Stereothrix*, etc., *Chamaecytisus*, *Ebenus*, *Genista*, *Lathyrus, Onobrychis*, *Vicia*; *Polygala* (Fabales); *Achillea*, *Potentilla* s.l.; *Rhamnus* s.l. (Rosales); *Euphorbia*; *Viola*; *Linum*; *Hypericum* (Malpighiales); *Erodium, Geranium* (Geraniales); *Daphne*; *Helianthemum* (Malvales); *Aethionema*, *Alyssum, Arabis*, *Aubrieta*, *Draba*, *Erysimum*, *Hesperis*, *Noccaea* s.l., *Odontarrhena, Ricotia* (Brassicaceae); *Thesium* (Santalaceae); *Acantholimon*; *Arenaria, Bolanthus* [only west of the Anatolian Diagonal], *Bufonia*, *Cerastium*, *Dianthus*, *Eremogone*, *Gypsophila*, *Minuartia*, *Minuartiella*, *Sabulina*, *Saponaria*, *Silene* sect. *Auriculatae*, sect. *Caespitosae*, sect. *Lasiostemones*, sect. *Pinifoliae* and *Sclerocalycinae* (Caryophyllales); *Androsace* (Ericales); *Asperula, Galium* (Rubiaceae); *Alkanna, Omphalodes, Onosma*, *Matthiastrum*, *Myosotis* (Boraginaceae); *Convolvulus*; *Globularia, Linaria, Plantago*, *Veronica* (Plantaginaceae); *Scrophularia*, *Verbascum* (Scrophulariaceae); *Ballota, Lamium, Marrubium, Micromeria, Nepeta, Origanum*, *Phlomis* sect. *Dendrophlomis*, *Salvia, Scutellaria, Sideritis* sect. *Empedoclea*, *Stachys, Teucrium,* *Thymus* (Lamiaceae); *Asyneuma*, *Campanula* sect. *Quinqueloculares* and *Tracheliopsis*; *Michauxia* (Campanulaceae); *Achillea*, *Anthemis*, *Centaurea*, *Cota*, *Crepis, Cyanus*, *Helichrysum, Hieracium*, *Iranecio*, *Jurinea*, *Lactuca* s.l., *Podospermum*, *Psephellus*, *Scorzonera*, *Tanacetum* (Asteraceae); *Dichoropetalum*, *Eryngium*, *Johrenia*, *Ferulago*, *Laserpitium* s.l., *Prangos* [Eastern Taurus], *Pimpinella* s.l., *Seseli* (Apiaceae); *Cephalaria, Lomelosia, Pterocephalus* and *Valeriana* (*Caprifoliaceae*).

Here follows a selection of important high-mountain plants of the Taurus (mostly species associated to thorn-cushion vegetation and grasslands): *Alyssum argyrophyllum, Anthemis cretica* s.l., *A. kotschyana*, *Asperula stricta, Asphodeline taurica*, *Astragalus angustifolius, A. condensatus*, *A. microcephalus*, *A. pinetorum*, *A. plumosus, Asyneuma limonifolium*, *A. linifolium*, *Barbarea minor*, *Bromopsis tomentella*, *Campanula stricta*, *Cyclotrichium origanifolium*, *Cruciata taurica*, *Daphne oleoides* subsp. *oleoides*, *Dianthus anatolicus*, *D. zonatus*, *Eremogone acerosa*, *E. ledebouriana*, *Euphorbia kotschyana*, *Festuca valesiaca*, *Galium incanum*, *Helichrysum plicatum*, *Hypericum aviculariifolium*, *H. linarioides*, *Iberis sempervirens*, *I. simplex*, *Koeleria macrantha*, *Lactuca intricata*, *Leontodon oxylepis* var. *oxylepis*, *Melica ciliata* subsp. *ciliata*, *Minuartia erythrosepala* var. *erythrosepala*, *Minuartiella dianthifolia*, *Odontarrhena pateri, Omphalodes luciliae*, *Onobrychis cornuta*, *O. montana* subsp. *cadmea*, *Ononis adenotricha*, *Onosma armena*, *Paronychia chionaea*, *Phlomis armeniaca*, *Pimpinella lithophila*, *Podospermum canum* s.l., *Prometheum chrysanthum*, *Pterocephalus pinardii*, *Sabulina juniperina*, *Salvia caespitosa*, *Sideritis citrina* subsp. *citrina*, *Silene caryophylloides*, *Tanacetum armenum*, *Teucrium chamaedrys* s.l., *Thesium procumbens* and *Ziziphora clinopodioides* (Parolly, pers. obs.).

As expected, the floristic links to other mountain ranges are multifold and particularly close to those areas which form the Tauric System, i.e. the mountains of southern Greece (Hellenic Province), Crete, Cyprus, the Amanos range as a branch of the Taurus Mts., the Lebanon and Anti-Lebanon, as well as the Inner Anatolian volcanoes and the mountains of the East Anatolian highlands. At the periphery of the Tauric System, especially in the east and in the northeast, where many of the main forest species are lacking as well, the floristic connection weakens to gradually merge into the Caucasic System – and the assumed – 'Zagrosic System'. The floristic links in the eastern parts of the country are discussed below in more detail.

In most parts of the coastal western half of the Taurus *Anemone blanda, Astragalus angustifolius*, *Aubrieta* spp., *Cicer incisum*, *Euphorbia herniariifolia* var. *glaberrima*, *Hieracium pannosum*, *Lamium garganicum* agg., *Matthiastrum lithospermifolium* subsp. *cariense* and *Ranunculus brevifolius* are widespread and often occur in several other mountain ranges of the East-Mediterranean Subregion as well. The distribution area of *Sabulina juniperina* includes Greece, Turkey, northern Iraq and western Syria (McNeill 1967). Important high-mountain taxa such as *Eryngium heldreichii*, *Heldreichia bupleurifolia*, *Heracleum humile*, *Nepeta cilicica, Noccaea oppositifolia* (Fig. 7.5d) and *Vavilovia formosa* (close to *Pisum*; Fig. 7.5c) irradiate into the Lebanon and Antilebanon; *Aethionema speciosum*, *Arenaria balansae*, *Campanula cymbalaria*, *Crepis frigida*, *Oreoherzogia* *libanotica*, *Potentilla speciosa*, *Scrophularia rimarum*, *Silene odontopetala* and *Vavilovia formosa*, to name just a few, into northern Iran, north-western Iraq and (sometimes) the Caucasus. The ranges of *Aethionema stylosum* and *Arabis caucasica* reach western Syria. In the Lebanon, *Veronica caespitosa* var. *caespitosa* is replaced by its var. *leiophylla* (Parolly 1998).

Beyond that there are long-known and well supported "significant floristic links between the mountain flora of the Taurus and mainland-Greece – indeed the links are probably stronger than between the mountain floras of west Anatolia and Greece" (Davis 1971). These include species with disjunct ranges such as *Biebersteinia orphanidis*, *Omphalodes luciliae* (Fig. 7.5j), *Podocytisus caramanicus*, *Scrophularia myriophylla*, *Vicia canescens* and arrays of closely allied vicariants, especially in *Alyssum* s.l., *Asperula*, *Campanula*, *Potentilla*, *Galium*, *Nepeta*, *Sabulina*, *Scutellaria*, *Silene*, *Valeriana* and *Veronica* (Parolly 1995).

The Western Taurus is geologically the extension of the Aegean Arc into mainland Anatolia (Fig. 7.2). Consequently, the mountain floras of the Taurus and Crete share many species such as *Bromopsis tomentella* and *Matthiastrum lithospermifolium* and close vicariants alike; *Astragalus creticus* s.l. and *Ormosolenia alpina* connect the western parts of the Taurus with the mountain flora of Crete. *Lomelosia solymica*, a paleo-endemic chasmophyte of Tahtalı Dağı, has probably its next ally within the *L. cretica* group (Parolly et al. 2005).

The links between the South Anatolian flora and Cyprus are much less pronounced than might be expected from the proximity of the two areas (Ekim and Güner 2000). Such links are found, e.g. in *Cedrus libani* and *Ranunculus cadmicus*, albeit with distinct subspecies. *Jurinea cypria* was discovered in South Anatolia near Kozlar (Mut) as well (Everest and Raus 2002). It seems that the strongest affinities lie within the serpentine flora and vegetation. The ultramafic vegetation of the Taurus corresponds with its substrate-analogon of the Trodoos Mts. in Cyprus. It is composed by East Mediterranean elements (*Odontarrhena cyprica*, etc.) and local endemics which are closely related to Anatolian species. Examples include *Clinopodium troodi* subsp. *troodi* (Cyprus) vs. subsp. *vardaranum* s.l. (South-west Anatolia), *Odontarrhena akamasica*, *O. chondrogyna* and *O. troodi* (Cyprus) vs. *O. masmenaea* (Anatolia) and *Onosma troodi* (Cyprus) vs. *O. frutescens* (Parolly 2020).

The affinities to the Caucasus and the adjacent North Anatolian Mts. are mostly very weak and based on species which migrated down the Anatolian Diagonal during the Quaternary glaciations (see Sect. 7.4.4.1 and below).

7.4.4.3 Phytogeographic Subdivision and Peculiarities of the Different Sections (Fig. 7.4: 3–7)

Today, an orographical and tectonical division of the Taurus Mts. into three parts, based on the same number of continuous or broken arch systems, is generally accepted, although there is continuing disagreement about the borders of the sections. Figure 7.4 illustrates the here preferred subdivision of the Taurus range as the biogeographically best supported one (Parolly 2004; Parolly et al. 2010). The parts are called Western Taurus (Turkish: Batı Toroslar), Central Taurus (Orta Toroslar) and Eastern Taurus (Güney Doğu Toroslar; for details see Kürschner 1982, 1984 and Parolly 1995). Both the Amanos mountain range and the Inner Anatolian volcanoes have many affinities with the Central Taurus and the westernmost part of the Eastern Taurus, but are better treated as particular sections.

There is now increasing support for the present subdivision of the Tauric System. The few molecular studies from the wider Taurus range have noted the existence of important phylogeographic convergences outlining some of the main sections of the Tauric System, with *Abies cilicica*, *Arabis alpina*, *Cedrus libani*, *Heldreichia bupleurifolia* and *Juniperus drupacea* showing considerable genetic differentiation among the Western Taurus Mts., the Eastern Taurus Mts. and the Lebanon Mts. (Dagher-Kharrat et al. 2007; Parolly et al. 2010; Ansell et al. 2011; Sękiewicz et al. 2015, 2018).

A. Coastal Mountain Ranges: The Western and Central Taurus Mts. and the Amanos Range

Western Taurus (Lycian Sector) and Outliers (Fig. 7.4: 3) In the coastal part of the Taurus, the deepest floristic divide (even more clearly expressed by its forest and high-mountain vegetation) is between the Western Taurus (the 'Lycian Sector' s.l.; Fig. 7.4: 3) – as understood here – and the Central Taurus (Fig. 7.4: 4). In spite of the fact that the Western and the Central Taurus are largely limestone ranges and the Amanos Mts. are not, the overall similarity is stronger between the Central Taurus and the Amanos Mts. In the west, otherwise so typical forest trees such as *Abies isaurica* and *Juniperus drupacea* are absent from the mountain forests, and the asylvatic mountain vegetation displays many taxonomically isolated species without vicarious species (schizo-endemism is otherwise the prevailing endemism pattern within the Taurus) in the adjacent mountain ranges, such as *Asyneuma junceum*, *A. lycium* and the monotypic genus *Dorystoechas* (Parolly 1998, 2004). Especially the south-eastern edge of the Beydağları (Tahtalı Dağı area; 2366 m a.s.l.) is well-known for its paleo-endemics and other systematically isolated taxa (see below, Sect. 7.6).

By putting emphasis on the separation of the Western and the Central Taurus along the line Aksu river – Isparta – Uşak, I do not ignore that there are dozens of species such as *Minuartiella pestalozzae*, *Ormosolenia alpina, Noccaea papillosa*, *Poa akmanii* and *Veronica cuneifolia* s.l. whose distribution area comprises both the Western Taurus and the western Central Taurus (i.e. the mountains of the Pisidian Lake district; Parolly 1998; Eren et al. 2004). In many respects, the floristic exchange between the two mountain ranges may have happened along the mountains encircling the Pisidian lakes ('Arc of Isparta', Güldalı 1986) during the Pleistocene, when depressed vegetation zones have furthered the migration of high-mountain plants between isolated peaks (Parolly 1998 and Fig. 7.2).

The Western Taurus consists of many smaller and isolated mountain ranges separated by large karstic depressions. Its mountains only reach at two places altitudes of more than 3000 m a.s.l. and culminate in the Kızlar sivrisi (3086 m a.s.l., Beydağları) and Lycian Akdağ (3024 m a.s.l., Akdağlar). Due to different delimitations of the range and the few studies available, it is impossible to give a precise species number for the higher elevations of the Western Taurus; it may clearly exceed 1500 subgeneric taxa (species and subspecies). For the eastern part (Beydağları) an estimate of close to 1000 taxa appears realistic, because Bakırlı Dağı and its surroundings in the north-eastern Beydağları have already a flora close to 540 subgeneric taxa in a small area (Eren et al. 2004). The flora of the whole Olimpos-Beydağları NP comprises nearly 900 taxa and the preliminary inventory of Düşen and Sümbül (2001) along the Sarisu-Antalya transect includes 702 taxa. The western outliers of Batı Toroslar are similarly diverse and add many local endemics (see below).

Typical high-mountain species with wider distribution ranges in the Western Taurus include *Alyssum aurantiacum*, *Asyneuma michauxiodes*, *Centaurea cariensis* subsp. *maculiceps*, *Dianthus acrochlorus*, *Fritillaria crassifolia*, *Minuartiella dianthifolia*, *Omphalodes luciliae* subsp. *luciliae* (Fig. 7.5j), *Papaver pilosum* agg., *Polygonum karacae*, *Polylophium petrophilum*, *Ranunculus cadmicus* var. *cadmicus*, *Silene caryophylloides* subsp. *eglandulosa*, *Tanacetum cadmeum* and *Tulipa armena* var. *lycica*.

The core part of the Western Taurus is formed by the Beydağları and the Akdağlar (Lycian Subsector; Fig. 7.4: 3c). The following selected species are confined to them (sometimes to a single mountain range): *Aethionema lycium*, *Alkanna pamphylica*, *A. attilae*, *Allium antalyense*, *Arenaria elisiana*, *Astragalus microrchis*, *Ballota cristata*, *B. glandulosissima*, *Carum rupicola*, *Centaurea drabifolia* subsp. *austro-occidentalis*, *C. lycia*, *C. pestalozzae*, *Cyanus bourgaei*, *Ebenus boissieri*, *Erysimum pallidum*, *Euphorbia pestalozzae*, *Ferula lycia*, *Fritillaria whittalii*, *Lamium cymbalariifolium* agg., *Muscari muscarimi*, *Nepeta phyllochlamys*, *Odontarrhena huber-morathii*, *Origanum minutiflorum*, *Paronychia lycica*, *Rhamnus pichleri*, *Ricotia davisiana*, *Scrophularia candelabrum*, *Sternbergia albida*, *Tanacetum praeteritum* s.l., *Verbascum bourgeauanum*, *V. orgyale*, *V. pestalozzae*, *Veronica cuneifolia* subsp. *massicytica*, *V. elmaliensis* and *Veronica lycica* (Eren et al. 2004; Parolly 2015).

The few isolated high-mountain ranges north-west of the Beydağları and the Akdağlar stand slightly apart in their flora and vegetation and could be considered as a section of its own (Lydian Subsector; Fig. 7.4: 3a–b). In spite of being rather small, it is notable that all of these mountains are rich in endemics, with totals oscillating around 100 endemic taxa (Özhatay et al. 2005). This diversity might be linked to their isolation and often relatively high geologic age (Güldalı 1979). These South-west and West Anatolian mountains at the outer edge of the Taurus Mts. proper (Sandras Dağı, Honaz Dağı, Baba Dağı) or even slightly beyond (Bozdağ, and even more Murat Dağı; Fig. 7.4: 2c) show gradually enhanced floristic links to the northwest, for example to Kaz Dağı and Uludağ near Bursa, but also to the mountains of the Balkan Peninsula. This is expressed by vicarious taxa, including e.g. *Galium aretioides* (on Honaz Dağı) and *G. olympicum* (Uludağ) or by examples in *Sabulina* (*S. saxifraga* subsp. *tmolea* on Bozdağ, subsp. *saxifraga* on the mountains of Bulgaria), revealing links between western Anatolia and the Balkans. The discovery of *Festuca punctoria* on Honaz Dağı, formerly believed to be exclusive to Uludağ, strengthens the link between these two mountains as well (Parolly and Scholz 2004).

Limestone ranges such as Honaz Dağı (2528 m a.s.l., 128 endemic taxa, including *Alyssum cephalotes* and *Centaurea zeybekii*; Özhatay et al. 2005) bear close affinities to the flora of the Akdağlar and Beydağları. Their considerable set of local endemics and other more localized species are vicarious to those of the ecosystems of the Beydağları and the Akdağlar.

The flora of the non-limestone mountain areas differs much more from the Lycian Subsector. The best-known examples include the serpentine massif of Sandras Dağı (Fig. 7.5i) and the igneous rock massifs of Baba Dağı (mica schist) and Bozdağ (orthogneiss; Fig. 7.4: 3a). The latter, the classical mons Tmolos (2159 m a.s.l.), is well known among horticulturalists as being home to a number of localized 'glory of the snow' species (*Scilla* spp., often classified in *Chionodoxa*; Meikle 1984; Mordak 1984; Speta 1981). Beyond that, Bozdağ displays a fairly diverse flora, with a total of 103 endemic taxa (Özhatay et al. 2005) and some 25 more localized species, including *Anthemis xylopoda*, *Campanula teucrioides*, *Corydalis lydica*, *Cota dipsacea*, *Hieracium tmoleum*, *Lamium pisidicum* and *Sideritis tmolea* (Eken et al. 2006). Structurally important species of the much bigger but otherwise species-poor Baba Dağı (2308 m a.s.l.) include *Astragalus flavescens*, *A. plumosus*, *Asyneuma limonifolium* subsp. *pestalozzae*, *Bromopsis tomentella*, *Gypsophila tubulosa*, *Koeleria macrantha*, *Minuartia recurva* subsp. *carica*, *Ranunculus argyreus* and *Thymus longicaulis* subsp. *chaubardii* (Parolly, pers. obs.).

Sandras Dağı (2294 m a.s.l.) displays an impressive concentration of serpentinophytes of East Mediterranean origin, including more than 25 narrow endemics such as *Ferulago sandrasica*, *Lamium sandrasicum*, *Prometheum serpentinicum*, *Stipa cacuminis* and *Viola sandrasica* subsp. *sandrasica* (Hartvig and Strid 1987; Özhatay 1993; Parolly 2020). Its highly specialised flora with many nickel-hyperaccumulators such as *Centaurea ensiformis* and *Odontarrhena masmenaea* (Kruckeberg et al. 1999; Reeves and Adıgüzel 2004) has its best matches in other serpentine areas of the coastal Taurus and Amanos Mts. (Parolly 2020). The significant links to the Trodoos range of Cyprus have been addressed above.

Pisidian-Isaurian Sector (Fig. 7.4: 4a) The Göksu Çay cuts the Central Taurus into a central, lower Pisidian-Isaurian and an eastern, higher Cilician section. The Göksu valley and an adjacent mid-elevation mountain range (Mut-Göksu corridor; Parolly 1998) seemed to have functioned as an efficient dispersal barrier for high-mountain plants; in addition, the lower elevations of the Cilician part are considerably drier and warmer than the coastal mountain slopes of the adjacent Taurus sections. The Pisidian-Isaurian Taurus, again, is made up by two subunits with their own patterns of endemism and physio-geographic peculiarities. With the exception of the Sultan Dağları (2610 m a.s.l.), which are composed essentially of metamorphic formations (Brunn et al. 1971), the Pisidian Taurus (Fig. 7.4: 4a1) consists largely of hard limestone (and some ultramafic outcrops) and comprises a series of larger, isolated mountain stocks, including the Bozburun Dağları (2505 m a.s.l.), Dedegöl Dağları (2982 m a.s.l.), Barla Dağı (2799 m a.s.l.) and Davras Dağları (2637 m a.s.l.). The Isaurian Taurus (Fig. 7.4: 4a2) to the southeast is a group of high plateaus with the Geyik Dağları (Büyük Geyik Dağı and Akdağı, 2877 m a.s.l.) in the centre. The high central part is less diverse than the Lycian and Cilician Taurus, although there are also numerous interesting and local species.

Plant diversity of the Pisidian-Isaurian Taurus boasts in montane elevations, where especially in sheltered valleys an incredibly rich chasmophytic flora has been discovered, which establishes itself on soft parent rock, especially on Köprüçayı conglomerate at the foothills of the Bozburun Dağları in the west and on the chalky limestones in the area of the Ermenek Vadisi (including Oyuklu Dağı as highest point, 2427 m a.s.l.) and between Hadim and Alanya, with the many narrow gorges draining the high plateau. Cavernicolous species are more frequent than in any other place of Turkey and include e.g. *Arenaria speluncarum*, *Omphalodes ripleyana* (also in the Pisidian Taurus), *Poa speluncarum* (also found at Lamas Çay), *Potentilla ulrichii*, *Teucrium cavernarum*, *Valeriana speluncaria* (east to the Hakkâri-Taurus) and *Erodium pelargoniflorum* (Davis 1971; Quézel 1973; Mill 1994c; Hein et al. 1998; Parolly and Nordt 2002), which has its nearest ally in north-west Africa (Davis 1971). From a biogeographical point of view, the presence of the localized, small perennial herb *Pentanema alanyense* at the foothills of the Isaurian Taurus is also very interesting, because this is the only East Mediterranean member of a genus otherwise centred in Iran, Afghanistan and Pamir-Alay and reaching the Arabian Peninsula with an annual species. The 'next' congeneric perennial species grows in northern Iraq (Duman and Anderberg 1999). Such an eastern affinity appears to be unaffected, if a generically strongly recircumscribed *Pentanema* is considered, comprising e.g., many previous *Inula* species of the Mediterranean area and of Europe (Gutiérrez-Larruscain et al. 2018). Only a very few examples with similar disjunctions as in *P. alanyense* are known, all coming from this area. They include *Arnebia purpurea* (with *A. euchroma* from Afghanistan and Iran), *Pyrus serikensis* (with *P. boisseriana* in Iran, Azerbaijan, etc.), *Scorzonera ulrichii* (with related species in the Taurus, but also with *S. xylobasis* from central Iran) and *Aethionema alanyae* (with *Moriera* from Iran; Duman and Anderberg 1999; Kilian and Parolly 2002).

Cilician Sector (Fig. 7.4: 4b) The eastern part of the Central Taurus (Cilician Taurus, eastern Orta Toroslar) consists of two extensive and massive high-mountain fronts (Bolkar Dağları, Aladağlar) with arrays of peaks and summit regions exceeding 3200 m a.s.l. The highest peaks (>3700 m a.s.l.) are situated in the Aladağlar, which mark the easternmost end of the Orta Toroslar. The Aladağlar are often treated as a part of the Anti-Taurus and thus as the onset of the Eastern Taurus. Hard carbonate rock prevails, but in both areas substantial ultramafic outcrops add much to the diversity with species such as *Crepis dioritica* (Bolkar Dağları), *Centaurea aladaghensis*, *Sideritis phlomoides* and *Viola sandrasea* subsp. *cilicica* (Aladağlar).

The Bolkar Dağları represent the most diverse mountain range in Turkey (Davis 1971). Gemici (1995) records (for the wider mountain range) a total of 1647 subgeneric taxa, of which 323 are endemic (Özhatay et al. 2005). This corresponds to ca. 14% of all vascular plant taxa in Turkey and to ca. 9.1% of all endemic taxa! The lower elevations of the sea-facing side abound in unusual, rare and taxonomically isolated species such as *Ajuga postii*, *Echinops mersinensis*, *Hypericum rupestre* and *Flueggea anatolica* (Kotschy 1858; Gemici 1993, 1995). The latter is a paleo-endemic Tertiary relict, related to the paleotropical *F. virosa*, with its closest station of occurrence in Egypt (Gemici and Leblebici 1995).

Because they do not slope down to the Mediterranean Sea, but rise from all sides from a steppe environment, the Aladağlar support with ca. 600 taxa a much lower total of species (Kürschner 1982 and additional later records scattered across a wide range of references) and much fewer endemic taxa (101) than the Bolkar Dağları (Özhatay et al. 2005), but this diversity is still impressive enough. Among the ca. 15 local endemics are taxa such as *Astragalus stridii*, *Centaurea chrysantha*, *Galium aladaghense*, *Noccaea rubescens*, *Potentilla aladaghensis*, *P. pulvinaris* subsp. *argentea* and *Veronica tauricola* (e.g. Kürschner 1982; Mill 1994a; Parolly 1995, 1998).

As is typical of the western half of the Taurus, Mediterranean chorotypes still predominate the flora of the Cilician Taurus, but the proportions of Irano-Turanian and Eurasian/Euro-Siberian chorotypes are much higher than further west. 'Pluvial' northern and eastern migroelements (or chronelements) contribute much to the diversity of the flora of the Cilician Taurus. They are mostly meso- to hygrophytes, which arrived step-wise there from the north and east within a relatively short period at pluvial times (Hein et al. 1998; Kürschner 1982, 1984; Gemici 1995; Kürschner et al. 1998; Parolly 1998), persisting today as 'glacial relicts' at damp and sheltered places in almost all elevations. The hypothesis of such a Pleistocene migration along the nearby Anatolian Diagonal (Fig. 7.2) has been supported by a phylogeographic study on *Arabis alpina* s.l. (Ansell et al. 2011). In chorological respects (by focusing on mountain plants only) these relicts are mainly taxa with Euro-Siberian (often Euxine, Euxine-Hyrcanian or Euxine-Hyrcanian-Caucasian or sometimes boreo-alpine) ranges such as *Anthriscus kotschyi*, *Bistorta officinalis* subsp. *carnea*, *Botrychium lunaria*, *Carex tristis*, *Cerastium cerastioides*, *Gentiana orbicularis*, *Pinguicula balcanica* subsp. *pontica*, *Saxifraga kotschyi* and *Sedum tenellum* (Kürschner 1982; Gemici 1995; Parolly 1998, 2015) or taxa with wide Irano-Turanian distribution patterns (e.g. *Oxytropis savellanica*). Some local endemics such as *Gentiana boissieri* and *Gentianella holosteoides* (Bolkar Dağları) have their next allies in the wider Caucasus range and the Asian mountains (Kürschner et al. 1998; Davitashvili and Karrer 2006; Parolly 2015).

In the Cilician Taurus, the xerophytic Central Anatolian mountain flora of the adjacent steppe areas is well developed at montane to low subalpine elevations and centred at dry and often disturbed places. *Acantholimon* spp., *Allium* spp., *Asphodeline taurica* and related species, *Astragalus* spp. and graminoids prevail. Besides that there is a high percentage of remarkable Irano-Turanian high-mountain xero- or mesophytes, which reach subnival elevations. Examples include *Androsace multiscapa*, *Crepis frigida*, *C. willdenowii*, *Jurinea moschus* subsp. *moschus*, *Prometheum aizoon*, *Scorzonera rigida*, *Tanacetum armenum*, *Tulipa humilis*, *Valeriana sisymbriifolia* and *Vicia alpestris* subsp. *hypoleuca* (Kürschner 1982; Hein et al. 1998; Parolly 1998, 2015).

The high-alpine to subnival rock flora (in the western half of the Taurus developed in the Cilician part only) with the notable *Draba acaulis* s.l. can also be seen in this context. Vicariously allied *Draba* species, all forming compact cushions, play an important role in the rock vegetation of Caucasian and Irano-Turanian type mountain ranges (Coode and Cullen 1965; Parolly pers. obs.). Species of this group include *D. haradjianii* (Amanos Mts.), *D. cappadocia* (Erciyes Dağı to eastern Anatolia), *D. polytricha* (Anatolian Diagonal, e.g. on Keşiş Dağı; east to northern Armenia and Adjara), *D. araratica* (Ararat Mts., Süphan Dağı and Armenia and Georgia) and, outside Anatolia, *D. bryoides* in the Transcaucasus.

Amanos Sector (Fig. 7.4: 6) The Nur Dağları (Amanos Mts., 2268 m a.s.l.) bridge the Taurus Mts. and the Lebanon, but are partly set apart by their deviating geology (Avcı 2014). Formed in the Miocene, the central part of the ca. 85 km long and 10–25 km wide mountain chain is covered mainly by calcareous rocks, schists, quartzites and greywackes. The eastern and western limits of the Amanos Mts. are intruded with ultramafic rocks of the ophiolites of the Periarabian Crescent (Brooks 1987). The climate is typically Mediterranean, but the annual precipitation (1000 mm) is relatively high for this region. Due to the diverse geology, the climatic conditions and its setting at one fork of the Anatolian Diagonal (Fig. 7.2) acting as a migration corridor, the flora is exceedingly rich. As already mentioned, the flora of the Amanos Sector is well known for enhanced proportions of Euxine and Euro-Siberian elements (see above). Examples from the woody flora include *Acer platanoides*, *Buxus sempervirens*, *Danae racemosa*, *Fagus orientalis*, *Ilex aquifolium*, *Staphylea pinnata*, *Taxus baccata*, *Tilia tomentosa* and *Ulmus* spp. (Zohary 1973; Türkmen et al. 2015). All these taxa have reached the Amanos from the north, by migrating down the Anatolian Diagonal during the glacial (pluvial) phases of the Pleistocene (Davis 1971).

The number of endemic vascular plants is also very high (251 taxa; Özhatay et al. 2005). As in all of Anatolia, the serpentine flora stands out by a high proportion of species of Fabaceae (*Chamaecytisus drepanolobus*, *Cytisopsis dorycniifolia*, *Genista antiochia*, *G. lydia*), Asteraceae (*Centaurea arifolia*, *C. cassia*, *C. ptosimopappa,* also in Syria, etc.), Brassicaceae (especially endemic *Odontarrhena* species such as *O. cassia*, *O. constellata*, *O. samifera*, *Noccaea* spp., *Pseudosempervivum* spp.) and fairly few Caryophyllaceae (*Silene haradjianii*; e.g. Adıgüzel and Reeves 2012). This is largely explained by the nature of the source pool from the surrounding non-serpentine taxa, which is typically Mediterranean (Brooks 1987). There are a substantial number of non-serpentine endemics too, including *Silene doganii* (on granite), *Ferula coscunii* and *Wulfenia orientalis* (both mainly on limestone; Eken et al. 2006). The latter is a very interesting and phytogeographically well-studied species, those congeners grow – equally localized – in the Alps and Dinarids, while

W. amherstiana from the western Himalayas has been shown to be distantly related and placed in the genus *Wulfeniopsis* (Albach et al. 2004a, b).

B. Inland Mountain Ranges: Inner Anatolian Volcanoes, Mountains of the Anatolian Diagonal and the Eastern Taurus

Sector of the Inner Anatolian volcanoes (Fig. 7.4: 5) A series of isolated volcanic cones overlooks the steppe area of the Inner Anatolian plateau, with Hasan Dağı (3268 m a.s.l.; near Aksaray; Fig. 7.5g), Keçiboyduran Dağı (2757 m a.s.l., between Hasan and Melendiz Dağı), Melendiz Dağı (2963 m a.s.l.; near Niğde) and Erciyes Dağı (3917 m a.s.l., near Kayseri) being the highest and the only ones to reach alpine to subnival elevations. Due to these additional life zones they have the most diverse flora among the volcanoes in Inner Anatolia. They result from the enormous volcanic activity that started with the rise of the Taurus Mts., the tectonic movements in the Middle Miocene, and that continued until the Quaternary (Kenar and Ketenoğlu 2016). They lie on a north-east–south-west-stretching fault zone, along which the Toroslar was up-lifted against the Inner Anatolian highland. Their main activity, correlated with massive lava production, was in the Pliocene. Besides volcanic tuff, block lava, lapilli fields and basalts, andesite is widespread. Grey steppe soils and ashy to rocky volcanic acidic soils prevail, which are prone to erosion.

Thanks to the works of Düzenli (1976), Kürschner (1982, 1984), Başköse and Dural (2011), Kenar and Ketenoğlu (2016) and others, the plant life of the Inner Anatolian volcanoes is relatively well known. In general, their flora is Irano-Turanian in character, with many wide-Irano-Turanian species and others of the local floristic stock of the Central Anatolian Province. As to be expected, Mediterranean elements are rare on mountains rising from a steppe environment (Kürschner 1982, 1984; Kenar and Ketenoğlu 2016). Eurasian and Euro-Siberian taxa are more important, gaining in significance with altitude and increasing water-supply (Parolly 2015).

Compared to the neighbouring Taurus Mts., the flora of the Inner Anatolian volcanoes is relatively poor and the endemism rate is lower. This has been attributed to the young geologic age of the volcanoes, the soil chemistry (mainly acidic) and the weathering conditions, supporting fewer habitat types than e.g. on limestone (Kürschner 1982; Parolly 1995). Different climates may also play a role. In addition, a massive human impact since time immemorial has led to the destruction of their vegetation zones. Grazing on these mountains is particularly severe and their flora displays over vast ranges many perennials unpalatable to animals, such as *Euphorbia macroclada* and *Eryngium campestre*. For a survey of the effects of overgrazing on steppe-like vegetation in Anatolia, see Kürschner and Parolly (2012), Kenar and Ketenoğlu (2016) and references cited therein. The extensive forests these volcanoes once carried have been reduced to island-like fragments and were largely replaced by dwarf-shrub vegetation rich in thorn-cushions. It is the flora of this vegetation type, with abundant *Bromopsis cappadocica*, *B. tomentella*, *Acantholimon* spp., *Astragalus condensatus*, *A. micropterus*, *A. plumosus*, *Eremogone* spp. and *Festuca* spp., which shows the closest affinity to the non-limestone flora of the adjacent Taurus range. With the exception of the local and regional endemics, nearly all other species of the high-mountain zones of the volcanoes grow in the Taurus Mts. as well. This common intersection of species are mostly substrate-vague (*Astragalus angustifolius*, *Daphne oleoides* subsp. *oleoides*, *Phlomis armeniaca*, *Prunus prostrata*, *Sabulina juniperina*) or acidophilic taxa, while limestone-demanding plants such as *Onobrychis cornuta*, which often dominates in the subalpine belt of the Taurus Mts., are very localized to completely lacking (Kürschner 1982). Typical and widespread taxa of the higher elevations of the Inner Anatolian volcanoes include *Astragalus microcephalus, A. pycnocephalus*, *Dianthus zederbaueri*, *Festuca valesica*, *Lamium veronicifolium*, *Marrubium astracanicum*, *Rostraria cristata*, *Thymus argaeus*, *Stipa holoserica* and *S. lessingiana* (Kenar and Ketenoğlu 2016).

Erciyes Dağı is the highest peak west of the Anatolian Diagonal; it stands out not only in this respect. Its overall floristic diversity and many endemics make it the only IPA among the volcanic cones in the west (Özhatay et al. 2005). The Erciyes Dağı NP harbours ca. 130 endemic species, including some 40 more localized taxa such as *Astragalus argaeus*, *A. stenosemioides*, *Asyneuma trichostegium*, *Erigeron zederbaueri, Heracleum craterum* and *Hieracium subvandasii*. *Astragalus simonii*, *A. victoriae* and *Trigonella isthmocarpa* may be mentioned from the Hasan Dağı–Melendiz Dağı range (Eken et al. 2006).

Sections of the Eastern Taurus and the Anatolian Diagonal (Fig. 7.4: 7) The Eastern Taurus begins east of the Aladağlar. It forms a wide arch comprising different parallel mountain ranges in south-eastern Anatolia, before merging into the Zagros Mts. in South-west Iran. The average altitude of these mountains varies between 2000 and 3000 m a.s.l., while their north–south extension varies between 75 and 150 km. Their eastern part culminates in the Hakkâri-Taurus, not far from the Turkish-Iranian border, with many of its summits reaching beyond 3500 m a.s.l. A series of four elongated high plateaus and basins (Turkish: ovası), in the central section all situated between 1000 and 1500 m a.s.l. and separated from each other by higher land, divides the mountain mass of the Eastern Taurus into two great ranges: The Inner Eastern Taurus comprises the mountain chains to the north of the series of basins, while the Outer Eastern Taurus – corresponding to the mountains of the Anatolian Diagonal, following tectonically the Inner-Tauride-Suture and marking the northern edge of the Arabian platform – stretches to their south (Güldalı 1979; Mill 1994a). The most important complexes of the Inner Eastern Taurus are the Tahtalı Dağları (3054 m a.s.l.), Tecer Dağları (2808 m a.s.l.), Munzur Dağları (3462 m a.s.l.), Kop Dağı (2918 m a.s.l.), the Bingöl Dağları (3200 m a.s.l.) and the Ispiriz-Mengene Dağları (2587 m a.s.l.). The most significant mountain complexes of the Outer Eastern Taurus include the Malatya Dağları (2620 m a.s.l.), Sason Dağları (2500 m a.s.l.), Bitlis Güneyi Dağları (3050 m a.s.l.) and Cilo Dağları (= Hakkâri Dağları, 4168 m a.s.l.). It is important to note that there is an almost seamless transition between the Hakkâri area and the mountain ranges of the Anatolian high plateau (see below).

The flora of the area is exceedingly rich and diverse. Mill (1994a) estimates approximately 3200 vascular plant species for the "Anti-Taurus mountains and Upper Euphrates" (including the mountains between the Aladağlar and the Hakkâri range, but excluding the latter). More than 750 taxa are endemic to Turkey and ca. 450 taxa are more narrowly distributed endemics (Mill 1994a).

Through most of its extension the Eastern Taurus runs through vast Irano-Turanian territories, mostly of the Armeno-Iranian Province (Takhtajan 1986; Irano-Armenian Province sensu Zohary 1973), but the central part of the outer branch of the Taurus bounds the northern side of the Mesopotamian plains (the low Southeast Anatolian plateau) near the Syrian border that support a different Irano-Turanian flora and vegetation. This lowland part of Turkey belongs to the Mesopotamian Province of the Irano-Turanian Region (Davis 1971; Zohary 1973; Takhtajan 1986; Mill 1994a; Güner et al. 2012). The alpine flora of the Eastern Taurus is more Euro-Siberian in character than that of the Taurus ranges further west, including many *Carex* spp., *Gentiana verna* agg., *Myosotis alpestris*, *Poa longifolia* and *Primula elatior* subsp. *pallasii*; although (often widespread) Irano-Turanian chorotypes such as *Alopecurus textilis*, *Artemisia splendens*, *Festuca brunnescens*, *Lamium tomentosum*, *Scutellaria orientalis* agg. and *Sesleria phleoides* nearly always predominate (Mill 1994a; Parolly pers. obs.).

Due to the scarcity of consistent floristic and vegetation studies, it remains unclear, if the two branches of the Eastern Taurus represent separate phytogeographic units or not, as most of the subdivision of the Eastern Taurus needs still to be worked out. Nevertheless, its western and south-eastern edges seem to be sufficiently distinct in floristic and chorological respects to assume an at least tripartite biogeographic structure again.

*Western Part of the Eastern Taurus (**Fig. 7.4**: 7a)* The western section of the Eastern Taurus, with its floristically so well-known mountains such as Ahir Dağı (2339 m a.s.l.), Engizek Dağları (2814 m a.s.l.), Berit Dağı (3027 m a.s.l.) and Binboğa Dağları (2957 m a.s.l.), lies in the transitional area between the Mediterranean and Irano-Turanian regions. Turkish biogeographers usually treat it as part of the Akdeniz Bölgesi (Mediterranean region) and Adana Bölümü (Adana section; e.g. Güner and Ekim 2014), a view which is in general well supported, because the oro-Mediterranean type cedar-fir forest climax of the coastal Tauric System occurs scattered at sheltered places. Glimpses on the high-mountain flora and vegetation (Duman 1995: Engizek Dağı; Özhatay et al. 2005; Eken et al. 2006) tell another story and reveal differences between this area and the Cilician Taurus that advocate in support of the classification presented here (Fig. 7.4: 7a). This mountain-knot at the western end of the Anatolian Diagonal and the branches of the Eastern Taurus not yet diverging so widely corresponds to the 'Cataonian Sector' (Parolly et al. 2010; Parolly 2015). The transitional character of this area is reflected by chorotype spectra and by its particularly diverse flora. Diversity at genetic level seems also to be enhanced as revealed by molecular studies (Dagher-Kharrat et al. 2007: *Cedrus*; Parolly et al. 2010: *Heldreichia*; Ansell et al. 2011: *Arabis alpina*; Sękiewicz et al. 2015: *Abies cilicica*, 2018: *Cupressus*).

The distribution of at least 390 taxa is confined to the Anatolian Diagonal (e.g. *Papaver triniifolium*); and other species are occurring only west (e.g. *Bolanthus* spp., *Centaurea drabifolia* s.l.) or east (*Astragalus* sect. *Acanthophace* and *Chronopus*, *Prangos pabularia*) of this floristic discontinuity (Davis 1971; Ekim and Güner 1986; Mill 1994a). Abundant taxa of the thorn-cushion zone of this mountain range include *Astragalus asciocalyx*, *A. gummifer*, *A. kurdicus*, *A. pennatus*, *A. plumosus*, *A. xylobasis*, *Eremogone drypidea*, *Euphorbia denticulata*, *Hyacinthus orientalis* subsp. *chionophilus*, *Minuartiella dianthifolia*, *Onobrychis marashensis*, *Ranunculus pinardii*, *Silene capitellata*, *Tanacetum densum* subsp. *amanum*, *Thymus kotschyanus*, *Veronica macrostachya* subsp. *macrostachya* and *Veronica orientalis* (Duman 1995; Özhatay et al. 2005).

The main massifs represent notable centres of endemism and IPAs (Özhatay et al. 2005): Ahır Dağı for example has a total of 122, the Engizek Dağları 158, Binboğa Dağları 177 and Berit Dağı 192 endemic taxa (Özhatay et al. 2005). Important localized species of higher elevations include *Asyneuma ekimianum* subsp. *beritensis*, *Heracleum maraschicum*, *Odontarrhena haussknechtii*, *Scrophularia hyssopifolia* (on Berit Dağı), *Oxytropis engizekensis*, *Prangos platychlaena* subsp. *engizekensis*, *Scorzonera acantholimon* (on Engizek Dağları), *Astragalus akmanii* (on Ahır Dağı), *Doronicum haussknechtii* and *Paronychia cataonica* (on several mountains; Mill 1994a; Özhatay et al. 2005). The limestone chasmophyte *Graellsia davisiana* is known from the Binboğa Dağları and Engizek Dağları (Güner and Duman 1998) only. Related species grow in the east: the genus with nine species is South-west Asian with a centre of diversity in Iran (5 species); *G. davisiana* shows much affinity with the Iranian *G. isfahan* (Esmailbegi et al. 2017).

*Central Eastern Taurus (**Fig. 7.4**: 7b)* Due to the unclear delimitation and further subdivision of the central parts of the Eastern Taurus, I prefer to pick out just two remarkable centres of diversity. The Munzur Dağları, composed of limestone, serpentinite and Neogene sediments, extend from Kemaliye for 130 km in east–west direction. A greater number of species are endemic to them; examples include *Aethionema munzurense*, *Campanula munzurensis*, *Eryngium ilex*, *Omphalodes davisiana*, *Ranunculus munzurensis*, *Stachys munzurdaghensis* and *Vicia glareosa* (Mill 1994a; Özhatay et al. 2005; Eken et al. 2006). Some of these species are of isolated taxonomic position and are therefore of considerable evolutionary and floristic interest (Mill 1994a).

The Keşiş Dağı range harbours e.g. *Alchemilla erzincanensis*, *Paronychia kemaliya*, *Veronica montbretii* and *Viola odontocalycina*. Of particular biogeographical interest is the occurrence of *Oreoseris armena* as the only member of the Asteraceae tribe *Mutisieae* in Turkey. *Oreoseris armena* is presumably a relict (Mill 1994a) and endemic to Turkey (Gümüşhane, Erzurum and Artvin vilayets; Doğan et al. 2016) and Armenia. Its next ally grows in Afghanistan and on the Tien Shan and Pamir-Alay. The species was hitherto included in the genus *Uechtritzia* with two other species, namely *O. kokanica* from Central Asia (Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, Turkmenistan to Afghanistan) and *O. lacei* of the Himalayan region, and is now transferred to *Oreoseris* together with nine species of the Asian *Gerbera* (Xu et al. 2018).

*Hakkâri-Taurus (**Fig. 7.4**: 7c)* The mountains at the south-eastern edge of Turkey, the so-called Hakkâri-Taurus of the (older) literature, are floristically and geographically set apart from the central Eastern Taurus. The Buzul and Ikiyaka Dağları are an area of particularly high mountains, with Reşko Tepe (4168 m a.s.l.) in the Buzul (Cilo) Dağları being the highest peak of the entire Taurus Mts. The main summit of the latter has a glacier on its northern side. The Ikiyaka (Sat) Dağları reach 3396 m a.s.l. Near Yüksekova, several spurs run east (Mordağlar, 3809 m a.s.l.), north-east and south-west, with their principal peaks ranging between 3055 and 3550 m a.s.l. The western edge is composed by the Tanin Tanin Dağları (3213 m a.s.l.) and the whole range is drained by the Great Zab River and its tributaries.

Turkish plant geography recognizes the area's distinctiveness by assigning a Hakkâri Bölümü (Hakkâri section) within the Doğu Anadolu Bölgesi (East Anatolia region; e.g. Güner et al. 2012; Güner and Ekim 2014). It was as early as with the beginning of the 'Flora-of-Turkey project' that Davis (e.g. 1971) recognized a re-occurring pattern of plants such as *Trifolium longidentatum* that were reaching Anatolian territory in the Hakkâri section only. As Davis (1971: 21) put it, the flora is "evidently part of a marked natural floristic belt which extends south-eastwards down the Zagros mountains of western Iran, at least as far south as Shiraz; the distribution of *Phlomis bruguieri* and *Nepeta macrosiphon* delimit the extent of this belt pretty well". Later Takhtajan (1986) pointed out that both the outermost section of the Eastern Taurus and the surroundings of Lake Van form part of the Atropatenian Subprovince of the Armeno-Iranian Province. This special kind of flora thus extends a little bit further north along the mountains encircling Van Gölü, but it has its only and strongly localized occurrence in Anatolia here.

The Hakkâri area proper slopes down steeply to the Anatolian high plateau and there is a smooth transition between these two ranges, making the assignment of the one or other mountain to either side arbitrary, but there seems to be agreement to include the mountains south of Van Gölü (Bitlis Güneyi Dağları, Artos Dağı) to the Hakkâri area (Güner and Ekim 2014), to which I add the İspiriz Dağları (3668 m a.s.l.) and Van Doğusu Dağları (see Fig. 7.2: 54 and 7.4: 7c).

The upland flora of the Turkish-Iranian-Iraqi frontier region has been estimated to contain 2500 vascular plant species, of which ca. one fifth is endemic. "Some 1750 species have been recorded from South-east Anatolia; 200 of these are endemic to Turkey and over 100 are endemic to South-east Anatolia. A further 125 species are endemic to South-east Anatolia and the adjacent mountains in Iran and Iraq" (Mill 1994b; note that the area considered by Mill includes the whole flora of the Bitlis, Hakkâri, Siirt and Van vilayets, so that all figures might be better reduced by one third to get an approximation of the diversity of the range delimited here). The area is particularly rich in taxa often following a cluster endemism (compact endemism; Zohary 1973). A small selection of plant species characteristic of the Hakkâri area and the adjacent mountain ranges outside Turkey include *Astragalus siliquosus* and several other congeners, *Peltariopsis planisiliqua*, *Rosularia* *rechingeri*, *Ferula stellata*, *F. bernardii*, *Campanula persica*, *Omphalodes luciliae* subsp. *kurdica* (at the south-eastern margin of the range of the genus and disjunct from the Greek, Pisidian-Isaurian and Cilician subspecies) and *Veronica davisii* (Mill 1994b). *Ranunculus crymophilus* grows by melting snow on the Buzul (Cilo) Dağları and in northern and western Iran (Davis 1965–1985). *Potentilla hololeuca* also occurs here, but its range additionally includes Central Asia (Davis 1965–1985). *Pelargonium quercetorum* is not a high-mountain plant proper, but rather "inhabiting oak woods in Hakkâri and northern Iraq" (Mill 1994b).

Examples of high-mountain plant endemics confined to the wider Hakkâri section of the Eastern Taurus (Turkish side) include *Alchemilla burseriana*, *A. hessei*, *Gypsophila hakkiarica*, *Lathyrus satdaghensis*, *Vicia splendens*, *Senecio davisii*, *Solenanthus formosus* (on Ikiyaka [Sat] Dağları), *Delphinium carduchorum* (allied to *D. micranthum* from northern Iraq and *D. dolichostachyum* from the mountains around Van Gölü; Davis 1965), *Klasea hakkiarica*, *Scorzonera mirabilis*, *Crepis hakkarica* and *Dionysia teucrioides* (on the Buzul [Cilo] massif; Davis 1965–1985; Mill 1994b). The latter is a typical chasmophyte of limestone cliffs, which has its allied species in *D. bornmuelleri* of the adjacent mountains in the central Eastern Taurus (Cudi Dağı), western Iran and Iraq. *Isatis spateola* and *Thesium oreogetum* grow chiefly on Artos Dağı (3537 m a.s.l.) which is composed of crystalline limestone (Mill 1994b), as does *Fritillaria minima*, which occurs on nearby Müküs Dağı too (Koyuncu 2000d). The same area harbours *Tulipa biflora* (also north of Van Gölü), and *Bellevalia rixii* has its only occurrence on Güzeldere Pass (Koyuncu 2000a). The İspiriz Dağları (3668 m a.s.l.) are made up by marble separated by a broad band of serpentine in between; they display e.g. *Gypsophila graminifolia* (also in Erzurum), *Paronychia saxatilis* and *Acantholimon spirizianum* (Mill 1994b).

The flora of the wider Hakkâri section displays much similarity with the adjacent parts of East Anatolia, especially with the East Anatolian highlands, because there are many species endemic to both ranges. For instance, the lithophytic *Arabis carduchorum* is known from Artos Dağı and Pelli Dağı, but also displays floristic links further west in being related to other species of *Arabis* sect. *Drabopsis,* including *A. bryoides* (Balkan Peninsula), *A. drabiformis* (Uludağ), *A. lycica* (Lycian Taurus), *A. alanyensis* and *A. kaynakiae* (Isaurian Taurus; Parolly and Hein 2000; Daşkin 2013). *Arabis mollis* (including *A. graellsiformis*, a species formerly thought to be endemic to Cilo Dağı) also grows in Daghestan (Greater Caucasus) and is morphologically closest to *A. brachycarpa* and *A. nordmanniana* from the Black Sea Mts. and the Western Caucasus (Mutlu and Dönmez 2003; Güner et al. 2012). There is also a recordable influence of xerophytic Mesopotamian species in the local flora, which irradiate from the south and the south-west into the wider Hakkâri area. Examples of this distribution type include *Nigella unguicularis*, *Ranunculus diversifolius* and *R. myosuroides* (Gabrielian and Fajvush 1989; Güner et al. 2012).

7.4.5 The East Anatolian Highlands

7.4.5.1 Phytogeographical Nature of the Mountain Range

The East Anatolian highlands as delimited here (Fig. 7.4: 8) form part of the biogeographically well-defined Doğu Anadolu Bölgesi (East Anatolian region) of Turkish plant geography (Güner and Ekim 2014), but narrowed down considerably by excluding the Eastern Taurus Mts. and the mountains forming the Anatolian Diagonal (which I treat as a part of the Taurus Mts.). Since all mountains which do not line the Black Sea coast proper are integrated in the Tauric System, it is rather a matter of concepts. Here, the East Anatolian highlands are taken as a high and very rugged plateau, whose eastern base runs from the big soda lake Van Gölü (1640 m a.s.l.) at its south-eastern edge along the eastern border of Turkey north to Kars, while its bifid apex and its sides are wedged between the branches of the Inner and Outer Eastern Taurus. Even in this delimitation, the area remains heterogeneous in landscape-ecological respects by comprising two subunits: The eastern half of the Erzurum-Kars Bölümü and all of the Yukarı Murat-Van Bölümü (Güner and Ekim 2014).

The Yukarı Murat-Van area (Fig. 7.4: 8b) is characterized by volcanic landscapes and Mediterranean semi-arid and arid types of bioclimate sensu Akman and Ketenoğlu (1986). The southern margin of Van Gölü marks the boundary between the metamorphic rocks of the Bitlis Massif and the volcanic strata from the Neogene and Quaternary periods. High, dormant volcanoes located in the collision zone of the Arabian and Eurasian tectonic plates tower over a vast steppe area with a severe climate, where basaltic lava-flows cover much of the area to the north (Güldalı 1979; Mill 1994b). Major mountain ranges, all of volcanic origin, include the massive shield volcano Tendürük Dağı (3660 m a.s.l.; Fig. 7.6a), the stratovolcanoes Nemrut Dağı (2935 m a.s.l.), Süphan Dağı (4058 m a.s.l.) and Büyük Ağrı Dağı (Ararat Mt., 5137 m a.s.l.) — the highest point of Turkey —, as well as Pirreşit Dağı (3110 m a.s.l.) and Erek Dağı (3250 m a.s.l.).

The Erzurum-Kars Bölümü (Fig. 7.4: 8a) has largely a severe continental climate (Akman and Ketenoğlu 1986). The Allahuekber Dağları (3120 m a.s.l.) and Palandöken Dağı (3271 m a.s.l.) are most notable mountain ranges. Other mountains such as Gâvur Dağı (Abdal Musa Dağı; 3313 m a.s.l.), Kop Dağı (2409 m a.s.l.) and Kargapazarı Dağları (3132 m a.s.l.), which are traditionally attached to that range, are better included into the Inner Eastern Toroslar. The Allahuekber Dağları embody stratigraphic series of the Cretaceous, Eocene and Neogene; however, more than three third of their area are covered by acidic and basic volcanic deposits of the Neogene. Palandöken is mainly composed of ophiolites and magmatic andesite tuffs of Tertiary age mixed up with small quantitiesof Pliocene sediments as well as serpentine formations (Öztürk et al. 2015).

Much of the flora and vegetation of the East Anatolian Plateau and its mountains is Armeno-Iranian in character, with a transition zone towards the Atropatenian Subprovince in the south around Van Gölü (for its differentiation, see below). At high-mountain elevations and at damp places in the whole area, Euro-Siberian elements are abundant, while noticeable percentages of Mediterranean plants are found in sheltered valleys only. However, the number of species belonging to Mediterranean chorotypes is relatively high and include e.g. *Allium flavum* subsp. *tauricum*, *Carex flacca* subsp. *serrulata* (Bitlis), *Cistus salviifolius*, *Dactylorhiza iberica, D. romana* subsp. *romana*, *Echium plantagineum*, *Heliotropium greuteri*, *H. suaveolens*, *Orchis punctulata (*Bingöl), *Sideritis montana* subsp. *montana* and *Sternbergia lutea* (Öztürk et al. 2015). These taxa putatively reached the area "by crossing the Anatolian Diagonal and East Taurus and proceeding along Euphrates and Murat basins" (Öztürk et al. 2015) or invaded from the Mediterranean Black Sea exclaves.

A fairly large group of species is of 'Antasian', respectively 'Asia Minor–Caucasian' distribution type, i.e. they grow from the mountains in Syria and Iraq to the Greater Caucasus, and often extend to Daghestan. Widespread examples include *Campanula aucheri* (Fig. 7.6e), *C. collina*, *Cephalaria gigantea*, *Corydalis alpestris* and *Dianthus cretaceus* (Gabrielian and Fajvush 1989).

On the high volcanoes, the percentage of Irano-Turanian chorotypes is well above 40% (total flora, all habitat types; Öztürk et al. 2015). To the north, the proportion of the Euro-Siberian element increases steadily. The ratio of the different elements depends on their ecological setting. On the Allahuekber Dağları (Kars) chorotype spectra of the degraded *Pinus sylvestris* var. *hamata* forest ecotone, occurring up to an altitude of 2600 m a.s.l., show 56% Irano-Turanian vs. 24% Euro-Siberian elements on eastern and south-eastern slopes, whereas on northern and north-western slopes Euro-Siberian elements reach 58% and Irano-Turanian only 20% (Öztürk et al. 2015). The boundaries between the Euxine territory of the Black Sea Mts. in the north and of the steppe belt of the East Anatolian highlands are smooth, being largely a broad transition zone with (mostly destroyed) Sub-Euxine oak forest (sensu Zohary 1973) interspersed (while Zohary even considers all of the nowadays zonal vegetation of the plateau as a mosaic of Anatolian *Artemisia* steppe and remnants Sub-Euxine oak forest).

7.4.5.2 Important Floristic Components and Floristic Affinities

The largest genera (with most species in the area) of the East Anatolian highlands – and with the exception of *Verbascum* also well represented in high altitudes – are *Astragalus*, *Centaurea* s.l., *Allium*, *Carex*, *Dianthus*, *Gypsophila*, *Ranunculus*, *Silene*, *Trifolium*, *Verbascum*, *Vicia* and *Veronica* (Gabrielian and Fajvush 1989; Öztürk et al. 2015). At higher elevations, one could add *Festuca* (a minimum of 18 taxa), *Onosma* (38 taxa), *Potentilla* s.l. (24 taxa), *Draba* (14 taxa), *Delphinium* (12 taxa) and *Campanula* (29 taxa; all figures are own counts based on Güner et al. 2012). *Alchemilla* is by far not so well represented as in the Black Sea range, but yet comprises a minimum of 14 species, including species such as *A. crinita*, *A. persica* and the endemic *A. procerrima* which occur in Turkey only here (Güner et al. 2012).

Gypsophila has a centre of diversity and many endemics in the East Anatolian highlands too, with more than 20 taxa in the mountain-steppe zone and some species growing higher up, including *G. adenophylla*, *G. bicolor*, *G. briquetiana*, *G. bitlisensis*, *G. elegans*, *G. graminifolia*, *G. nabelbekii*, *G. peshmenii*, *G. pulvinaris* and *G. ruscifolia* (also in the Hakkâri-Taurus; Huber-Morath 1967; Özçelik and Özgökçe 1996). Poppies (*Papaver*, 15 ssp.) are another frequent and sometimes spectacular sight. They include, often at damper slopes with better water-supply or on alluvial gravel with taller vegetation, members of the *P. orientalis* group, the ancestors of the large red oriental poppies of horticulture.

The high-altitude flora is largely a mixture of Irano-Turanian and Caucasian floristic elements (Fig. 7.2). Typical and widespread high-mountain hemicrypto- and chamaephytes include *Acantholimon* spp., *Alchemilla caucasica*, *Alyssum* s.l. spp., *Anchonium elichrysifolium* subsp. *persicum, Anemonastrum narcissiflorum*, *Asperula prostrata*, *Aster alpinus*, *Astragalus* spp. (e.g. *A. alyssoides*, *A. aureus*, *A. pinetorum*), *Bromopsis erecta*, *Chamaesciadium acaule*, *Cerastium purpurascens, Daphne oleoides* subsp. *kurdica*, *Draba bruniifolia*, *Drabopsis verna, Eremogone blepharophylla, E. dianthoides* subsp. *dianthoides, Erigeron caucasicus* subsp. *venustus*, *Erysimum leptocarpum*, *Onobrychis cornuta*, *O. sulphurea*, *Pimpinella peucedanifolia*, *Poa bulbosa, Prangos* spp., *Ranunculus crateris*, *R. millefolius* subsp. *millefolius*, *Rindera* spp., *Sibbaldia parviflora*, *Silene araratica*, *S. dianthoides* and *Tanacetum chiliophyllum.*

The East Anatolian highlands support a particularly rich geophyte flora (also in terms of endemism), embellishing in spring snow-patches and mountain-steppes. It comprises e.g. *Puschkinia scilloides*, *Othocallis* spp. (*O. rosenii*, *O. siberica* subsp. *armena*), three species of *Crocus*, five *Tulipa* spp., six *Corydalis* spp., eight *Bellevalia* spp., no less than nine taxa of *Iris* and at least 12 species of *Fritillaria* (own counts based on Koyuncu 2000a, b, c, d; Güner et al. 2012), including *F. minima*, *F. minuta* (both also in the Hakkâri section of the adjacent Eastern Taurus), *F. alburyana* and the stately *F. imperialis*, well-known to gardeners. The Crown Imperial grows only at a few places on mountains in eastern Anatolia, but is a magnificent sight in its wild setting.

The East Anatolian highlands can be seen as an extension of the Armenian high plateau, which in turn continues in the Iranian plateau. These areas form a geomorphological entity, but have a diverse and regionally well-structured flora (Zohary 1973; Gabrielian and Fajvush 1989). To no surprise, the flora of the East Anatolian highlands bears closest affinities with these neighbouring mountain areas of southern Caucasia (Armenian highlands, Iranian plateau) and other areas with a prevailing Armeno-Iranian flora (mountains of the Eastern Taurus and Anatolian Diagonal). According to Takhtajan (1986), the Armeno-Iranian Province "embraces the eastern part of the Anatolia Plateau (east of the Anatolian Diagonal), most of the Armenian Highlands, dry regions of southern Transcaucasia, Zuvand [….]". It is important to understand that this kind of flora penetrates deeply – sometimes in isolated outposts – into the dry valleys of the southern incline of the Black Sea Mts. (Fig. 7.2). Due to this situation, there is no need to deal with these types in the chapter on the flora and vegetation of the Black Sea Mts. in greater detail again.

According to Gabrielian and Fajvush (1989), the level of floristic wealth in the adjacent parts of the Anatolian, Armenian and Iranian highlands "is approximately the same; each contains some 3200–3500 species, of which some 60–70 % are common to all three parts, or two of them". Approximately one third of the species of the trans-boundary area is said to be endemic (Zohary 1973; Gabrielian and Fajvush 1989).

Generic endemism is fairly weakly developed and comprises (at higher altitudes) *Peltariopsis* (3 species, with *P. planisiliqua* also in East Anatolia) and *Physoptychis* (2 species, also on the Iranian plateau and with *P. haussknechtii* as far west as Sivas vilayet) in Brassicaceae and *Szovitsia* (*callicarpa*) in Apiaceae (Gabrielian and Fajvush 1989; Güner et al. 2012). Other examples given by Gabrielian and Fajvush (1989), including *Smyrniopsis, Diplotaenia* and *Stenotaenia* (all Apiaceae), are no longer ranked among the endemic genera of the East Anatolian highlands due to modified generic circumscriptions and the discovery of newly described taxa further west (Güner et al. 2012). This holds also true for the local Anatolian endemic *Physocardamum davisii* (Rešetnik et al. 2014; see below). The small gentian *Lomatogonium carinthiacum* has a very disjunct distribution pattern, its area ranging from the eastern Alps, Caucasia and Central Asia to northern America, with the only Turkish stations on the East Anatolian highlands and the Hakkâri-Taurus (Edmondson 1978).

7.4.5.3 Phytogeographic Subdivision and Peculiarities of the Different Sections

With the exception of the mountains around Van Gölü adjacent to the Hakkâri-Taurus (Atropatenian Subprovince), most of the land falls into the range of the Armeno-Iranian flora (Takhtajan 1986). A couple of typical Armeno-Iranian elements may be mentioned: *Allium karsianum*, *Campanula massalskyi*, *Festuca karsiana*, *Heracleum transcaucasicum*, *Othocallis rosenii* and *Scrophularia macrobothrys* (Gabrielian and Fajvush 1989). With its many xerophytes, especially sub-shrubby mountain-steppe plants and geophytes, the Atropatenian flora is very diverse and rich in endemics such as *Acantholimon araxanum*, *Allium akaka*, *Centaurea vanensis*, *Cousinia* spp., *Dianthus crossopetalus*, *Dracocephalum aucheri*, *Iris* sect. *Oncocyclus*, *Oxytropis kotschyana*, *Nepeta* spp., *Polygala hohenackeriana*, *Prangos uloptera* and *Tanacetum* spp. (Takhtajan 1986; Gabrielian and Fajvush 1989). There are of course also many species which mark both subprovinces (Armeno-Iranian/Atropatenian elements). These species include *Acanthophyllum mucronatum*, *Eremogone blepharophylla*, *Hedysarum formosum*, *Hypericum armenum*, *Scrophularia atropatana*, *S. ilwensis* and others (Gabrielian and Fajvush 1989).

To the north of the area, and with increasing altitude and water-supply, Euxine-montane (e.g. *Chamaesciadium acaule*, *Heracleum crenatifolium, Hypericum orientale*, *Pedicularis condensata, Pimpinella tripartita*) and Caucasian elements gain in significance. The latter include e.g. *Aster amellus* subsp. *ibericus*, *Astrantia maxima*, *Fritillaria caucasica, F. latifolia, Gentianella caucasea*, *Potentilla adzharica*, *Saxifraga paniculata* subsp. *cartilaginea* and *Scrophularia olympica* (Gabrielian and Fajvush 1989; Öztürk et al. 2015).

7.5 Endemism

7.5.1 Evolutionary Drivers in the Plant Historical Past

Before providing selected examples of endemics considered to display ancient or recent links, it may be welcome to briefly summarize some of the most important historical drivers of Anatolian flora evolution (following Thompson 2005; Korotkova et al. 2018; Sękiewicz et al. 2018 and references therein).

The uplift of land in South-East Europe, South-West and Central Asia during the early Miocene caused the development of a considerably drier and cooler continental climate in the wider region. This mid-Miocene climate transition (14.2–13.8 Mya) terminated a relatively warm and humid period. A sclerophyllous, xerophytic flora adapted to arid conditions gradually replaced the subtropical and tropical flora previously dominating the Paleogene/early Neogene thermo-hygrophytic and evergreen forests along the Tethys shore, which were drastically reduced in range. The Messinian salinity crisis, a late Miocene desiccation of the Mediterranean Sea (5.96–5.33 Mya) caused by the closure of the Gibraltar Strait, brought further massive changes in the evolutionary trajectories of many plant groups. Subsequently, the contemporary Mediterranean climate (with two main seasons, including mild rainy winter and a dry hot summer with the regular occurrence of an effective drought at the hottest time of the year, as essence of the Mediterranean climate region) and vegetation established throughout the wider Mediterranean range and parts of South-West Asia during the late Pliocene (ca. 3.2 Mya). With the onset of a prolonged summer drought which is now related to the Atlantic anticyclone of the Azores imposing fairly uniform sunshine and a quasi-absence or scarcity of rainfall, species-rich broad-leaved forests gradually became restricted to Tertiary refugia along the coast of the Black Sea, the Caspian Sea and the Mediterranean Sea (Thompson 2005; Médail and Diadema 2009; Korotkova et al. 2018). In addition, during the late Pliocene and the early Pleistocene the final phase of vertical uplift, folding and fracturing in the orogeny of several Alpide systems in western Eurasia occurred (Hofrichter 2002; Thompson 2005), facilitating even more localized speciation.

Finally, there is ample evidence that some of the current patterns of plant diversity and differentiation found in Anatolia are also essentially related to the Pleistocene glacial/interglacial cycles (Davis 1971; Kürschner 1982; Médail and Diadema 2009). Repeated drops of sea level and snow-lines not only enabled plant migrations via land bridges and along or between mountains; they also led to waves of extinction (e.g. Thompson 2005; Médail and Diadema 2009; Korotkova et al. 2018). The complex orography and mosaics of habitats in Anatolian mountains enhanced survival possibilities during the Pleistocene climate fluctuations for many species, including some of Tertiary origin (Sękiewicz et al. 2018). It has also left imprints on the genetic diversity and intraspecific differentiation of species, resulting in divergence and vicariant speciation (Bou Dagher-Kharrat et al. 2007; Parolly et al. 2010; Sękiewicz et al. 2018). The intensified aridity during the Holocene limited the geographical ranges of many species, deepening isolation and promoting divergence (Sękiewicz et al. 2018).

7.5.2 Spatial Patterns of Endemism

Turkey shows, with ca. 11,800 subgeneric taxa (species and subspecies), an outstanding floristic diversity of native vascular plants and an enormously rich endemic flora, including 3035 endemic species (31.1%) and 500 endemic subspecies (25.2%; Güner et al. 2012).

As nearly everywhere, the endemics can occupy differently large areas. There are Anatolian-wide mountain endemics (e.g. *Minuartia erythrosepala*), species confined to a single ecoregion (e.g. *Kundmannia anatolica* in the Antalya Bölümü) or much more localized taxa, known to occur only on a single massif (e.g. *Seseli ramosissimum* on the eastern Beydağları), summit, valley or cliff (e.g. *Scorzonera karabelensis* on Karabel pass; Parolly and Kilian 2003; Güner et al. 2012). In case of such narrow endemics, the reasons behind such range restrictions is often not fully understood, but may include floral-historical events (including extinction events) and natural distribution barriers e.g. caused by topography, geology and dispersal biology.

Most endemics are scattered throughout the country, but are few in Thrace (Ekim and Güner 2000). Endemism concentrates in the Irano-Turanian and Mediterranean Regions (Davis 1971; Ekim and Güner 2000). A fairly large number of endemics are apparently confined to areas where adjacent regions meet or intergrade (Davis 1971; Ekim and Güner 2000; Parolly 2015) – and this is often along the borders of the different mountain ranges. Consequently, the most diverse centres of endemism in Turkey are located in the mountain ranges (Davis 1971; Kürschner 1984; Ekim and Güner 1986; Ekim et al. 2000; Özhatay et al. 2005; Eren et al. 2004; Parolly 2004, 2015).

Already a first look on maps compiling the numbers of endemic taxa and the rate of endemism per 'Flora of Turkey' grid cells (Davis 1965) clearly shows that all seven grid cells (out of 30 in total) with more than 400 endemic species are connected with the extension of the Taurus Mts. (including the Anatolian Diagonal; Özhatay et al. 2005). Only few other cells have totals of more than 250 endemics. Four of them are in Inner Anatolia and their enhanced rate of endemism is certainly also connected with the local mountains. A further five high-endemism cells include the four comprising the Black Sea Mts. and the isolated one framing the East Anatolian Highlands with Van Gölü in its centre.

Similar impressive totals are revealed by focussing on the number of endemic vascular plant taxa of Turkish vilayets (provinces) with large portions of their territories being part of the Taurus range (including the Anatolian Diagonal), such as Adana (470 taxa), Antalya (840), Burdur (302), Denizli (282), Hatay (258), İsparta (446), Kahramanmaraş (502), Kayseri (543), Konya (726), Malatya (308), Mersin (560), Muğla (479), Niğde (507) and Sivas (481; Torlak et al. 2010). By contrast, vilayets forming part of the Black Sea Mts. range are normally well below the 200 endemic-taxa-per-vilayet threshold, while the East Anatolian Highlands display higher figures, e.g. Van (372; Torlak et al. 2010).

In general, the rate of endemism per 'Flora of Turkey' grid cell is well above 20% within the Taurus range (but drops to ca. 10% in the Hakkâri range), between 10 and 14% in cells passed by the Black Sea Mts. and around 14% in the East Anatolian Highlands around Van Gölü (Özhatay et al. 2005).

In some of its massifs, total endemism rates up to 30% have been recorded (Eren et al. 2004). As a rule, the highest number of endemic species of the Taurus Mts. certainly concentrates in the lower elevations (montane belt complex s.l.), along with many different habitat types offered in the various forest ecosystems, gorges and valley bottoms with xeric and hygric sites, cliffs and scree and a diverse geology (Parolly 2015). However, due to the normally very species-rich community inventories at these elevations, the percentage of endemism is lower than higher up, where endemic species (narrow endemics, Taurus endemics and Anatolian-wide endemics) increasingly dominate the vegetation of scree slopes, cliffs, snow-patches, grasslands and open dwarf-shrub and thorn-cushion communities (Kürschner 1982; Parolly 1995, 2004; Hein et al. 1998; Kürschner et al. 1998). Typical communities of high-mountain vegetation display percentages of endemic species ranging between 20 and 60%, often with rates of endemism rising with altitude, making the highest elevations of the area outstandingly important in terms of conserving the high-mountain diversity (Parolly 2015).

Already Davis (1971) has identified the most important centres of diversity (Lycian Taurus, Isaurian Taurus, Bolkar Dağları, etc.) as being related to mountain ranges. They often correspond to the present day's IPs (Özhatay et al. 2005). In addition, Médail and Quézel (1999) consider all the south-west and south coast of Anatolia as representing a particular biodiversity hotspot.

7.5.3 Spatio-Temporal Components of Endemism

7.5.3.1 Generic Endemism

Overall, the rate of generic endemism in Anatolia is moderate. Depending on taxonomic concepts, Turkey has got 14 (Güner et al. 2012) to 15 mostly monotypic genera (Ekim in Güner 2014), of which *Aegokeras caespitosa* (*Olymposciadium caespitosum*), *Crenosciadium siifolium* (both Apiaceae), *Physocardamum davisii* (Brassicaceae), *Phrynella ortegioides* (Caryophyllaceae), *Sartoria hedysaroides*

(Fabaceae), *Dorystoechas hastata* (Lamiaceae), *Oreopoa anatolica*, *Pseudophleum* (*P. anatolicum* and *P. gibbum*) and *Thurya capitata* (all Poaceae) are more or less associated to the mountain vegetation of the Tauric System, while *Tchihatchewia anatolica* (Brassicaceae) is confined to the steppe belt of the mountains of the Anatolian Diagonal.

Recently, the generic status of some of these genera has been challenged. *Phrynella ortegioides* was sunken in *Bolanthus* by Madhani et al. (2018). *Physocardamum davisii*, which has a narrow distribution in East Anatolia (Güner et al. 2012), was formally combined under *Bornmuellera* (Rešetnik et al. 2014). The other two cases require further studies. *Dorystoechas* was found in a monophyletic lineage within *Mentheae* (and a polyphyletic *Salvia*) consisting of the genera *Lepechinia*, *Melissa*, *Salvia* p. p., *Meriandra*, *Zhumeria*, *Perovskia* and *Rosmarinus* (Walker and Sytsma 2007). For *Oreopoa,* more sampling was recommended, but the first data indicate its position within a wide *Poa* (Amiri 2016). Among these genera, *Aegokeras caespitosa*, *Crenosciadium siifolium* and *Oreopoa anatolica* are the only high-mountain plants in a strict sense and only the latter grows in high-alpine elevations (Parolly and Scholz 2004; Eren et al. 2004).

7.5.3.2 Paleo-Endemism and Further Ancient Links

Most of the endemic species of the high-mountains of Turkey, the Eastern Mediterranean and the Near East are geologically young (Davis 1971; Zohary 1973; Thompson 2005; Sękiewicz et al. 2015, 2018). However, there are a remarkable number of taxonomically and geographically isolated taxa which are often considered as paleo-endemics (Davis 1971, 1965–1985; Parolly et al. 2005). The above mentioned endemic genera may also be seen under this perspective. As to be expected for putative survivors of former moister (and warm) conditions, they mostly dwell in montane rather than in higher elevations; exceptions might include *Asyneuma compactum*, *A. junceum* and *Oreopoa anatolica* in the Taurus range.

The Colchic Sector of the Black Sea Mts. range has the densest concentration of Arcto-Tertiary relicts in Anatolia, many of them woody plants and again, often confined to lowland and montane situations. Most of them, including *Hedera colchica*, *Ilex colchica*, *Ruscus colchicus* and *Staphylea colchica*, have their main centres of occurrence in the Colchic ranges of the Western Caucasus across the border and do extend further west than the Melet River (see above). Only few of them form part of the subalpine vegetation such as *Betula browicziana*, *Rhododendron ungernii*, *R. smirnowii*, *Quercus pontica* and *Scutellaria pontica*. A few other species-poor genera (and further species revealing ancient links) with narrower ranges in North-eastern Anatolia and adjacent Caucasia have been discussed above (Sect. 7.4.3.2).

In a comprehensive molecular study, the North-east Anatolian/Caucasian tall forb *Gadellia lactiflora* (as *Campanula lactiflora*) was resolved in a well-supported basal clade together with two out of three species of the Madeiran endemic genus *Musschia* and three further of *Campanula*, namely *C. axillaris* (endemic to Turkey), *C. peregrina* and *C. primulifolia* (Mansion et al. 2012). This so-called '*Musschia* clade' "depicts interesting geographical links between the eastern and western Euro-Mediterranean area. The great morphological and cytological diversity found in this clade, with overall rather low diversification rates […], could suggest a high age and active episodes of extinction during the last ten million years" (Mansion et al. 2012). Some ancient taxa are abundant in the wider Black Sea range, such as *Rhododendron ponticum* subsp. *ponticum* or *Fagus orientalis* (west to the eastern Balkans). *Abies nordmanniana* comprises two subspecies: subsp. *nordmanniana* in the Western Caucasus and the Colchic Sector and subsp. *equi-trojani* (incl. subsp. *bornmuelleriana*) in the western Black Sea Mts. and on some mountains of Western Anatolia.

Within the Tauric System, most of the putatively relictual species are found scattered and localized at sheltered places on the mountains across the Taurus, as in *Amphoricarpus exsul*, growing at a very few places in the Lycian Taurus. It has a similar congener in the adjacent Pisidian Taurus and much taller allies in the Dinarids and the Georgian Caucasus (Grierson 1975). By contrast, there are also areas, especially in the coastal Taurus, which show enhanced proportions of ancient species growing localized on well-protected sea-facing cliffs of never glaciated mountains and promontories. The eastern part of the Lycian Taurus between Tahtalı Dağı and Bakırlı Dağı above Saklıkent stands out in this respect by supporting a particularly high number of tentative paleo-endemics such as *Asyneuma lycium*, *A. pulvinatum*, *Ballota cristata*, *Dorystoechas hastata*, *Echinops emiliae*, *E. onopordon*, *Globularia davisiana*, *Lomelosia solymica*, *Scrophularia candelabrum*, *Seseli hartvigii* and *Verbascum pestalozzae* (Davis 1971; Eren et al. 2004; Parolly et al. 2005). For examples from the Isaurian and Cilician Taurus, see Sect. 7.4.4.3.

The two Anatolian species of the mainly South African genus *Pelargonium* are considered as isolated relict species, which are also caryologically distinct (Mill 1994b). Interestingly, both are associated to fairly dry woodlands in mid-range elevations and by no means confined to 'sheltered' situations. *Pelargonium endlicherianum* (Fig. 7.5e) grows in open and rocky coniferous forest in many parts of Anatolia and in the Syrian Desert; Davis 1967); *P. quercetorum* is restricted to the south-east of the range and grows in xerophytic woods in Hakkâri and northern Iraq (Mill 1994b).

7.5.4 Neo-endemism and Further Patterns of Endemism

Endemism in mountainous Anatolia is strongly linked to genera which are particularly well developed in Turkey (Davis 1971; Zohary 1973; see the genera listed for the mountain systems and below), i.e. endemism is often clustered. There are many groups of plants displaying compact endemism confined to nuclei of floristic differentiation (Zohary 1973) such as along the boundaries of the phytochoria (Davis 1971; Takhtajan 1986; Parolly et al. 2010). Many endemics have small to extremely narrow distribution areas. The morphological differences between such biological units are often only slight and this can provide difficulties in identifying the taxa.

This often relates to low genetic differentiation because of relatively recent separation of populations and/or effective gene flow (Thompson 2005). Two further predominant patterns of diversity and differentiation are observed for narrow endemic plants from the area: (1) a high level of among-population differentiation due to long-lasting isolation, random genetic drift and bottleneck effect; (2) no clear genetic structure associated with a profound loss of genetic diversity (Sękiewicz et al. 2018).

The vast majority of the endemic species of the high-mountains of Turkey with range restrictions are neo-endemics (Davis 1971; Zohary 1973; Thompson 2005; Sękiewicz et al. 2015, 2018). Good examples are found in *Alyssum*, *Erysimum*, *Hesperis*, *Noccaea* and *Odontarrhena* in Brassicaceae; *Alkanna* in Boraginaceae; *Campanula* sect. *Rupestres* and *Tracheliopsis* in Campanulaceae; *Astragalus* sect. *Hololeuce* in Fabaceae; *Origanum*, *Phlomis* sect. *Dendrophlomis*, *Salvia* (though more prominent in the steppe zone than at higher elevations), *Sideritis* sect. *Empedoclea* and *Stachys* in Lamiaceae, in *Verbascum* (Scrophulariaceae) and in *Veronica* (Plantaginaceae; Davis 1965–1985, 1971; Davis et al. 1988; Güner et al. 2000). They contain many corresponding or vicarious taxa replacing each other locally, following geographical, altitudinal or site-edaphical patterns. Anatolia is especially rich in endemic plant species, which demonstrate such schizo-endemic distribution patterns (Parolly 1995, 2004; Médail and Quézel 1999; Thompson 2005), although for most of them a molecular support of this hypothesis is pending. The schizo-endemic model assumes the existence of widespread ancestral species that evolved into narrowly distributed and geographically isolated sister species as a result of range fragmentation and subsequent allopatric speciation (Thompson 2005).

The high-mountain vegetation of the Taurus reveals a major principle of the taxonomic structuring of the vegetation and the phytogeographic patterning in the Mesogean Tauric System: Its vegetation units are often characterized by complexes of vicarious and/or corresponding species. Analysing their distribution patterns and species differentiation is a keystone in understanding evolution processes in the area. Many genera contribute with two or more allopatric (or at least allotropic) taxa to the high-mountain flora and vegetation of a particular vegetation type or biogeographic sector and morphologically close species often differentiate the flora and vegetation of neighbouring mountains, as exemplified by the South-West Asian scree-creeping *Heldreichia*, comprising a single polymorphic species, *H. bupleurifolia*, with four largely geovicarious subspecies (Parolly et al. 2010). The scree vegetation of each Taurus section in the west is characterized by a particular taxon; along the Anatolian Diagonal and on the Eastern Taurus three taxa occur, but never sympatrically. Geographical areas with higher morphological and molecular diversity correspond to the generally accepted diversity centres of the Taurus Mts. Interpluvial migration events between isolated mountain ranges may have contributed to the morphological and genetic diversity within *Heldreichia* (Parolly et al. 2010).

Sympatric substrate vicarism (especially limestone vs. serpentine) within the same type of ecosystem is frequently found and occurs e.g. in *Eryngium* (*E. thorifolium* on serpentine, *E. pseudothorifolium* on calcareous soil; Davis et al. 1988). Geovicarism can additionally involve substrate vicarism, sometimes in combination with habitat shifts (Parolly 2015). In some genera, as in *Ricotia*, *Scorzonera* and partly in *Lamium* (see below), species of different evolutionary lineages (so-called corresponding species) colonize the same habitat type within different mountain sections. A few examples may illustrate these scenarios.

The best understood example is provided by *Ricotia* (*Biscutelleae*), which is a monophyletic crucifer genus of nine species endemic to the East Mediterranean Subregion; their origin (ca. 9.2–11.3 Ma) predates the Messinian Salinity Crisis (5.9–5.3 Ma) and the onset of the Mediterranean climate (Özüdoğru et al. 2015). Three perennial scree species characterize three different parts of the Taurus Mts. *Ricotia davisii* (eastern Lycian Taurus) and *R. varians* (western Pisidian Taurus) have narrow ranges and are morphologically very close to each other. The more widespread *R. aucheri* stands morphologically apart and replaces them on the mountains of the Anatolian Diagonal to the east (Parolly 1995). In a molecular study (Özüdoğru et al. 2015) *R. aucheri* formed a distinct lineage sister to all remaining *Ricotia* species. Interestingly, *R. davisiana* and *R. varians* were resolved in different clades, each together with annual species. The same study revealed that Mediterranean *Ricotia* species arose in southwest Anatolia (likely Antalya region), with the perennial life cycle as appearing to be ancestral. The latter is a key prerequisite of colonising subalpine-alpine habitats prone to physical damage (Parolly 1995, 1998).

A similar scenario might be expected for parts of *Lamium*. Some of its members play an important role on scree. *Lamium eriocephalum* subsp. *eriocephalum* (*L. amplexicaule* group) is a dominant of mobile limestone screes of the Cilician Taurus, and its subsp. *glandulosidens* occupies the same habitat in the Pisidian and Isaurian Taurus (Parolly 1995). To the west and to the east, *L. eriocephalum* is replaced by members of the *L. garganicum* group (hence, they are corresponding species – occupying the same ecological niche at different places without being too closely allied): The screes of the westernmost edge of the Taurus (e.g. Honaz Dağı) are marked by *L. microphyllum*, those of the Lycian Taurus by the very similar vicariant *L. cymbalariifolium* (both *L. cymbalariifolium* agg.). This principle continues on the Inner Anatolian volcanoes and on the mountains east of the Diagonal (including North-eastern Anatolia), where scree vegetation displays the variable *L. armenum* (incl. *L. veronicifolium*), often in combination with a substrate shift (often on non-limestone rock). In contrast to the other mentioned species, *L. armenum* has a much wider range, growing also outside Anatolia in the neighbouring countries to the east (Parolly 1995). Another closely related species of this group is *L. sandrasicum*, colonizing a different substrate (serpentine) and habitat (rocks and gullies) more or less within the same range as the *L. cymbalariifolium* agg. (Parolly 1995, 2015). In addition to this, *L. garganicum* subsp. *striatum* (incl. subsp. *reniforme*) grows throughout the Taurus Mts. (sympatrically and often syntopically) together with one of the other *Lamium* species on scree and rock, but without being confined to lithophytic habitats.

Habitat shifts are also observed in *Scorzonera* sect. *Nervosae*. This mainly Irano-Turanian group shows traits of secondary evolution in the Taurus Mts. (Parolly and Kilian 2003). In the montane belt of southern Anatolia, rosulate hemicryptophytes prevail on rocky slopes and in open forests. The vicarious *S. karabelensis* and *S. ulrichii* occur localized on limestone in open, montane pine forests of the Lycian and Isaurian Taurus, respectively. By contrast, the pseudovicarious *S. pisidica* is a serpentinophyte of barren landscapes in the Lycian Taurus once occupied by pine forests (Kilian and Parolly 2002; Parolly and Kilian 2003). Further east, the widespread *S. cinerea* grows in different open habitats and on various substrates up to subalpine elevations. Here, rosulate hemicryptophytes or pulvinate chamaephytes of *Scorzonera* sect. *Nervosae* and *S.* subgen. *Pseudopodospermum*, especially of the *S. suberosa* group (*S. sandrasica*, *S. szowitzii*, *S. phaeopappa*), are typical. In the alpine belt, they are replaced by pulvinate chamaephytes such as *S. pygmaea, S. rigida* and *S. sericea* (*Scorzonera* sect. *Pulvinares*/*S. sericea* group; Parolly 2015).

Comparable patterns, underpinning the phytogeographical subdivision of Anatolia, are found in *Galium, Nepeta*, *Noccaea, Omphalodes luciliae* (Fig. 7.5j), *Potentilla* sect. *Crassinervis*, *Scrophularia*, *Valeriana* spp. and *Veronica* (Hein et al. 1998; Parolly 1995, 1998; Parolly and Nordt 2002).

7.6 Major Vegetation Types

7.6.1 High-Mountain Vegetation of the Black Sea Mts. and Their Outliers

The classification of the North Anatolian high-mountain vegetation above the treeline is still in flux and the local classification schemes tend to over-emphasize the distinctness of the local vegetation classes by neglecting the rich literature about the sometimes very similar European high-mountain vegetation (e.g. Caucasus, Balkans, Alps; Parolly 2004). Some major vegetation types remain entirely unstudied. Nevertheless, a certain number of regional studies provide a good overview of the existing diversity in terms of plant species and vegetation (Düzenli 1988; Vural 1996; Öztürk et al. 1998; Eminağaoğlu and Kutbay 2006; Eminağaoğlu et al. 2007; Terzioğlu et al. 2007, 2015; Uzun and Terzioğlu 2008; Huseyinova and Yalcin 2018).

The mountains of the region are mainly covered by forest and subalpine–alpine vegetation types. There is a very wide range of different and well-studied mountain forests (Querco-Fagetea), including deciduous forest, mixed forest and coniferous forest, all characterized by widespread Euro-Siberian species such as *Aruncus vulgaris, Athyrium filix-femina, Blechnum spicant, Carex ornithopoda* subsp. *ornithopoda, C. sylvatica, Neottia ovata, Myosotis sylvatica, Sanicula europaea, Stellaria holostea* and *Viburnum opulus* (Quézel et al. 1980; Quézel 1986; Akman 1995). In lower and mid-montane elevations broad-leaved *Fagus orientalis* forests (Rhododendro-Fagetalia orientalis) with higher percentages of evergreen species such as *Hedera colchica, Hypericum androsaemum, Ilex colchica, Rhododendron ponticum*, *Ruscus hypoglossum* and *Smilax excelsa* prevail. Their species inventory includes e.g. *Acer cappadocicum, Acer trautvetteri, Daphne pontica, Epimedium* *pubigerum, Rhododendron luteum, Salvia forsskaolei, Scilla bithynica, Hypericum calycinum, Lapsana communis* subsp. *alpina, Quercus petraea* subsp. *iberica, Sophora jaubertii, Taxus baccata, Tilia begoniifolia, Trachystemon orientalis* and *Vaccinium arctostaphylos* (Quézel et al. 1980; Quézel 1986; Eminağaoğlu and Kutbay 2006; Eminağaoğlu et al. 2007; Terzioğlu et al. 2015). The river courses and deep valleys of this zone are lined by lush gallery forests (Alnion barbatae) dominated by *Alnus glutinosa* subsp. *barbata, Oreopteris limbosperma* and *Circaea lutetiana*. Higher up, conifers, mostly *Abies nordmanniana* s.l., *Picea orientalis* (in the eastern part) and *Pinus sylvestris* var. *hamata*, gradually gain dominance in monospecific or mixed stands in the mountain forests (Pino-Piceetalia orientalis; Fig. 7.6g). Frequently associated species include e.g. *Campanula latifolia*, *Cardamine pectinata*, *Chaerophyllum macrospermum*, *Cyclamen coum* subsp. *caucasicum*, *Digitalis ferruginea* subsp. *schischkinii*, *Dryopteris aemula*, *D. dilatata*, *Gentiana asclepiadea, Paris incompleta*, *Phedimus stoloniferus*, *Ranunculus cappadocicus*, *Symphytum asperum*, *Telekia speciosa*, *Valeriana alliarifolia*, *Viburnum orientale* and *Vicia crocea* (Quézel et al. 1980; Eminağaoğlu et al. 2007; Manvelidze et al. 2009; Terzioğlu et al. 2015).

7.6.1.1 Lithophytic Vegetation

Vegetation on Scree and Flood Plain Pebble Beds Scree vegetation of the Irano-Turanian (Caucasian) type, which is composed by species of the Mesogean floristic stock, some Caucasian species and a few widespread Eurasian species, is confined to dry valleys or to the southern macroslope of the Black Sea Mts. In the Kaçkar Mts. above Olgunlar I recorded e.g. *Coluteocarpus vesicaria* subsp. *vesicaria, Lamium tomentosum*, *Ricotia aucheri*, *Rumex scutatus*, *Silene lacera* and *Vicia alpestris* subsp. *alpestris* on mobile granitic scree (Parolly 2004 and pers. obs.). This vegetation type will be dealt with in some detail in the chapter on East Anatolian vegetation (Sect. 7.6.3.1).

In addition, there is also an Euro-Siberian type (Caucasian type) siliceous scree vegetation (Androsacetalia alpinae, Thlaspietea rotundifolii) present, colonizing mesic to damp places. The typical species inventory of hygrophytic subalpine-alpine scree vegetation (Murbeckiellion huetii), growing on moraines and talus slopes with a permanent or sufficient seasonal water supply, is given below in the context of chionophytic vegetation. Another vegetation (Allosuro-Athyrion alpestris) dwells in subalpine (to alpine) elevations on stabilized mesic granite talus slopes and boulder-fields, together with abundant *Rubus idaeus* and ferns such as *Athyrium alpestre*, *Polystichum aculeatum*, *P. woronowii* and *Woodsia alpina* (Parolly 2004 and pers. obs.).

Some of the high-mountain rivers and larger brooks still run free and meander through wide flood plains. The vegetation on their pebble beds (Epilobietalia fleischeri) is of Euro-Siberian type and includes open stands of *Myricaria germanica*, few other woody species (*Hippophae rhamnoides* subsp. *caucasica*, *Salix* *purpurea*) and herbs such as *Atocion compactum*, *Epilobium colchicum* and *E. dodonaei* (Parolly 2004).

Chasmophytic Vegetation The rock vegetation (Asplenietea trichomanis) of the western outliers of the Black Sea Mts. range (Uludağ and surroundings) features *Anthemis cretica* subsp. *carpatica*, *Aubrieta olympica*, *Centaurea drabifolia* subsp. *drabifolia*, *Hesperis montana*, *Hieracium bornmuelleri*, *Iberis spruneri* and *Iranecio hypochionaeus* (Quézel and Pamukçuoğlu 1970; Güleryüz 2000). This vegetation (Aubrietion olympicae) interposes between the rock vegetation of the Balkan Peninsula and the one of the Taurus Mts. (Silenetalia odontopetalae), in which it can be included (Hein et al. 1998).

The chasmophytic vegetation on siliceous rock of the Black Sea Mts. (Androsacetalia multiflorae) deviates strongly from it and remains unstudied (Parolly 2004). The following species list is taken from my field book notes of the eastern Black Sea area, and comprises only a small selection of the rich flora found on cliffs: *Asplenium ruta-muraria*, *A. septentrionale*, *Campanula* sect. *Symphyandriformes* (*C. betulifolia*, *C. choruhensis*, *C. seraglio*, *C. troegerae*), *Crytogramma crispa*, *Dianthus cretaceus*, *D. crinitus*, *D. orientalis* s.l., *Draba* spp., *Erysimum ibericum*, *Potentilla adzharica*, *Psephellus* spp., *Pseudocherleria imbricata*, *Sabulina biebersteinii*, *Saxifraga juniperifolia*, *S. kolenatiana*, *S. kotschyi*, *S. paniculata* subsp. *cartilaginea*, *Seseli petraeum*, *S. tortuosum* and *Silene saxatilis* (Parolly, pers. obs.).

7.6.1.2 Euro-Siberian High-Mountain Vegetation

Crooked Birch Forest Vegetation The subalpine belt is marked by a vegetation complex involving birch forest, tall forb vegetation and/or *Rhododendron caucasicum* scrub (Fig. 7.6h). Birch forests are represented by dwarf, semi-creeping formations of crooked-stem trees, mainly composed by dense stands of *Betula litwinowii*, *Sorbus aucuparia* s.l. and *Salix caprea*; the trees are pressed to the ground under snow masses and the lower parts of their trunks are rooted. They occur mainly between 2000 and 2300 m a.s.l. The tree-layer is often sparse. This kind of vegetation is very diverse; sometimes more than 100 taxa have been recorded, including many attractively flowering species such as *Aconitum nasutum* (Fig. 7.6i)*, Anemonastrum narcissiflorum, Astrantia maxima, Helianthemum nummularium* subsp. *tomentosum* and *Lilium ponticum* (Terzioğlu et al. 2015). In the Colchic Sector, structurally similar stands are centred in the montane forest belt, which are composed of *Quercus pontica, Rhododendron smirnowii* and *R. ungernii*. They additionally display *Betula medwediewii* in the tree layer and *Doronicum balansae, Epigaea gaultherioides, Helichrysum artvinense*, *Inula helenium* subsp. *orgyalis*, *Papaver lateritium*, *Ruscus colchicus* and *Veronica peduncularis* in the understory (Eminağaoğlu and Kutbay 2006; Terzioğlu et al. 2015).

Rhododendron caucasicum **scrub** At and above the tree-line, as a natural belt or as replacement vegetation of degraded forest, the Black Sea Mts. feature extensive stands of subalpine dwarf-shrub heathland of the European boreo-arctic type (Rhododendro-Vaccinietalia, Loiseleurio-Vaccinietea). They are rich in ericaceous dwarf-shrubs, cryptogams, graminoids and lycopodioids (e.g. *Lycopodium alpinum*, *Selaginella denticulata*), but otherwise fairly species-poor and grow mostly on poor acidic soils. On the mountains of North-west Anatolia and on the western Black Sea Mts., this vegetation is mainly *Bruckenthalia spiculifolia* heathland (Bruckenthalion), characteristic for the Central Balkans and northern Turkey (Quézel and Pamukçuoğlu 1970; Parolly 2004). In the Colchic Sector, it is replaced by Caucasian *Rhododendron caucasicum* scrub (Fig. 7.6h), typical of montane to alpine altitudes (Vaccinio myrtilli-Rhododendrion caucasici; Vural 1996; Parolly 2004). These heathlands often form vegetation complexes with siliceous grasslands, snow-bed vegetation or with birch forests of the tree-line and are mainly distributed between 2300–2700 m a.s.l. Their key components include *Deschampsia flexuosa*, *Empetrum nigrum* subsp. *hermaphroditum*, *Juniperus communis* subsp. *nana*, *Milium schmidtianum*, *Oxalis acetosella*, *Rhododendron caucasicum*, *Solidago virgaurea* subsp. *minuta*, *Vaccinium myrtillus* and *V. uliginosum* (Vural 1996; Terzioğlu et al. 2015).

Tall Forb Vegetation Subalpine tall forb vegetation (Lilio pontici-Anemonion narcissiflorae p.p., Mulgedio-Aconitetea) is a particularly diagnostic feature of Caucasian type mountains. Often associated with subalpine woody vegetation such as mountain forest, birch krummholz or *Rhododendron* scrub, the rainy climate and good nutrient supply allows the accelerated growth of many tall herbs, composing different kinds tall forb vegetation. Its stands attain quickly heights of 1.5–2 m or more, and grow at naturally nutrient-rich places on the mountain slopes such as ravines or near water courses. Typical species include *Aconogonon alpinum*, *Aconitum nasutum*, *A. orientale*, *Angelica purpurascens*, *Anthriscus nemorosa*, *Calamagrostis* spp., *Campanula latifolia*, *Centaurea macrocephala*, *Cephalaria gigantea*, *Delphinium flexuosum*, *Deschampsia cespitosa*, *Epilobium angustifolium*, *Gadellia lactiflora*, *Galega orientalis*, *Geranium psilostemon*, *Heracleum* spp., *Inula* spp., *Knautia montana*, *Lactuca bourgaei*, *L. deltoidea*, *L. macrophylla*, *Lilium* spp., *Silene multifida*, *Symphytum* spp., *Tanacetum macrophyllum* and *Vicia balansae*.

In all of northern Anatolia, close to mountain settlements and on pastures, nitrophytic tall herbaceous vegetation (Rumicion alpestris) is found, often to form distinct lair communities led by *Rumex alpestris*, giant *Heracleum* spp. and *Urtica dioica* (Rehder et al. 1994; Parolly 2004).

Alpine siliceous Grasslands Above the dwarf-shrub belt, siliceous 'northern type' grasslands (Caricetea curvulae) form the predominating plant cover (Parolly 2004; Huseyinova and Yalcin 2018). In North-western Anatolia, namely on Uludağ, Bozdağ and Kaz Dağı and under increasingly Mediterranean conditions, this vegetation is restricted to places with a long-lasting snow cover (Quézel and Pamukçuoğlu 1970; Gemici et al. 1994). It develops into a particular kind of hygro- to mesophytic siliceous carpet turf found on the high-mountains of Greece and North-West Anatolia (Trifolietalia parnassi) only, which bears a transitional character between boreo-alpine grasslands and the chionophytic vegetation of the Taurus range (Quézel 1973; Kürschner et al. 1998; Parolly 2004). Its characteristic species include *Astragalus idea*, *Bromopsis riparia*, *Cerastium banaticum*, *Hypericum aucheri*, *Viola gracilis*, etc. (Quézel and Pamukçuoğlu 1970; Ketenoğlu et al. 2014).

In the Euxine and Colchic sectors, extensive siliceous grasslands of the boreo-alpine type form the zonal vegetation of the alpine belt. Several major vegetation units have been described within this vegetation type (Düzenli 1988; Vural 1996), but there is still no convincing classification scheme available which would integrate the conflicting syntaxonomic approaches from Europe, the Caucasus and Turkey (Parolly 2004; Huseyinova and Yalcin 2018). These grasslands (Alchemillo retinervis-Sibbaldietalia parviflorae, Caricetea curvulae) are taken here in a narrow sense by excluding all stands from hygrophytic vegetation (see below, Swertio ibericae-Nardion strictae) and dwarf-shrub heaths (Vaccinio-Rhododendrion caucasici, see above) as suggested in an earlier paper (Parolly 2004). They comprise mesophytic alpine turf, open swards, alpine cushion vegetation and meadow-like stands with higher proportions of taller forbs. Its various communities are distributed over North-eastern Anatolia between 2000 and 3100 m a.s.l. and are rich in herbaceous species (Vural 1996; Terzioğlu et al. 2015). Characteristic species of this vegetation type include *Achillea latiloba*, *Alchemilla caucasica*, *A. pseudocartalinica*, *Androsace albana, Allium dijimilense, Anthoxanthum odoratum* subsp. *alpinum*, *Astragalus oreades*, *Betonica macrantha*, *Bistorta officinalis* subsp. *carnea*, *Campanula aucheri* (Fig. 7.6e), *C. collina*, *C. stevenii* s.l., *C. tridentata*, *Carex atrata* subsp. *aterrima* and subsp. *atrata*, *C. caucasica*, *Cerastium dahuricum*, *C. purpurascens*, *Chaerophyllum astrantiae*, *Crocus vallicola*, *Cyanus nigrifimbrius*, *Daphne glomerata*, *Draba hispida*, *Erigeron caucasicus*, *Festuca anatolica* subsp. *borealis, F. chalcophaea*, *F. lazistanica, F. woronowii, Gentiana septemfida*, *Gentianella caucasea*, *Geranium lazicum, G. ponticum, G. platypetalum, Gnaphalium stewardtii*, *Gypsophila silenoides*, *Hedysarum hedysaroides*, *Helictotrichon argaeum, Luzula pseudosudetica*, *Pedicularis nordmanniana*, *Phedimus spurius*, *Phleum alpinum*, *Pilosella hoppeana* subsp. *testimonialis*, *Poa longifolia*, *Polygala alpestris*, *Potentilla ruprechtii*, *Pseudocherleria imbricata*, *Ranunculus brachylobus* subsp. *brachylobus*, *Rumex tuberosus* subsp. *horizontalis*, *Stachys balansae* subsp. *balansae*, *Tanacetum kotschyi, Thymus praecox* subsp. *grossheimii*, *Trifolium ambiguum*, *Veronica gentianoides* (Fig. 7.6b) and *Viola altaica* subsp. *oreades* (Düzenli 1988; Vural 1996; Terzioğlu et al. 2015). Pastures dominated by *Nardus stricta* are abundant.

Chionophytic Vegetation Chionophytic vegetation of the alpine belt (2500–3200 m a.s.l.) occurs in various forms, ranging from extensive siliceous snow-bed turf dotted by *Campanula tridentata* to damp block scree, where the snow hangs late. The phytosociological affinities of the many units described (Vural 1996; Onipchenko 2002) are yet unsettled, but possible classifications have been discussed by Parolly (2004). In typical snow-beds (Salicetea herbaceae) on relatively thick layers of raw humus, the vegetation is dense but low, attaining hardly more than 20 cm in height. *Alchemilla retinervis*, *A. sericea*, *Carum* spp., *Cerastium cerastioides*, *Corydalis alpestris*, *C. conorhiza*, *C. oppositifolia*, *Pseudocherleria aizoides* and *Sibbaldia parviflora* are often found associated to snow-bed sites on siliceous substrates. In the shelter of the stones of block scree, some plants can grow higher. The vegetation bears the character of a meltwater community. Such places are colonized by *Alchemilla ellenbergiana*, *A. rizensis*, *Alopecurus glacialis*, *Arabis caucasica* subsp. *caucasica*, *Cerastium purpurascens*, *Epilobium algida*, *Hyalopoa pontica*, *Iranecio taraxacifolius*, *Murbeckiella huetii*, *Oxyria digyna*, *Saxifraga sibirica* (incl. subsp. *mollis*), *Sedum tenellum*, *Veronica telephiifolia* and *Viola altaica* subsp. *oreades* (Vural 1996; Terzioğlu et al. 2015; Parolly. pers. obs.).

7.6.1.3 Azonal Vegetation: Low-Sedge Fens and Vegetation Along Springs and High-Mountain Rapids

Hygrophytic terrestrial vegetation is a frequent sight in the water-rich Black Sea Mts. Two principal vegetation types can be distinguished: The edges of the many cold springs and fast-running high-mountain rapids are lined by low-growing, bryophyte- and herb-rich acidophytic vegetation (Montio-Cardaminetea; see Parolly 2004). During mountain summer they often appear as a narrow yellow fringe along the water runnels due to the abundance of the numerous lavishly flowering *Alchemilla* species. Other typical elements include *Arenaria rotundifolia*, *Cardamine acris* subsp. *raphanifolia*, *Juncus alpigenus* and *Mentha* spp. (pers. obs.).

The second vegetation type grows on seepage slopes and occupies large parts of damp valley bottoms, often cut by rapids or supported along meandering creeks (Byfield and Özhatay 1997). This acidophytic to subneutral vegetation of transitional mires, low-sedge fens and bog hollows (Caricetalia fuscae, Scheuchzerio-Caricetea fuscae) is in the Black Sea Mts. and the Caucasus represented by a particular unit (Swertio ibericae-Nardion strictae). Besides many mosses, characteristic species are e.g. *Alchemilla mollis, Blysmus compressus*, *Caltha polypetala, Cardamine uliginosa, Carex nigra* subsp. *nigra, C. pallescens, C. pyrenaica, Cirsium rhizocephalum*, *C. simplex*, *Dactylorhiza euxina, Geum coccineum, Nardus stricta, Pinguicula balcanica* subsp. *pontica, Primula auriculata*, *Swertia iberica*, *Taraxacum crepidiforme* and *Trifolium spadiceum* (Vural 1996; Parolly, pers. obs.). Both units often form vegetation complexes; the limits between the two and its contact communities have still to be clarified.

7.6.1.4 Temperate Grasslands, Hay-Meadows

The Black Sea range is famous for its colourful and diverse extensively managed hay-meadows (Molinio-Arrhenatheretea), mostly dwelling between 1400 and 2200 m a.s.l. (Fig. 7.6f). Most species of this anthropogeneous habitat certainly originate from the siliceous grasslands of the higher elevations and from tall forb vegetation. Frequently found taxa include *Alchemilla barbatiflora*, *Anemonastrum narcissiflorum*, *Anthoxanthum odoratum*, *Aquilegia olympica*, *Asyneuma amplexicaule, A. campanuloides*, *Betonica macrantha, Centaurea* spp., *Cynosurus cristatus*, *Dactylis glomerata*, *Euphrasia sevanensis*, *Festuca* spp., *Geranium ibericum*, *Lilium* spp., *Lomelosia caucasica*, *Ornithogalum platyphyllum*, *Polygala anatolica*, *Ranunculus kotschyi*, *Tragopogon aureus*, *Trifolium alpinum*, *T. canescens*, *T. trichocephalum*, *Tripleurospermum monticolum* and *Veronica gentianoides* (Vural 1996; Terzioğlu et al. 2015; Parolly, pers. obs.).

7.6.1.5 Mesogean High-Mountain Vegetation

Besides meso- to hygrophytic Euro-Siberian type mountain vegetation, there is also xerophytic grassland and dwarf-shrub vegetation (Astragalo microcephali-Brometea tomentelli), often with tragacanthic species and always largely composed of species of the Mesogean floristic stock, i.e. of Mediterranean and Irano-Turanian elements.

On the mountains of Western Anatolia, the following abundant species are important edificators of Mediterranean type xerophytic dwarf-shrub and thorn-cushion communities (Astragalion ptilodis, Alopecurion lanatae): *Acantholimon ulicinum*, *Astragalus angustifolius*, *Daphne oleoides* subsp. *oleoides*, *Juniperus communis* subsp. *nana*, *Nardus stricta* and *Prunus prostrata*. Many local (often endemic) peculiarities are growing alongside with them, including e.g. *Aegokeras caespitosa*, *Alopecurus lanatus*, *Androsace villosa*, *Arabis drabiformis*, *Astragalus hirsutus*, *A. ptilodes*, *A. sibthorpianus*, *Festuca punctoria*, *Galium olympicum*, *Pedicularis olympica*, *Saxifraga sempervivum*, *Scorzonera pygmaea* and *Thymus bornmuelleri* (on Uludağ; Quézel and Pamukçuoğlu 1970; Rehder et al. 1994) or *Armeria trojana*, *Asperula sintenisii*, *Astragalus idea*, *Dianthus erinaceus* var. *alpinus*, *Hypericum kazdaghense* (Fig. 7.5f), *Jasione idaea*, *Saxifraga sancta* and *Silene bolanthoides* (on Kaz Dağı; Quézel and Pamukçuoğlu 1970; Efe et al. 2015).

The Western and Central Black Sea Mts. support the site-ecological analogon (Hyperico linarioidis-Thymetalia skorpilii) of the above vegetation, but intermediate in integrating elements of all three phytochoria at almost equal proportions. Its stands are characterized by e.g. *Allium olympicum*, *Asperula capitellata*, *Bunium microcarpum* subsp. *bourgaei*, *Cota melanoloma*, *Dianthus balansae*, *Hypericum linarioides*, *Scorzonera pygmaea*, *Stachys bithynica*, *Thymus praecox* and *Veronica gentianoides* (Akman et al. 1983, 1987). Various local subtypes have been distinguished, including e.g. units with *Astragalus densifolius*, *Erysimum pulchellum*, *Minuartia hirsuta* subsp. *falcata* and *Silene olympica* (on Ilgaz Dağları) or *Astragalus amoenus*, *Festuca cyllenica* subsp. *uluana*, *Verbascum armenum* var. *occidentale* and *Viola gracilis* (Köreoğlu Dağları and Semen Dağı; Akman et al. 1983, 1987).

On the eastern Black Sea Mts., e.g. on Ovit Dağı and in some valleys of the Kaçkar Dağları (Parolly 2004), xerophytic dwarf-shrub vegetation is represented by outpost of the Armeno-Iranian *Astragalus aureus* communities as they are typical of East Anatolia (Hamzaoğlu 2006) and described below (Sect. 7.6.3.2).

7.6.2 *High-Mountain Vegetation of the Taurus Mts. and Their Outliers*

The Taurus range, mainly in its coastal parts, still supports extensive and diverse mountain forests (Querco pseudocerridis-Cedretalia libani) dominated by conifers, including *Abies cilicica*, *Cedrus libani*, *Juniperus excelsa*, *J. foetidissima*, *J. drupacea*, *J. oxycedrus*, *Pinus brutia*, *P. nigra* subsp. *nigra* var. *caramanica* and locally *Cupressus sempervirens* (Quézel and Pamukçuoğlu 1973; Quézel 1986; Ayaşlığıl 1987; Akman 1995; Ketenoğlu et al. 2014). These forests further display *Acer hyrcanum* s.l., *Quercus petraea* subsp. *pinnatiloba* and *Sorbus umbellata* s.l. in the tree-layer and *Anemone blanda*, *Cyclamen* spp., *Delphinium fissum* subsp. *anatolicum*, *Doronicum orientale*, *Eremopoa persica, Geum heterocarpum*, *Lecocia cretica*, *Pimpinella tragium* and *Potentilla kotschyana* in the understory. For their subdivision and further details, see the references cited above. In the eastern parts of the range, deciduous open forest of the 'Kurdo-Zagrosian' type (Zohary 1973) dominated by *Quercus brantii*, is scattered; its stands often additionally include *Q. ithaburensis* subsp. *boissieri*, *Q. libani* and *Celtis* spp., *Cotoneaster racemiflora*, *Daphne angustifolia*, *Pistacia* spp., *Prunus microcarpa*, *Pyrus* spp. and a rich steppe flora in the understory (Zohary 1973).

The following section deals formation-wise with the high-mountain vegetation of the Taurus range, and here mainly with its western half (from Honaz Dağı to the mountains of Kahramanmaraş), as there is very little information regarding the mountains further east and no workable classification system.

7.6.2.1 Lithophytic Vegetation

Scree Vegetation Extensive scree and talus slopes are an outstanding physiognomic feature of the high-mountain landscapes of the Taurus Mts. Mobile scree and instable raw lithosols are occupied by very open scree vegetation (Heldreichietea; Parolly 1995, 1998). It is highly diverse; approximately 250 species have recorded in the plots (Parolly 2015); it is also endemic-rich and chiefly composed of creeping hemicryptophytes and rhizome geophytes adapted to burial, and often considerable proportions of bulbous geophytes move with the unstable substrate. Depending on the mobility, the structure, the contents of fine soil and altitude, various associations have been described from the Taurus Mts. (Quézel 1973; Parolly 1995; Eren 2006). Throughout the whole range *Cicer incisum*, *Euphorbia herniariifolia* var. *glaberrima*, *Heldreichia bupleurifolia* (in four vicarious subspecies), *Heracleum humile*, *Oxyria digyna*, *Ranunculus brevifolius*, *Rumex scutatus*, *Vavilovia formosa* (Fig. 7.5c) and *Viola crassifolia* are among the most typical scree species (Parolly 1998; Parolly et al. 2010).

The scree vegetation of the Western Taurus (Scrophularion depauperatae, Lamietalia cymbalariifolii) displays additionally e.g. *Lamium cymbalariifolium*

(Beydağları, Akdağlar) and *L. microphyllum* (Honaz Dağı), *Fritillaria crassifolia*, *Noccaea sintenisii*, *Ormosolenia alpina*, *Ranunculus cadmicus*, *Ricotia davisii* and *Scrophularia depauperata*. It interposes between the scree vegetation further east and of the Balkans and North-western Anatolia.

Scree vegetation of the Central Taurus (Heldreichietalia) falls into three groups. Typical scree plants of the Pisidian-Isaurian Taurus (Scrophularion myriophyllae) are *Lamium eriocephalum* subsp. *glandulosidens*, *Ricotia varians* and *Scrophularia myriophylla*. In the Cilician Taurus, two altitudinally arranged major vegetation types occur, both comprising e.g. *Arenaria balansae*, *Cerastium gnaphalodes*, *Lamium eriocephalum* subsp. *eriocephalum*, *Silene nuncupanda* and *Vicia alpestris* subsp. *hypoleuca*. The first unit (Scrophularion rimarum) with *Anthriscus kotschyi*, *Aurinia rupestris* subsp. *cyclocarpa*, *Lactuca glareosa*, *Nepeta cilicica* and *Scrophularia rimarum* is centred in the subalpine belt and inhabits relatively coarse, moving mounds and scree. The second (Jurinellion moschus) grows in the upper alpine to subnival belt of the Bolkar Dağları and Aladağlar, where it occupies cryoturbated, finer-structured and partly stabilised talus or even rock-glacier fronts, moist moraines and patches in scree with a long snow-cover. Diagnostic species include *Astragalus pelliger*, *Crepis frigida*, *Hedysarum erythroleucum*, *Isatis frigida* and *Jurinea moschus* subsp. *moschus*. There are no relevés from a scree community further east, but the species inventories available make the occurrence of similar stands very likely.

Chasmophytic Vegetation The higher-mountain range of the Taurus Mts. shows spectacular sceneries, with rugged ridges and cliffs towering over gorges, cut hundreds of meters deep into various bedrock and ledges supporting sheltered half-caves. These rocks provide a wide range of chasmophytic habitats (sloping rock, overhanging rock, vertical rock, step crevices; Davis 1951; Hein et al. 1998) and harbour an extremely diverse chasmophytic flora. More than 340 species have been sampled by relevés in the Western and Central Taurus alone (Parolly 2015).

The inventory of chasmophytic sites includes e.g. *Arenaria deflexa* (in various subsp.), *A. tmolea*, *Arnebia densiflora*, *Arabis alpina* agg., *Asplenium* spp. (incl. *A. lepidum* subsp. *haussknechtii*), *Asyneuma linifolium*, *Aubrieta* spp., *Dianthus elegans*, *Hieracium pannosum*, *Hypericum origanifolium*, *Oreoherzogia libanotica*, *Polylophium petrophilum*, *Potentilla speciosa, Rosularia libanotica* agg. (incl. *R. sempervivum* subsp. *pestalozzae* and subsp. *glaucophylla*), *Scrophularia libanotica*, *Silene odontopetala* and *Tanacetum canum* s.l. (Hein et al. 1998).

The chasmophytic vegetation of north-western, western and southern Anatolian and the adjoining Levantine mountain ranges belongs to one major syntaxon (Silenetalia odontopetalae, Asplenietea trichomanis; Quézel 1973; Hein et al. 1998; Parolly 2004, 2015). It is a predominantly basiphytic vegetation, but there are also floristically depauperated stands on siliceous and ultramafic rock. Locally such places may be embellished by substrate-specialists, but without composing a particular vegetation unit worth to be recognized syntaxonomically.

There are two principal types of chasmophytic vegetation. Type A comprises all mesophytic to xerophytic communities, which predominately dwell at warm sites under sunny conditions and whose species evolved from a Mesogean floristic stock. The stands are largely made up by chamaephytes. This vegetation groups into four phytogeographically and ecologically differentiated major units: In the Western Taurus (Silenion odontopetalae) *Aethionema lycium, Asyneuma linifolium*, *A. lycium*, *Polylophium petrophilum* and *Silene odontopetala* are important components, locally additionally associated with *Arabis lycica*, *Verbascum pestalozzae* (eastern Beydağları) and *Galium aretioides* (Honaz Dağı). The Pisidian-Isaurian Taurus section (Campanulion isauricae) is characterized by *Arabis aubrietioides*, species of the *Campanula isaurica* agg. (*C. ermenekensis*, *C. isaurica*, *C. leucosiphon*), *Euphorbia isaurica*, *Hypericum origanifolium* and *Prometheum chrysanthum.* In the Cilician Taurus (Bolkar Dağları and Aladağlar), the high alpine-subnival Drabion acaulis replaces above (2700) 2900 m a.s.l. a montane-subalpine vegetation (Onosmion mutabilis) with e.g. *Campanula trachyphylla*, *Michauxia tchihatcheffii*, *Onosma mutabilis*, *Potentilla speciosa*, *Rosularia sempervivum* subsp. *glaucophylla* and *Tanacetum argenteum* s.l. (Hein et al. 1998). More than 15 vascular plant species have been recorded dwelling on rocks at altitudes up to more than 3600 m a.s.l., including *Draba acaulis*, *Gnaphalium leucopilinum*, *Potentilla pulvinaris* (two subspecies), *Sabulina rimarum*, *Saxifraga kotschyi* and *Veronica kotschyana*. The proportion of endemics exceeds the 60% level (Hein et al. 1998; Parolly 2015).

Vegetation type B (Campanulion cymbalariae) deviates clearly from all previous units, because the basis of shady cliffs, N-facing rock walls in cirques, rock in deep dolines or gorges and the entrance of the frequent grottos provide totally different site-conditions. The sciophytic and hygro- to mesophytic vegetation at such humid places is physiognomically dominated by hemicryptophytes and chorologically distinct by enhanced proportions of Euro-Siberian taxa. They include also elements of the so-called ‘Balmenflora’ (dwellers of half-caves and grottos). Typical sciophytes are *Campanula cymbalaria*, *Omphalodes luciliae* (Fig. 7.5j), *Saxifraga corymbosa*, *S. moschata* and *Valeriana speluncaria*; they grow locally associated with *Asplenium tadei*, *Poa akmanii* (on top of Kızlar sivrisi, Beydağları), *Doronicum cacaliifolium* (Geyik Dağları), *Geranium glaberrimum* and *Erodium pelargonifolium* (Pisidian-Isaurian Taurus). *Scrophularia kotschyana* and *Galium canum* are part of the ‘Balmenflora’ of the Cilician Taurus and strictly confined to rocks of canyons and grottos. Further east (Binboğa Dağları and Engizek Dağları; Duman 1995), *Graellsia davisiana* is the eponymous element of a sciophytic community, which at the same time represents the easternmost sampled rock plant community in the Taurus Mts. Since more than one third of all characteristic species of both vegetation types grow also on the eastern edge of the Taurus Mts. and beyond, we at least have some ideas how rock communities are composed in the east.

7.6.2.2 Oro-Mediterranean High-Mountain Vegetation

Subalpine Thorn-cushion and Dwarf-shrub Vegetation, Limestone Swards Open limestone swards, dwarf-shrub communities and thorn-cushion communities (Astragalo-Brometalia, Astragalo-Brometea; Fig. 7.5a, h, l) are the dominant and most prominent formation of the South-West Asian high-mountain vegetation (Quézel 1973; Kürschner 1986a, b), representing the zonal vegetation of the subalpine belt of the Taurus Mts. (Quézel 1973; Ayaşlığil 1987; Eren et al. 2004; Parolly 2004). The thorn-cushion vegetation and limestone swards are species-rich; a total of 570 taxa have been sampled from the Western and Central Taurus alone (Parolly 2015). They have clear Mediterranean floristics links, including a moderate number of endemics of East Mediterranean origin (ca. 15–20%). The influence of the Irano-Turanian element is fairly low (<15%). Many stands of limestone swards are nothing but initial dwarf-shrub and thorn-cushion communities establishing themselves on stabilised scree slopes or old rock slides. The proportion of tragacanthic species varies greatly with altitude, exposure and substrate (fine soil content and water capacity). Physiognomically, tragacanthic sub-shrubs and caespitose graminoids dominate, while a few annuals and many geophytes colonise the gaps. Typical edificators of the stands are e.g. *Acantholimon lycaonicum*, *A. ulicinum*, *Aethionema cordatum*, *Anthemis cretica* subsp. *anatolica*, *Asperula stricta* subsp. *monticola, Asphodeline taurica*, *Astragalus angustifolius, A. microcephalus*, *Asyneuma limonifolium*, *A. lobelioides*, *A. rigidum*, *A. virgatum* subsp. *cichoriiforme*, *Bornmuellerantha aucheri*, *Bromopsis cappadocica*, *B. tomentella*, *Cyanus pichleri*, *C. reuterana*, *Daphne oleoides* subsp. *oleoides*, *Dianthus anatolicus*, *D. micranthus*, *Elytrigia tauri*, *Eremogone acerosa*, *Eryngium heldreichii*, *Erysimum pusillum*, *Festuca anatolica*, *F. elwendiana*, *F. valesiaca*, *Galium incanum*, *Iberis simplex*, *Koeleria macrantha*, *Marrubium globosum*, *Minuartia erythrosepala* var. *erythrosepala*, *M. hirsuta* subsp. *falcata*, *Minuartiella dianthifolia, Noaea mucronata* subsp. *mucronata*, *Noccaea iberidea*, *Odontarrhena pateri* subsp. *pateri, Onobrychis cornuta* (Fig. 7.5l), *Ononis adenotricha*, *Onosma armena*, *O. aucheriana*, *O. roussaei*, *Papaver pilosum* s.l. (Fig. 7.5k), *P. polychaetum*, *Pterocephalus pinardii*, *Salvia cadmica*, *Sedum ursi*, *Sesleria alba*, *Sideritis libanotica* s.l., *Silene armena*, *Thymus sipyleus* s.l. and *Verbascum cheiranthifolium* s.l. (Quézel 1973; Parolly 2015).

There is a great range of different communities (Quézel 1973; Kürschner 1986a, b; Duman 1995; Eren et al. 2004; Parolly 2020), partly substrate-specific and partly geographically arranged. All stands from the western half of the Taurus Mts. can be grouped into a single order (Astragalo-Brometalia), disregarding of the substrate type (limestone, schist or serpentine). Particular vegetation rich in serpentinophytes develops on ultramafic soil (Thuryion capitatae). Many of its species are locally confined, such as *Aethionema speciosum* subsp. *compactum*, *Ferulago sandrasica*, *Genista sandrasica*, *Prometheum serpentinicum* and *Verbascum cariense* to the wider Sandras Dağı range (Parolly 2020). Two units are distinguished on calcareous soil, each with clear sets of diagnostic species (Parolly 2015). In the Western Taurus

(Tanacetion praeteriti) these are e.g. *Alkanna areolata*, *A. attilae*, *Anthemis rosea* subsp. *carnea*, *Astragalus microrchis*, *Centaurea cariensis* subsp. *maculiceps*, *C. luschaniana*, *Cephalaria lycica*, *Cyanus bourgaei*, *Elytrigia divaricata*, *Marrubium bourgaei* subsp. *bourgaei*, *Minuartiella pestalozzae*, *Papaver pilosum* subsp. *spicatum*, *Salvia pisidica*, *Silene rhynchocarpa* and *Tanacetum praeteritum* s.l. (Eren et al. 2004), while e.g. *Acantholimon kotschyi* subsp. *kotschyi*, *Achillea kotschyi* subsp. *kotschyi*, *Aethionema coridifolium*, *Allium callidictyon*, *Arabis androsacea*, *Astragalus amoenus*, *Asyneuma rigidum* subsp. *rigidum*, *Bupleurum falcatum* subsp. *cernuum, Erodium cedrorum* s.l., *Gypsophila libanotica*, *Salvia microstegia* and *Veronica thymoides* subsp. *pseudocinerea* mark the vicarious unit (Agropyro tauri-Stachydion lavandulifoliae) of the Central Taurus (Quézel 1973; Kürschner 1986a; Parolly et al., unpublished data).

The dry grassland and acanthophytic vegetation of the Inner Anatolian volcanoes (Bromion cappadoci sensu Kürschner 1982, 1984) closely resembles its counterpart in the Central Taurus, but appears to be floristically depauperate. For some typical species and further details, see Sect. 7.4.3.3.

There seems to be an important floristic shift of characteristic species along and east of the Anatolian Diagonal. All what we can say with reliability is that the species inventory given above is step-wise replaced by the set of species typical of the kind of steppe vegetation (Festuco oreophilae-Veronicetalia orientalis), which dominates large parts of East Anatolia (Hamzaoğlu 2006; see also below, Sect. 7.5.3.2).

Vegetation of Wind-Swept Mountain Habitats, Zonal Alpine and Subnival Vegetation At the highest elevations, mat- and cushion-forming vegetation (Drabo-Androsacetalia, Astragalo-Brometea; Quézel 1973, Parolly 2004) prevails, in which small pulvinate, creeping and suffruticose chamaephytes dominate together with caespitose hemicryptophytes. This kind of vegetation represents the ‘zonal’ vegetation of the alpine to subnival belts on alkaline, often heavily cryoturbated substrates. Some outposts may occur at windswept rocky flats and exposed ridges lower down. The proportion of thorn-cushions is reduced, although *Onobrychis cornuta* (Fig. 7.5l), *Astragalus angustifolius* and *Acantholimon ulicinum* can become key components. The vegetation structure is open and the species diversity is high, with 25–50 species recorded within 10 m^2 plots (Eren et al. 2004; Parolly 2015). More than 380 taxa have been noted in stands of this vegetation type. The vegetation stands out by its great number of endemics and high rates of endemism. Sixteen out of 24 communities distinguished display endemism rates above 40% and 7 units around 50% (Parolly 2015).

Its vegetation is divided into three groups which reflect the main phytogeographical sections of the Taurus Mts. (Lycian, Pisidian-Isaurian, Cilician Taurus Sector; the fourth occurs on Uludağ; Parolly 2015). Throughout the Taurus Mts., the most abundant species at high-alpine wind-exposed places include *Alopecurus lanatus*, *Androsace villosa*, *Anthyllis vulneraria* subsp. *pulchella*, *Bromopsis tomentella* subsp. *nivalis*, *Centaurea drabifolia* s.l., *Draba heterocoma*, *Erigeron cilicicus*, *Erysimum kotschyanum*, *Festuca pinifolia*, *Minuartia leucocephala*, *Odontarrhena condensata* subsp. *condensata*, *Noccaea oppositifolia* (Fig. 7.5d), *Pedicularis* *cadmea*, *Polygala pruinosa* subsp. *megaptera*, *Sabulina umbellulifera* and *Silene caryophylloides* s.l. In the Lycian Sector (Paronychion lycicae), *Alyssum aurantiacum*, *Centaurea drabifolia* subsp. *austro-occidentalis*, *Dianthus brevicaulis* subsp. *setaceus*, *Paronychia lycica* and *Silene caryophylloides* subsp. *eglandulosa* are important components. The Pisidian-Isaurian Sector (Silenion oreadis) is marked by *Aethionema subulatum*, *Alyssum aizoides*, *A. lepidotum*, *Asyneuma compactum*, *Bolanthus cherlerioides* and *Thymus cherlerioides* var. *cherlerioides*; the Cilician Taurus Sector (Silenion pharnacaeoidis) by *Androsace multiscapa*, *Arenaria uninervia*, *Dianthus brevicaulis* subsp. *brevicaulis*, *Linum empetrifolium*, *Potentilla pulvinaris*, *Scorzonera rigida*, *S. sericea*, *Silene nuncupanda* and *Thymus brachychilus* (Quézel 1973; Parolly 2015). There are no studies of this type of vegetation further east.

Chionophytic Vegetation Snow-patches developed in dolines, along meltwater runnels and similar chionophytic sites provide at least temporarily moist environments for plants in otherwise dry surroundings. Such damp places show particular types of vegetation rich in geophytes and hemicryptophytes (Trifolio anatolici-Polygonetalia arenastri, Astragalo-Brometea), which establish themselves as open meltwater community or as dense carpet turf (Fig. 7.5h) at the bottom of dolines (Quézel 1973; Kürschner et al. 1998; Parolly 2004). Floristically and site-ecologically, these stands are closely connected with the zonal xerophytic thorn-cushion and dwarf-shrub vegetation (Astragalo-Brometea; Parolly 2004). Throughout its range, *Astragalus angustifolius* var. *violaceus*, *Colchicum trigynum*, *Geranium tuberosum*, *Plantago* spp., *Polygonum arenastrum*, *Ranunculus demissus* var. *major*, *Taraxacum bithynicum* and *Trifolium hybridum* var. *anatolicum* are nearly always present. In the Western and the Pisidian-Isaurian Taurus (Thlaspion papillosi and Bolanthion frankenioidis), the snow-patch and meltwater vegetation is enriched by *Bolanthus frankenioides*, *Crocus* spp., *Gagea villosa* var. *hermonis*, *Fritillaria pinardii*, *Marrubium bourgaei*, *Noccaea papillosa*, *Ornithogalum brevipedicellatum*, *Scilla pleiophylla* and *Veronica cuneifolia* s.l. (Kürschner et al. 1998). The serpentinophytic meltwater community on Sandras Dağı is floristically distinct by e.g. *Anthemis cretica*, *Barbarea brachycarpa* subsp. *anfractuosa*, *Colchicum figlalii*, *Gagea bithynica*, *Muscari sandrasicum*, *Ornithogalum alpigenum*, *Ranunculus heterorhizus*, *Polygonum karacae* and abundant *Plantago holosteum* (Parolly 2020). The eastern Central Taurus (Trifolio-Polygonion) is weakly studied in this respect and seems to have hardly any characteristic species of its own, but *Gagea foliosa, G. glacialis, G. uliginosa*, *Silene olympica* and *Taraxacum scaturiginosum* are significant (Quézel 1973; Kürschner et al. 1998). The range of this vegetation type may – though unstudied – extend till the Turkish border area in the east.

7.6.2.3 Azonal Hydro- and Hygrophytic Vegetation

Besides snow-bed turf, there is a remarkably wide range of hydro- and hygrophytic vegetation in the Taurus Mts. (for syntaxonomic details, see Parolly 2004). All of these hygrophytic communities are mainly composed of Euro-Siberian taxa, with Irano-Turanian species being a distant second. In most units a large number of species of Balkan, Euxine, Caucasian or Hyrcano-Euxine distribution patterns occurs.

Above the tree-line, we encounter scattered flushes, seepage meadows, transitional mires and mires, lining permanent streams and lakes. Their vegetation is mostly basiphytic low-sedge fen of Euro-Siberian type (Caricetalia davallianae, Scheuchzerio-Caricetea fuscae). Such stands comprise dense carpets of graminoids, including *Blysmus compressus*, *Carex cilicica*, *C. davalliana*, *C. panicea*, *C. tristis*, *Eleocharis quinqueflora* and *Juncus articulatus*, and a great variety of colourful herbs such as *Allium schoenoprasum*, *Arenaria rotundifolia*, *Bistorta officinalis* subsp. *carnea*, *Cirsium simplex*, *Gladiolus kotschyanus*, *Inula acaulis*, *Pinguicula balcanica* subsp. *pontica*, *Polygala supina*, *Primula auriculata* and *Taraxacum crepidiforme*. This kind of vegetation is intertwined with the bryophyte- and herb-rich vegetation of springs and edges of fast-running high-mountain rapids (Montio-Cardaminetea) forming small mossy patches along runnels and springs.

In the highest elevations of the Cilician Taurus, patchily scattered *Kobresia humilis* turf has been sampled on moist alpine to subnival rock ledges situated in cirques (Parolly 2004, 2015). The *Kobresia* turf of the Taurus is fairly species-poor, bears many Alpic-Asian floristic links (with the Caucasus and Central Asian mountain ranges) and includes species such as *Alchemilla paracompactilis*, *Botrychium lunaria*, *Carex tristis*, *Dianthus brevicaulis* subsp. *brevicaulis*, *Deschampsia cespitosa*, *Gentiana boissieri*, *G. orbicularis*, *Kobresia humilis*, *Ranunculus brachylobus* subsp. *incisilobatus*, *Silene olympica* and *Veronica pusilla* (Parolly, unpubl. data).

7.6.3 High-Mountain Vegetation of the East Anatolian Highlands

Forest occurs on the slopes of sheltered valleys, and includes *Quercus libani* intermixed with scattered trees of *Acer*, *Celtis*, *Pistacia*, *Rhamnus* and *Sorbus* (Davis 1956). *Quercus infectoria* scrub grows between Pelli Dağı and Tatvan, near Van Gölü (Mill 1994b). At some sheltered places at the southern margins of the range, there are also some 'Kurdo-Zagrosian' *Quercus brantii* open forests sensu Zohary (1973). The few stronger wooded areas display a rich herb flora, too, mainly comprising steppe elements.

7.6.3.1 Lithophytic Vegetation

Scree Vegetation The lithophytic vegetation of the area harbours many peculiarities. The non-limestone high-mountain scree vegetation of the East Anatolian highlands deviates floristically considerably from the limestone scree vegetation of the Taurus Mts. (Heldreichietea), but it matches closely those from southern Caucasia and the Eastern Black Sea Mts. Nevertheless, the occurrence of *Vavilovia formosa*, *Coluteocarpus vesicaria* subsp. *vesicaria, Alopecurus textilis*, *Silene chlorifolia, Jurinea moschus* (on stabilized scree) and of the Eurasian *Androsace villosa*, *Oxyria digyna* and *Rumex scutatus* allow attaching the local stands to the Heldreichietea class. This similarity is enhanced by (pseudo)vicarious scree-creeping taxa, especially *Lamium tomentosum* (corresponding to other *Lamium* species in the west) and by *Ricotia aucheri* (replacing *R. davisii* and *R. varians*). Often associated with *Silene lacera* and *Vicia alpestris* subsp. *alpestris* (subsp. *hypoleuca* grows in high-alpine scree of the Cilician Taurus), igneous scree is locally overgrown by *Sobolewskia clavata* (Fig. 7.6d), a crucifer which apparently substitutes *Heldreichia* site-ecologically. Both taxa are not related at all, but resemble each other in many vegetative characters. Members of the genus *Heldreichia* occur in the Hakkâri-Taurus and on Keşiş Dağı (on the Anatolian Diagonal), but may have a distribution gap in the East Anatolian highlands (Parolly et al. 2010).

Chasmophytic Vegetation There are no studies on the rock vegetation of Eastern Anatolia, but the distribution areas of some Silenetalia odontopetalae character species suggest that this syntaxon is occurring also in the east (Parolly 2004). From the highest places (Büyük Ağrı Dağı), species such as *Potentilla polyschista*, *P. subpalmata*, *Saxifraga adscendens* (Ararat), *S. exarata* var. *adenophora*, *S. hirculus*, *S. moschata* and *S. sibirica* have been recorded (Davis 1965–1985).

7.6.3.2 East Anatolian (Zonal) High-Mountain Vegetation

Mountain Steppe and Thorn-Cushion Vegetation Due to the high elevation of the plateau, already the foothills of the mountains are covered by steppe-like high-mountain grassland and dwarf-scrub with tragacanthic species (Festuco oreophilae-Veronicetalia orientalis) such as *Acantholimon caryophyllaceum*, *Astragalus aureus*, *A. kurdicus*, *A. caspicus* and *Onobrychis cornuta*. The many grasses such as *Agrostis stolonifera*, *Alopecurus pratensis*, *Bromopsis erecta*, *B. tomentella*, *Elytrigia intermedia*, *Festuca brunnescens, F. cyllenica*, *F. oreophila*, *Phleum pratense* and *Poa bulbosa* grow associated with numerous hemicryptophytes or chamaephytes, including *Achillea schischkinii*, *Artemisia spicigera*, *Asperula prostrata*, *Astragalus cinereus*, *A. lagopodioides*, *A. onobrychis*, *Centaurea carduiformis* subsp. *orientalis*, *C. rhizantha*, *Cephalaria sparsipilosa*, *Daphne oleoides* subsp. *kurdica*, *Eremogone armeniaca*, *Erysimum pycnophyllum*, *E. leptocarpum*, *Gypsophila bitlisensis*, *Helichrysum arenarium* subsp. *rubicundum*, *Isatis candolleana*, *Malabaila dasyantha*, *Medicago papillosa*, *Odontarrhena pateri* subsp. *prostratum*, *Onobrychis hajastana*, *O. transcaucasica*, *Pimpinella peucedanifolia*, *Pulsatilla armena*, *Salvia rosifolia*, *Scutellaria orientalis* subsp. *orientalis*, *Securigera orientalis*, *Silene montbretiana*, *Tanacetum aucherianum*, *Thymus pubescens*, *T. transcaucasicus* and *Veronica orientalis* subsp. *orientalis*. They all are diagnostic species within the steppe vegetation of East Anatolia (Festuco-Veronicetalia orientalis and subunits; Hamzaoğlu 2006).

A subalpine thorn-cushion vegetation of Irano-Turanian character, dominated by tragacanthic species of *Astragalus* and species of *Onobrychis* and *Acantholimon*, occurs from 2400 to 3200/3300 m a.s.l., mainly on soil developed over basalt and andesite bedrock of volcanic origin (Davis 1956; Behçet 1990, 1994; Mill 1994b; Hamzaoğlu 2006; Öztürk et al. 2015). Many thistle-like species belonging to *Cousinia* and *Cirsium* are characteristic of the thorn-cushion zone, as are spiny herbs such as *Eryngium* spp. Herbs such as *Astragalus subrobustus*, *Helichrysum* spp., *Ranunculus isthmicus* subsp. *stepporum*, *Scorzonera mollis*, *Stachys lavandulifolia* and *Artemisia vermicularis* are also typical (Behçet 1990; Mill 1994b). The most important species of this kind of vegetation (Astragalo aurei-Festucion caucasicae) are *Astragalus aureus*, *Cephalaria procera*, *Festuca woronowii* subsp. *caucasica*, *Nepeta transcaucasica*, *Silene arguta*, *Vicia alpestris* subsp. *alpestris*, *Erigeron caucasicus* subsp. *venustus*, *Poa longifolia* and *Senecio pseudo-orientalis* (Hamzaoğlu 2006). *Astragalus aureus* vegetation dwells on all East Anatolian high-mountains as defined here (Erzurum province and the high volcanoes, including Süphan, Nemrut and Pirreşit Dağı; Behçet and Ünal 1999; Hamzaoğlu 2006). Very similar stands grow on the Armenian plateau (Parolly, pers. obs.), but also on dry, south-facing and rocky slopes of the eastern Black Sea Mts. (Parolly 2004) as outpost of this type of Irano-Turanian vegetation.

Tall Forb Vegetation A special kind of mountain steppe, dominated by tall, yellow-flowered Apiaceae and other tall ephemeroids and occurring at elevations between 2200 and 2700 m a.s.l., was first mentioned by Davis (1956) from the mountains around Van Gölü. Later, it was occasionally sampled by vegetation studies (e.g. Behçet 1990 on Süphan Dağı), but without recognizing its status as a distinct habitat type and particular vegetation class (Prangetea ulopterae) as it is accepted today (Parolly 2004). Such vegetation is typical the mountain ranges between East Anatolia and Central Asia (Klein 1988, 2001; Noroozi et al. 2014). The umbellifers composing the communities in East Anatolia belong to *Ferula haussknechtii*, *F. orientalis*, *Ferulago stellata*, *F. angulata*, *Prangos ferulacea*, *P. pabularia* and other genera (e.g. *Opopanax persicus*). The stands also include other tall forbs such as *Centranthus longiflorus*, *Isatis cappadocica* and *Rheum ribes*.

Alpine Carpets and Chionophytic Vegetation At still higher altitudes, alpine turf occurs, which gradually gives place for open and low-growing cushion plant vegetation at wind-swept, rocky sites over shallow soil. In this yet unclassified vegetation, species such as *Astragalus hirticalyx*, *Artemisia splendens*, *Bornmuellera cappadocica*, *Campanula aucheri*, *C. tridentata*, *Carum caucasicum*, *Cerastium cerastioides*, *Chamaesciadium acaule*, *Didymophysa aucheri*, *Draba bruniifolia*, *D. rosularis*, *Jurinea moschus* subsp. *pinnatisecta, Noccaea kurdica*, *N. pulvinata*, *Onosma araraticum, Oxytropis albana*, *Potentilla argaea*, *P. geranoides*, *P. humifusa*, *P. pannosa*, *P. aucheriana*, *Pseudocherleria aizoides*, *Scorzonera rigida*, *Scutellaria orientalis* agg., *Veronica bornmuelleri* and *V. fridericae* can be found (Sorger 1994; Parolly, pers. obs.).

Where the snow hangs late in shallow depressions and along melt-water runnels below extensive snow fields, the damp ground is dotted by many spring geophytes, including *Colchicum trigynum*, *Corydalis oppositifolia* subsp. *kurdica*, *Fritillaria kurdica* (Fig. 7.6c)*, Pedicularis caucasica*, *Ranunculus aucheri*, *Trollius ranunculinus* and *Tulipa humilis* (Parolly pers. obs., Güzeldere Pass).

7.6.3.3 Azonal Vegetation

Meadows, damp grassland, high-mountain flushes and mesophytic herb communities display a diverse and colourful flora, too, including massive stands of *Alchemilla* spp., *Carex* spp., *Anacamptis laxiflora* subsp. *dielsiana*, *Dactylorhiza iberica*, *D. umbrosa*, *Dianthus calocephalus*, *Gladiolus atroviolaceus*, *Papaver orientale* agg., *Onobrychis stenostachya, Triglochin palustris* and *Vicia cracca* (Öztürk et al. 2015; Parolly, pers. obs.).

7.7 Conservation

Factors threatening the biodiversity of Turkey have repeatedly been summarized (Ekim et al. 2000; Özhatay et al. 2005; Eken et al. 2006). The Red Data book of Turkey (Ekim et al. 2000) lists among the 3008 threatened vascular plant species many mountain plants (Gökyiğit 2013).

Over-grazing is presently and since a long time among the most severe threats for conserving the diversity of open habitats in Turkey (e.g. Özhatay et al. 2005; Kürschner and Parolly 2012). Uncontrolled construction activities, especially the dam construction projects in the eastern part of the country (e.g. Çoruh valley), have led to dramatic losses of plant populations of rare and threatened species. Road constructions give way to ranges earlier hard to access and license shifts in land-use systems including wood cutting and the establishment of settlements, which may degrade whole ecosystems. A personal observation comes from the plateau between the Büyük Geyik Dağı and the Akdağ in the Central Taurus Mts. in mid of July 1992 (Parolly 2015), which was home to a rich plant life associated to glacial lakes and karstic pools. Only a few years later (1999 and 2000), the former narrow and bumpy transect dirt road was expanded and the local yayla (summer pasture) was replaced by a permanent settlement. As a consequence, the rising water consumption lowered the water table and turned the shallow, once clear water bodies into muddy flats. Moreover, grazing by an enhanced and now permanently present livestock severely has degraded the vegetation up to the alpine belt.

At a local scale, the expansion of skiing resorts harms the high-mountain flora and vegetation (for examples, see Eren et al. 2004). Overexploitation of plant species is also linked to these afore mentioned effects, but also involves a wide-spectrum of legal and illegal activities, were plants are collected in the wild, as e.g. for commercial purposes (herbal teas, bulb trade, salep production). Such overexploitation of populations and whole ecosystems, which exceeds the ability of species to recover, can lead to fragmentation of habitats and populations, and may result in small and often isolated demes suffering from local extirpation (Terzioğlu et al. 2015).

The effects of the predicted climate warming and impact on the hydrologic situation may seriously threaten the survival of the unique cryophilic and hygrophilic high-mountain flora of Anatolia. This topic has been addressed in a series of special publications (e.g. Efe et al. 2015; Kurt et al. 2015; Parolly 2015; Terzioğlu et al. 2015; Türkmen et al. 2015) and must not be repeated here.

In the last decade, Turkey's IPAs and KBAs (Özhatay et al. 2005; Eken et al. 2006) have been identified. Many of these areas are associated to mountain ranges and its nature is protected at various levels. Some of these mountains form part of one of the presently 57 forest conservation areas or 43 official national parks (www.goturkeytourism.com/things-to-do/national-parks-in-turkey.html; Gökyiğit 2013) of Turkey, including e.g. the Aladağlar Mts. NP, Kaçkar Mts. NP, Karagöl-Sahara NP, Mt. Ararat NP, Mt. Honaz NP, Mt. Ilgaz NP, Munzur Valley NP and Uludağ NP. Situated in all parts of the county, they intend in-situ conservation for a good deal of rare mountain species, although in view of Turkey's enormous biodiversity this is certainly not enough. To compensate this at least to a very small part, specialised seed banks should be built up, while the few botanic gardens in Turkey should be encouraged to establish satellite gardens in the mountain regions, because only here conservation collections could successfully help to recover local populations of threatened high-mountain plant species. Mountain plants are generally not well represented in Turkey's botanic gardens and there are hardly any conservation projects devoted to safe-guard the future of endemic mountain plants with limited distribution areas and weak population sizes. One notable exception is the Dağgülü (*Rhodothamnus sessilifolius*) project run by the Nezahat Gökyiğit Botanic Garden in İstanbul (Gökyiğit 2013).

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Chapter 8
The Transcaucasian Highlands

George M. Fayvush and Alla S. Aleksanyan

Abstract The Transcaucasian Highlands are among the most interesting areas in the World from a botanical point of view. The high diversity in flora and vegetation types has attracted the attention of botanists for more than 200 years. In this chapter we analyze this richness, show the diversity of ecosystems in this region, and the peculiarities of its flora with special attention to endemism in plant genera and species. A short section is devoted to the main threats to plant diversity in this area.

The Transcaucasian Highlands are located on the border of the Euro-Siberian and the Irano-Turanian biogeographical regions and at the junction of the Caucasian and Irano-Anatolian biodiversity hotspots. More than 4000 vascular plant species occur in the Transcaucasian Highlands of which around 10% are endemic to this region. The lower mountain belt (375–1200 m a.s.l.) is covered by semi-deserts of gypsophilous or halophilous vegetation types. There are salt marsh areas as well as the Transcaucasian sand desert. The middle and upper mountain belts (1200–2200 m a.s.l.) are characterized by various kinds of steppe and forest vegetation, meadow-steppes, shrub steppes and thorn-cushion (tragacanth) vegetation. The altitudinal span of the forest belt varies from 500 to 2000 m a.s.l. depending on the region, and may approach 2400 m a.s.l. when open park-like tree stands are included. The subalpine and alpine belts (2000–4000 m a.s.l.) are covered by tall-grass vegetation, meadows and carpet vegetation.

8.1 Introduction

The Lesser Caucasus, which is mainly located in the north-eastern part of the Armenian Highlands, is the core part of the so-called Transcaucasian Highlands (Fig. 8.1). This territory is orographically complex and is divided into four systems:

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Fig. 8.1 Map of the Transcaucasian Highlands

the Lesser Caucasus in the narrow sense, the Eastern Armenian (Syunik-Karabagh) volcanic highlands, the Near Araks folded-block ridges and the Middle Araks basin. For practical reasons, we deal here with a substantial part of Armenia, the mountain systems of the Nakhichevan Republic and a small part of the Javakheti Highland in Georgia (the continuation of the Javakheti ridge (Gabrielian 1986). In fact, the entire territory, starting from 375 m a.s.l. (the gorge of the Araks River and the gorge of the Debed River) up to 4095 m a.s.l. (the top of Mount Aragats) is a mountainous region. It should be noted that the most detailed data on flora and vegetation of this territory are our own, original data, for the territory of Armenia. Data on adjacent territories were taken from literature.

The study area lies at the intersection of two phytogeographical regions (the Euro-Siberian and Irano-Turanian regions; Takhtadjan 1986), and two biodiversity hotspots (Caucasian and Irano-Anatolian; Mittermeier et al. 2011). This position, in combination with its pronounced vertical zonation, is the cause of the great flora and vegetation diversity. Thus, the location of the Transcaucasian Highlands at the intersection of these phytogeographical regions, together with the diversity in climatic conditions and the active geological processes have resulted in the formation of a great diversity in ecosystems and plant diversity with a high level of endemism (Fayvush et al. 2013). As a result, within the territory of the Transcaucasian Highlands there are about 4000 species of vascular plants including 300 endemic species (Fayvush 2007).

The trip of the French botanist's P. Tournefort to the Ararat Mountain in 1700–1702, during which he first noted the vertical zonation of the vegetation, is usually considered as the starting point of systematic botanical investigations in Armenia. But the German botanist Karl Koch was the first scientist who especially focused on the vegetation of Armenia and the Caucasus. In the middle of the nineteenth century he visited the Caucasus and Armenia twice and published the first map of the Caucasian vegetation (Koch 1850). At the end of 19th and the beginning of 20th centuries many famous botanists visited Armenia (M. Wagner, A. Kalantar, K. Meyer, F. Buhse, G. Abich, P. Tchichachev, I. Shopen, G. Radde, Ja. Medvedev, A. Lomakin, B. Grinevetsky). They mainly paid attention to the inventory of the flora of Armenia, but in all their publications a short review of the vegetation also was provided. Very important publications in the beginning of twentieth century are those of N. Kusnetsov (1909) devoted to the phyto-geographical and geo-botanical division of the Caucasus. In the first years of the Soviet time, investigations on the vegetation of Armenia became more intensive. Special expeditions were organized, in which famous botanists participated (N. Kusnetzov, A. Grossheim. O. Zedelmeyer, T. Heideman, E. Kara-Murza, and others). At about the same time A. Takhtadjan, A. Magakyan, N. Troitzky and E. Kazaryan started their botanical investigations. In 1938, the Institute of Botany of the Armenian Branch of the Academy of Sciences of the USSR was founded. In 1954 A.L. Takhtadjan started the project "Flora of Armenia" which resulted in 11 volumes and was completed in 2009. During the past decade new data was obtained and a Manual of vascular plants of Armenia is in preparation.

In this chapter we summarize data on the flora and vegetation of Armenia and the Transcaucasian Highlands, focusing on the richness of the flora and vegetation and its conservation status.

8.2 Geology

From orographic and physico-geographical points of view, the Transcaucasian Highlands form the northern edge of the system of folded-block mountains of the Armenian Highland. Unlike the Greater Caucasus, the Lesser Caucasus is not a single, distinct watershed ridge. It is a system of coulisse-spaced ridges that merge with the mountain formations of the inner parts of the Armenian Highland and adjacent high areas.

Since early geological epochs the land surface of Armenia, and the surrounding Armenian plateau, has been mountainous, with further mountain building occurring during the Cenozoic era (particularly after the Miocene). These complex tectonic shifts have resulted in a country dominated by a series of mountain massifs and valleys as well as in extensive volcanic activity. Climatic changes over the last million years also have left their mark on the country, with evidence of two glacial periods (Riss and Wurm) preserved on almost all mountains over 3000 m a.s.l. (Aslanyan 1958, 1985).

8.3 Climate

A wide range of climatic zones are distinguished within the Transcaucasian Highlands (Fig. 8.2). This territory shows a pronounced vertical succession of six basic climate types - from dry subtropical up to severe alpine. The average annual temperature ranges from −8 °C in high-altitude mountainous regions (2500 m a.s.l. and higher) to 12–14 °C in low-traced valleys. In the lowlands the average air temperature in July and August reaches 24–26 °C, but in the alpine belt the temperature does not exceed 10 °C. January is the coldest month with an average temperature of −6.7 °C. The absolute minimum temperature is −42 °C. The overall climate is best characterized as dry continental, in some areas with an annual rhythm more or less similar to the Mediterranean climate regime. The average annual precipitation in Armenia is 592 mm. The most arid regions are the Ararat valley and the Meghri region with annual precipitations of 200–250 mm. The highest annual precipitation, 800–1000 mm, is observed in high altitude mountain regions. Major part of the precipitation falls in the spring. In the northern part of Armenia, humidity comes from the Black Sea in the west, in the southern part from the Caspian Sea in the east, while the central part lies in the rain shadow of mountain ridges and is the driest area (Bagdasaryan 1958; Third… 2015).

8.4 Flora and Phytogeography

8.4.1 Evolution of the Flora

The major processes of flora-building and the formation of vegetation of the region began in the Cretaceous period. As A. Krishtofovich (1936) showed, the modern vegetation of Eurasia and the rest of the world is derived from the Cretaceous flora as that is the oldest relevant flora that is still sufficiently similar to the present stage of development of the plant world; all the modern different types of vegetation developed from plants that inhabited Eurasia at the end of the Cretaceous period. As a result of global geological alterations during the Cretaceous (Weberling 1985; Derkur and Sonnenschein 1990) the Mediterranean Thetys Sea greatly increased and at the localities of the present Caucasus, the recent Armenian Highlands and Iran only separate large islands existed, with in their northern and central parts moist forests. On the southern shores of the Thetys xerophilous savannahs with oases and riparian forests already existed (Sinitsyn 1962). At the beginning of the

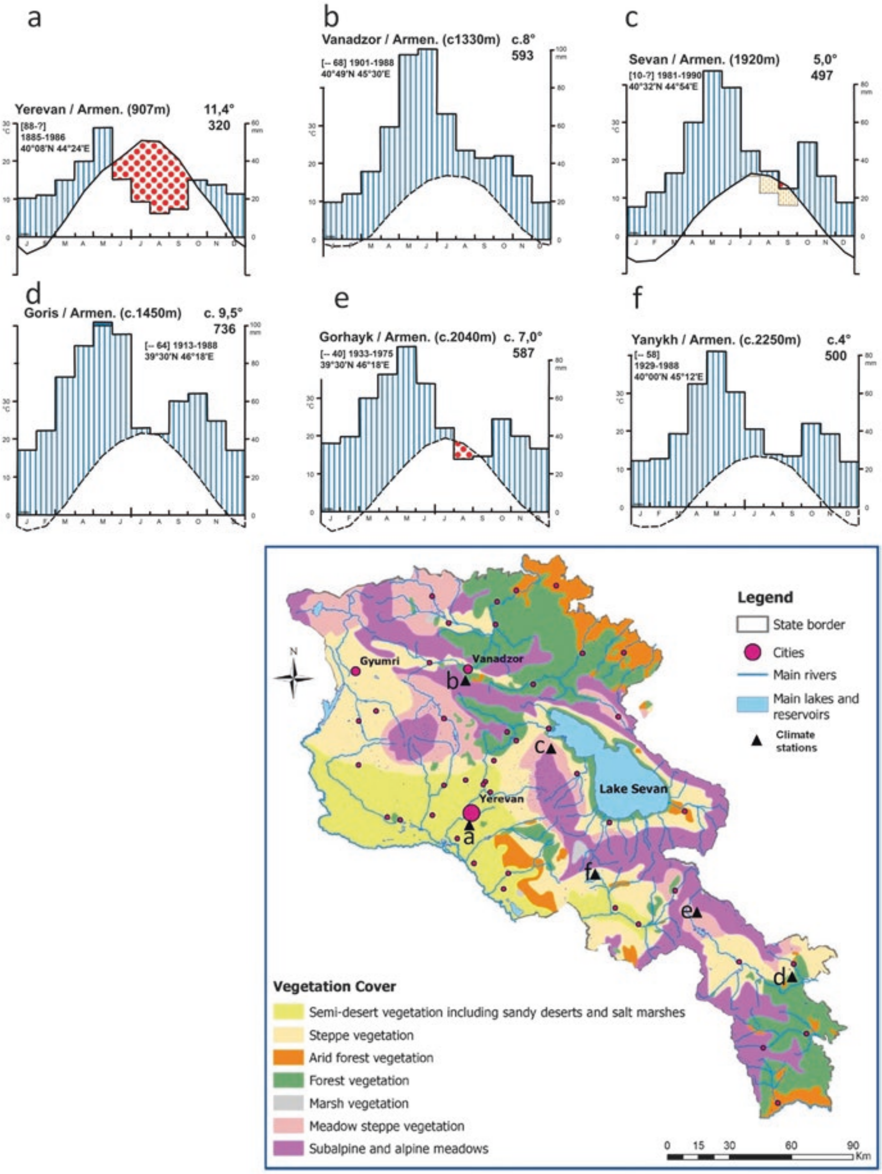

Fig. 8.2 The vegetation types of Armenia and climatic diagrams from different vegetation types (a–f)

Paleogene Laurasia split into North America and Eurasia, and Africa began to approach Eurasia. As a result the Thetys was closed. Today's Lesser Caucasus was situated in the middle of the Thetys. This is evident from ophiolites in Sevanside, that is part of the ophiolite joint which separated Gondwana and Eurasia. Thus, for example, modern Darelegis (Vayots Dzor province of Armenia) and some parts of the Nakhichevan republic, which both have deviating floras, are fragments of Gondwana (Derkur and Sonnenschein 1990), being of southern origin.

At the transition of the Cretaceous and Paleogene in Central Asia, a very varied complex of floristic types existed. The uplift of the earth's crust began in the Oligocene and this can be considered the beginning of the continental development of the Caucasus. At the end of the Paleogene, the Great and Lesser Caucasus got an overland connection. In the Neogene a vast expansion of the land, great orogenic processes and a gradual decrease in temperature started. The Miocene and Pliocene are the neotectonic stage in the development of the Caucasus. At that time, there was a general uplift of Asia Minor, the Tethys became drained and was replaced by mere saline and freshwater lakes. The upper Miocene is also characterized by intense volcanism. In the Armenian Highlands mixed forests dominated at that time, and only at the end of the Miocene herbaceous plants became a dominant part of the flora. Tumadjanov (1971) showed, that from the beginning of the Miocene, the dispersal of xerophytic Antasian species to the Great Caucasus continued, particularly under the dry continental climatic conditions of the Middle Pliocene. The route for the Antasian xerophytic flora to the Lesser and Great Caucasus might have been opened from the end of the Miocene, when the Caucasus became a large peninsula of Asia Minor. At that time there was no high mountain relief in the Caucasus. The intensive penetration of xerophytes still continued in the Middle Pliocene, as evidenced by halo-xerophytic relicts such as *Salsola dendroides, S. ericoides, Nitraria schoberi, Reaumuria hypericoides,* etc. of the ancient saltwort desert of Daghestan (Tumadjanov 1971).

In the Neogene, the Ancient Mediterranean element was the initial basis from which, due to active speciation, the numerous Armeno-Iranian, Armenian and Atropatenian species developed. Obviously, at the same time some North Mediterranean species began to spread on the Armenian Highlands. The Quaternary period is characterized by an even more intensive uplift of land and drying up of internal seas and lakes, while tectonic activity increased. Most probably, the Glacial and Post-glacial periods provided the best conditions for the mass migration of Boreal and Pannonian-Pontic species into the South Caucasus. During that time, most likely during the last 10000 years, great changes in vegetation types took place in the Armenian Highlands. Just 2000 years ago large forest areas occurred at even one degree further south than at present time.

The communities that formed in the Tertiary period survived the Ice Ages in some refugia. In the Post-glacial period they greatly spread and are now one of the most important ecosystems. Such ecosystems include beech forests (Tumadjanov 1971) and areas of deciduous forests with a high representation of *Taxus baccata*. In the Caucasus, these communities are very widespread, and in Armenia they are present almost exclusively in the northern part of the republic. However, in the south there is a relatively small area with a predominance of beech and a small *Taxus* grove. This indicates, most likely, that after the Ice Ages these communities occupied much larger areas and formed a single complex of similar communities in Northern Armenia, Nagorny Karabakh and the Greater Caucasus, and only under the influence of the anthropogenic factor did their area become highly fragmented.

8.4.2 Flora

The Transcaucasian Highlands are located on the border of the Euro-Siberian and the Irano-Turanian biogeographical regions and at the junction of the Caucasian and Irano-Anatolian biodiversity hotspots (Mittermeier et al., 2011). More than 4000 vascular plant species occur in the Transcaucasian Highlands, and the flora of Armenia alone comprises about 3800 species of vascular plants (The Fifth… 2014).

The largest families of the Armenian flora are listed in Table 8.1. As a matter of fact, the 30 largest families comprise more than 80% of all species of the flora of Armenia.

Table 8.1 Largest families of the flora of Armenia

NN	Family	Number of genera	Number of species	Number of endemics	% of endemics
1.	*Asteraceae*	90	442	27	6.1
2.	*Poaceae*	102	336	13	3.9
3.	*Fabaceae*	33	324	15	4.6
4.	*Rosaceae*	29	214	31	14.5
5.	*Brassicaceae*	68	203	7	3.4
6.	*Caryophyllaceae*	32	183	10	5.5
7.	*Lamiaceae*	33	153	1	0.7
8.	*Scrophulariaceae*	20	150	8	5.3
9.	*Apiaceae*	61	140	3	2.1
10.	*Cyperaceae*	16	108	0	0
11.	*Chenopodiaceae*	30	87	0	0
12.	*Boraginaceae*	23	78	2	2.6
13.	*Ranunculaceae*	17	68	1	1.5
14.	*Polygonaceae*	7	50	0	0
15.	*Orchidaceae*	17	44	0	0
16.	*Rubiaceae*	9	44	0	0
17.	*Euphorbiaceae*	4	43	1	2.4
18.	*Alliaceae*	2	42	3	7.1
19.	*Liliaceae*	5	38	0	0
20.	*Orobanchaceae*	4	36	6	16.7
21.	*Hyacinthaceae*	6	34	1	2.9
22.	*Campanulaceae*	4	32	1	3.1
23.	*Iridaceae*	3	29	2	6.9
24.	*Geraniaceae*	2	28	1	3.6
25.	*Papaveraceae*	4	28	5	17.9
26.	*Plumbaginaceae*	5	26	1	3.9
27.	*Dipsacaceae*	5	25	0	0
28.	*Primulaceae*	8	25	0	0
29.	*Onagraceae*	5	23	0	0
30.	*Malvaceae*	7	22	1	4.6

This flora contains very widespread, polychorous plant species such as *Chenopodium album, Lythrum salicaria, Phragmites australis,* etc., as well as many species that originated in the Mediterranean (*Malva neglecta, Platanus orientalis, Trifolium striatum, Vicia grandiflora,* etc.), Asia Minor (*Acantholimon armenum, Dianthus calocephalus, Helianthemum lasiocarpum, Linum hypericifolium,* etc.), and the Irano-Turanian region (*Alhagi pseudoalhagi, Camphorosma lessingii, Carex stenophylloides,* etc.). But at the same time the territory contains powerful foci of speciation of some genera such as *Astragalus, Centaurea, Cousinia, Verbascum,* etc. (Gabrielian and Fayvush 1986, 1989; Tamanyan and Fayvush 1987, etc.).

The largest genera of the Armenian flora are listed in Table 8.2.

In the next subchapters we discuss some of the largest genera of the Armenian flora from the points of view of endemism and speciation (*Astragalus, Centaurea, Cousinia, Verbascum, Pyrus*). Here we would like to draw attention to other genera. At the second place in the table we see the genus *Carex.* Most representatives of this genus are mesophilous and have an Euro-Siberian distribution and origin. *Vicia* and *Trifolium* have Mediterranean roots, and *Euphorbia* (our sections) are of Irano-Turanian origin. The diversity of *Verbascum* is connected mainly with hybridization processes in the Armenian Highlands, and *Alchemilla*'s variability is connected mainly with apomixes.

Table 8.2 Largest genera of the flora of Armenia

NN	Genus	Number of species
1.	*Astragalus*	134
2.	*Carex*	71
3.	*Centaurea s.str.*	46
4.	*Allium*	41
5.	*Vicia*	41
6.	*Silene*	38
7.	*Euphorbia*	37
8.	*Verbascum*	37
9.	*Veronica*	34
10.	*Pyrus*	32
11.	*Trifolium*	31
12.	*Potentilla*	29
13.	*Rosa*	28
14.	*Alchemilla*	26
15.	*Campanula*	25
16.	*Onobrychis*	25
17.	*Ranunculus*	25
18.	*Cerastium*	23
19.	*Dianthus*	23
20.	*Lathyrus*	23

About 1000 species, i.e. more than one third of the flora of Armenia and more than half of the flora of the mountains of Daghestan, are common to both floras, and more than 500 species are also found in Northern Iran. However, a detailed examination of these common species reveals that their vast majority (about 70%) are mesophytes confined to forests, meadows, meadow-steppes and wetland habitats. At the same time, most of them are widely distributed species of the lower and middle mountain belts or species with wide ecological amplitudes, which are found from the low mountains to the alpine belt. Xerophytes account for less than 12% of these species (a similar number as meso-xerophytes).

8.4.3 Phytogeography

The most important chorotypes of this region can be classified as below.

Euro-Siberian Elements This element includes quite widespread species in Europe and Siberia, which often act as edificators of plant communities. However, in Armenian Highlands their role is not very great, and more often they act as co-edificators or assectators. Many of them are confined to disturbed habitats. These include *Alisma lanceolatum, Calamagrostis epigeios, Dactylis glomerata, Descurainia sophia, Hypericum perforatum, Lactuca serriola, Poa bulbosa,* etc.

Euxine Elements They are very important in the Armenian Highlands flora. In the northern part of this region, the influence of the Euxine flora is dominant. The *Fagus orientalis – Corylus colurna* forests, as characteristic of the Euxine province (Davis 1985), are well represented in Armenia. South of the Pontus mountains, there are insurmountable barriers for many Euxine species. Nevertheless, some Euxine or Hyrcano-Euxine elements have penetrated into the Armenian Highlands (e.g. *Campanula lactiflora, Chamaesciadium acaule, Pimpinella rhodantha, Scaligera tripartita,* etc.) together with many relatively mesophytic Boreal and often Mediterranean species.

Caucasian Elements As noted above, the northern part of the Lesser Caucasus belongs to the Caucasian floristic province (Takhtadjan 1986). Thus, it obviously is to be expected to have close ties with the Caucasian flora. Naturally, the majority of the Caucasian species are concentrated in the northern part of the Lesser Caucasus (e.g., *Agasyllis latifolia, Astragalus calycinus, Astrantia trifida, Cerastium holosteum, Galanthus alpinus, Viola caucasica*), although many of these species also reach quite far south, into Syria and Iraq and in the southeast to the Zagros Mountains in Iran. These groups of species reflect ancient relations of the Caucasian steppes with the South Caucasus. In that community, dominated by *Rhododendron caucasicum*, different Holarctic and Caucasian species occur, such as *Actaea spicata, Aetheopappus pulcherrimus, Anthoxanthum odoratum, Coeloglossum viride, Daphne glomerata, Geranium sylvaticum, Myosotis alpestre, Nardus stricta,* *Pedicularis condensata, Poa nemoralis, P. longifolia, Scabiosa caucasica, Vaccinium myrtillus,* etc.; Fayvush and Aleksanyan 2016).

Irano-Turanian Elements The Irano-Turanian region, which is characterized mainly by xerophytic flora, has a very strong influence on the development of the flora and vegetation of the Armenian Highlands. The influence of the Irano-Turanian region is most pronounced in the flora and vegetation of the foothills and the lower mountain belt. They are well represented in the flora of deserts and semi-deserts, dominated by *Acantholimon glumaceum, Alhagi pseudoalhagi, Artemisia fragrans, Astragalus camptoceras, Atraphaxis spinosa, Calligonum polygonoides, Gypsophila aretioides, Halimodendron halodendron, Kochia prostrata, Noaea mucronata, Onobrychis cornuta, Physoptychis caspica, Zygophyllum atriplicoides,* etc.

The influence of the flora of the Iranian Plateau is most pronounced in the east and southeast of the Armenian Highlands. However, a fairly large number of Iranian species reach the Lesser Caucasus, such as *Acanthophyllum mucronatum, Allium viride, Echinops pungens, Euphorbia marschalliana, Onosma sericeum, Paracaryum strictum, Reseda microcarpa, Rosularia elymaitica, R. persica* (Sagatelian 1981).

Mediterranean Elements The majority of the Anatolian and Mediterranean species do not go further east than the "Anatolian Diagonal" (Davis 1971, 1985; Ekim and Guener 1986). However, a few Mediterranean species are widely distributed all over the Armenian Highlands, such as *Saponaria orientalis, Scleranthus uncinatus* and *Silene alba*. It is noteworthy that in the South Zangezur floristic region of Armenia, the largest community of *Platanus orientalis* in the Caucasus exists. From a floristic point of view, *Platanus* is a Mediterranean element, but the floristic composition and structure of this community indicate that it belongs to the "Irano-Anatolian mixed riverine forests" habitat (Fayvush and Aleksanyan 2016).

Mesopotamian From the south and southwest, the most xerophytic Mesopotamian and South Anatolian species migrated to the northeast of the Armenian Highlands. By spreading many of these species apparently migrated across the Kurdish mountains in the Hakkari and Van regions, but a rather large group of species of the "Asia Minor – Caucasian" distribution type grow from Syria and Iraq to the Great Caucasus (often extending into the mountains of Daghestan). These include, for example *Campanula aucheri, C. collina, Cephalaria gigantea, Corydalis alpestris, Dianthus cretaceous* and *Poa iberica,* etc.

8.4.4 Invasive Species

At present, we have compiled a list of about 400 species of woody and herbaceous plants that can pose a threat to natural ecosystems as invasive species. Almost all these species are neophytes; they appeared on the territory of Armenia as from the 19th century, and especially as from the second half of the 20th century. Among them, quite a few species were introduced because of their decorative value, but then they later showed invasive properties and began to penetrate into the natural ecosystems, such as, e.g. *Ailanthus altissima, Robinia pseudoacacia*. Some other species that also proved strongly invasive appeared accidentally in the second half of the 20th century and are presently intensively spreading and penetrating into natural ecosystems (e.g. *Ambrosia artemisiifolia, Silybum marianum, Clematis vitalba* and others). A significant group of plants that currently have a serious impact on natural ecosystems includes the so-called expanding species. Usually, we consider them indigenous, but they began to spread intensively in recent times due to the impact of the anthropogenic factor and climate change. But many of them, most likely, are archaeophytes – species that were brought into Armenia in the Middle Ages (or even earlier), because Armenia, as from ancient times, was on the "crossroads" of trade caravans and the arena of numerous wars of conquest. All this contributed to the introduction of new plant species and it is almost impossible to determine the time of their first introduction (for example, there is the assumption that *Acorus calamus* was brought by Mongolian warriors who used its rhizomes to disinfect water reservoirs during their military campaigns). Over the past centuries, many of them have not only adapted to the new conditions, but have also played a significant role in the composition of ecosystems. In this category we probably can include numerous weedy species that have spread recently in fields and pastures. They include numerous prickly species with wide distributions in the Holarctic (*Cirsium, Carduus, Onopordum* species, etc.).

8.5 Endemism

Here we consider the endemism of two floristic regions; the Caucasus (the Caucasian province) and the Armenian Highlands (the Armeno-Iranian province), which are associated with the Euro-Siberian and Irano-Turanian phytogeographical regions, respectively.

The flora of the entire Caucasian ecoregion is estimated at about 6000–6500 species of vascular plants; 40–45% of them (2791 species) are endemic in that ecoregion (Solomon e.a., 2013). Taxonomic analysis indicates that there are 21 genera of vascular plants endemic across the Caucasus region. These genera mostly are monotypic or oligotypic and some have unclear relationships. The vast majority of the genera endemic to the Caucasus grow in the Greater Caucasus, while in the Lesser Caucasus only four endemic genera exist: *Agasyllis* (Apiaceae; 1 species), *Grossheimia* (Asteraceae; 6 spp.), *Pseudovesicaria* (Brassicaceae; 1 sp.), and *Zuvanda* (Brassicaceae; 1 sp.). Species of these genera grow mainly in the highlands and are confined to stony habitats, screes, rocks and subalpine meadows.

Although generic endemism is very characteristic of the entire Irano-Turanian region, it is particularly strong in its eastern part (Kamelin 1965; Hedge and Wendelbo 1970, 1978). In the northeastern part of the Armenian Highlands there are eight genera of Ancient Mediterranean root: *Peltariopsis, Pseudoanastatica,* *Takhtajaniella* (all from Brassicaceae), *Smyrniopsis, Stenotaenia, Szovitsia* (all from Apiaceae), *Huynhia* (Boraginaceae) and *Callicephalus* (Asteraceae).

Approximately 10% of the species of the total flora of the Armenian Highlands is endemic (Gabrielian and Fajvush 1989). Asteraceae is the richest in endemic species (c. 90 species), followed by Fabaceae (c. 35), Brassicaceae (c. 30), Lamiaceae (c. 25), Scrophulariaceae (c. 20) and Caryophyllaceae (c. 15). At genus level, *Astragalus* is the largest in number of species in the Armenian Highlands (Table 8.2), but *Centaurea* is the richest in the number of endemics (c. 40 species). Besides *Centaurea, Astragalus* (c. 30 species)*, Pyrus* (c. 20), *Cousinia* (c. 15) *Allium* (c. 10) and *Verbascum* (c. 10) also have rather big numbers of endemics.

According to Wagenitz (1975, 1986), species and sections of the genus *Centaurea* are highly concentrated in eastern Anatolia, especially in the area where Iran, Iraq and Turkey meet, holding a total of 35 species. In the parts of eastern Anatolia bordering the Transcaucasian Highlands 18–34 species are found. Wagenitz predicted that at least as high a concentration of species and sections should also exist in the Southern Caucasus and nowhere else in the entire distribution area of the genus *Centaurea.* However, the data obtained by us greatly exceed all our expectations. In the tiny territory of the Republic of Armenia, occupying less than one grid square, there occur some 70 species of *Centaurea* s.l. (Fig. 8.3). From the adjacent territory of the Nakhichevan Republic, 30 species are known. There are even fewer species in the adjacent territories of Georgia and Azerbajdjan.

A large number of endemic species are found in the genera *Astragalus* and *Cousinia*. The genus *Astragalus* is very typical for the entire Irano-Turanian region, and it is the largest genus in Armenia and the Lesser Caucasus. However, there are relatively few narrowly endemic species (only 7%); the distribution ranges of most species are not limited to one country or a floristic region. Obviously, species of this genus have better opportunities for their spread and adaptation to new conditions. The distribution area of *Cousinia* lies almost entirely in the Irano-Turanian region. The maximum of its species diversity is confined to Central Iran, where about 300 species are concentrated (Rechinger, 1972, 1986). It can be confidently asserted that the main, primary center of speciation of this genus is located in the Iranian Highlands. But the genus has several secondary centers of speciation along the periphery of its range (Cherneva 1974). Two such centers are located in the Armenian Highlands - in the Lesser Caucasus and in the Turkish part of the Highlands (Huber-Morath 1972; Tamanyan and Fayvush 1987). In the Lesser Caucasian center the speciation takes place most intensively in the mountains of the southern part of the region - in the Meghri and South-Zangezur floristic regions of Armenia and in the Nakhichevan republic (Tamanyan and Fayvush, 1987).

Speciation in the genus *Verbascum* is also characteristic of the arid regions of the Ancient Mediterranean, but most of the species of this genus that are endemic to Armenia are obviously of hybridogenic origin. In general, the distribution of the numbers of endemics by genera and families shows that more of those taxa are related to the Ancient Mediterranean sub-kingdom than to the Boreal one (Takhtadjan 1986).

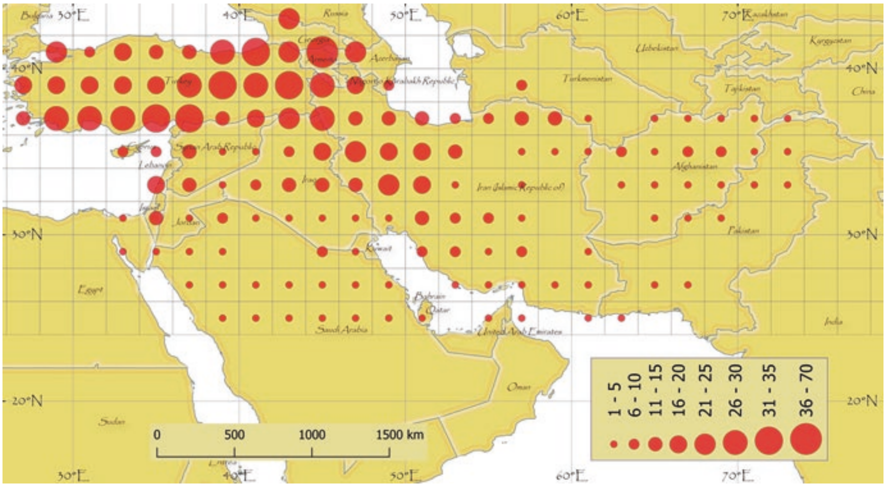

Fig. 8.3 *Centaurea* in SW Asia: species numbers per grid cell. After Wagenitz (1986), with additions by Gabrielian and Fajvush (1989)

Considering the distribution of endemic taxa along high altitude belts, it is clear that they are more concentrated in the middle and partly in the upper montane belts. Obviously, this montane belt has the greatest variety of habitats, and conditions are most conducive to speciation. In the lower as well as in the subalpine and, especially, the alpine belts, the extreme soil and climatic conditions make adaptation of new mutations difficult.

Approximately three-quarters of all endemic taxa grow in arid plant communities - steppes, arid open forests and shiblak, steppe shrubs communities, and semi-deserts, often preferring petrophilous variants of these vegetation types. Apparently, the vast majority of these species are neoendemic, and their abundance in these types of vegetation confirms the hypothesis of a “morphogenetic explosion” in arid habitats (Agakhaniants 1981). Approximately a quarter of the endemic species are found in more humid plant communities - forests, meadows, subalpine tall grasses and wetlands. These taxa are probably palaeoendemics, preserved in the humid refugia of arid mountains or in forests.

8.6 Major Vegetation Types

Armenia has diverse vegetation types due to the heterogenous landscapes and topography (Fig. 8.2). The lower mountain belt (375–1200 m a.s.l.) is covered by semi-deserts of gypsophilous or halophilous vegetation types. There are salt marsh areas as well as the Transcaucasian sand desert. The middle and upper mountain belts (1200–2200 m a.s.l.) are characterized by various kinds of steppe and forest vegetation, meadow-steppes, shrub steppes and thorny cushion (tragacanth) vegetation. The altitudinal span of the forest belt varies from 500 to 2000 m a.s.l. depending on the region, and may approach 2400 m a.s.l. when open park-like tree stands are included. The subalpine and alpine belts (2000–4000 m a.s.l.) are covered by tall-grass vegetation, meadows and carpet vegetation (Magakyan 1941; Takhtadjan 1941; Fayvush 2006).

In the monograph of Fayvush and Aleksanyan (2016), brief descriptions of the majority of ecosystems and habitats of Armenia are given. We used the EUNIS classification scheme (Davies et al. 2004), developed mainly for Europe, and we were forced to introduce new classification units for ecosystems absent in Europe.

8.6.1 Forests

The forest biodiversity of Armenia is evident from the many species of trees (125 species), shrubs (111), small shrubs (30), semi-shrubs (48) and woody lianas (9). Forest vegetation in the republic occurs mainly at altitudes of 500–2000 m a.s.l., while in some areas forests grow up to 2400 m a.s.l., forming so-called park forests. The main forest areas of the republic are confined to the northern (62%) and southern (36%) regions, the central part of Armenia being much less afforested (2%). The main forest-forming species in Armenia are *Fagus orientalis* (Fig. 8.4a), *Quercus iberica* (Fig. 8.4b) and *Q. macranthera*, and partly *Carpinus orientalis*. In general, forest communities in Armenia occur in the foothills and the lower and middle mountain belts at slopes with inclinations of 20–25°. The timberline reaches up to 2300–2400 m a.s.l., though individual trees occur above the upper timberline till altitudes of 2700–2800 m a.s.l. Oak and beech forests are most dominant, and are located at altitudes of 1300–2000 m a.s.l. The stands dominated by *Pinus kochiana*, *Taxus baccata*, *Corylus colurna* and other rare tree species decreased considerably in this area in historic time. At present they occur in patches or as sporadic trees. Moreover, *Taxus baccata*, *Corylus colurna* and *Platanus orientalis* (Fig. 8.4c), which occur in small populations, are remarkable relict elements (Fayvush 2006; The fifth … 2014).

The forest ecosystems are very diverse but occupy only about 10% of the territory of Armenia. We can distinguish riparian and gallery woodland dominated by *Populus* ssp. and *Salix* ssp., Irano-Anatolian mixed riverine forests (dominated by *Platanus orientalis* and *Populus euphratica*), *Fagus orientalis* forests, non-riverine woodland with *Betula, Sorbus*, *Quercus iberica, Q. macranthera*, *Carpinus betulus*, *Fraxinus oxycarpa*, *Acer ssp.*, *Tilia cordata, T. caucasica*, *Ulmus* ssp., *Pinus kochiana*, and *Taxus baccata*. About 20 locally endemic species are growing in the forests of the Transcaucasian Highlands, e.g. *Colchicum goharae, Merendera mirzoevae, Psephellus debedicus, Psephellus zangezuri* and *Pyrus elata.*

The open oak forests are important ecosystems in Armenia. *Quercus araxina* occurs only in the South Zangezur and Megri floristic regions in the lower montane belt, up to 1100 m a.s.l. The common species in these habitats are *Bothriochloa ischaemum, Carex humilis, Colutea cilicica, Cornus mas, Corylus avellana,*

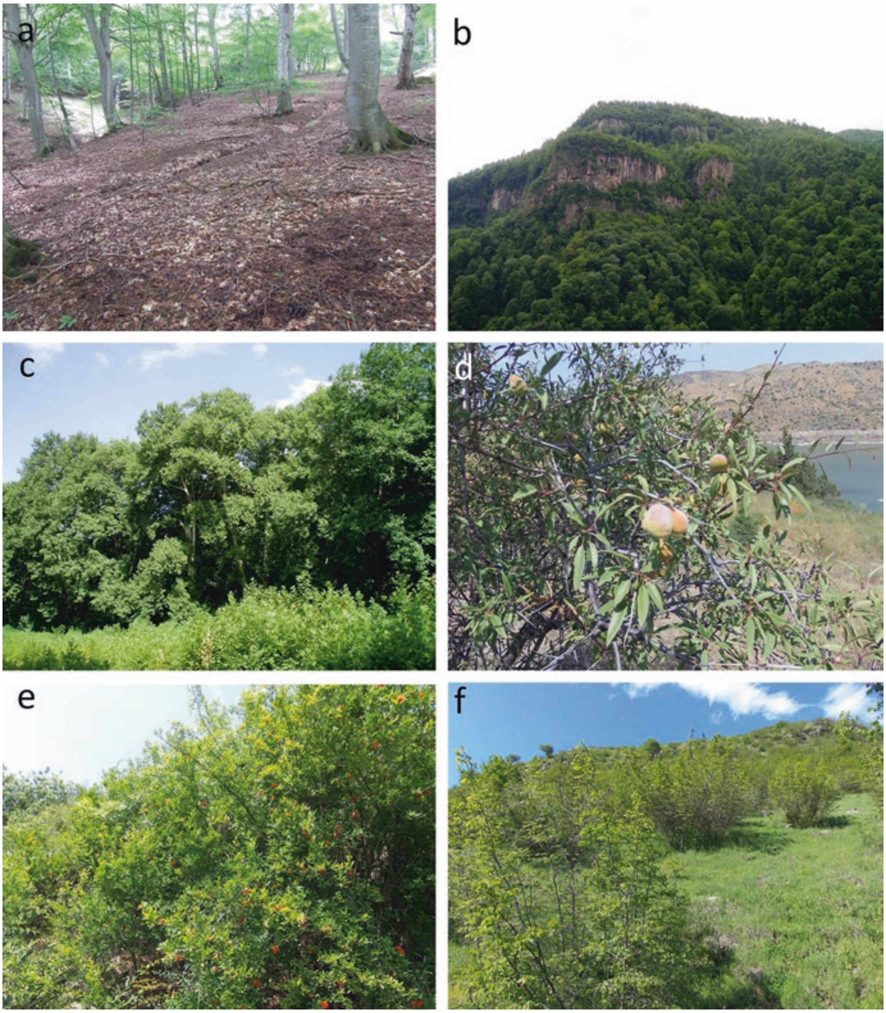

Fig. 8.4 (**a**) *Fagus orientalis* forest ("Dilidjan" National park, 1360 m a.s.l.); (**b**) *Quercus iberica* forest (Idjevan, Yenokavan, 1050 m a.s.l.); (**c**) *Platanus orientalis* grove (Kapan distr., "Plane grove" sanctuary, 800 m a.s.l.); (**d**) Open arid forest with dominance of *Amygdalus fenzliana* (Vayots Dzor region, vicinity of Her-Her reservoir, 1500 m a.s.l.); (**e**) Open arid forest dominated by *Punica granatum* (Vicinity of Akhtala town, 700 m a.s.l.); (**f**) "Shibliak" – communities with dominance of *Paliurus spina-christi* (Kapan distr., vicinity of Syunik village, 760 m a.s.l.; photos G. Fayvush)

Dactylis glomerata, Dictamnus albus,Genista transcaucasica, Jasminum fruticans, Ligustrum vulgare, Lonicera iberica, Melica transsilvanica, Origanum vulgare, Paliurus spina-christi, Rhamnus cathartica, Sambucus ebulus, Spiraea hypericifolia, Teucrium polium, and *Thalictrum minus*. In some regions, the upper forest line is formed by scattered *Quercus macranthera* trees with an undergrowth of subalpine herbaceous species (shrubs are usually very small).

8.6.2 Arid Open Woodlands and Tragacanth Vegetation

Arid open woodlands consist of both coniferous (juniper woodlands) and deciduous species (*Acer ibericum*, *Amygdalus fenzliana* (Fig. 8.4d), *Celtis glabrata*, *Pistacia mutica*, *Punica granatum* (Fig. 8.4e), *Pyrus salicifolia*, and others) and of shibliak (mainly spiny shrubs with *Paliurus spina-christi* (Fig. 8.4f) as a dominant). Floristically these communities are very rich. They occupy mainly the mid-montane belt, but also occur in the upper belt. In recent years, this formation has been expanding in area at the expense of the typical species of open woodlands and shibliak, mainly *Paliurus spina-christi* and *Rhamnus pallasii*, as well as due to the gradual reduction in tree density of the forest at the lower timberline. Conspicuous are the tragacanth communities dominated by the spiny cushions of small shrubs. They occupy rather big areas in the mid- and upper-montane belts. Some species of *Astragalus, Acantholimon,* as well as *Onobrychis cornuta* dominate these communities (Aleksanyan 2011; Fayvush and Aleksanyan 2016).

Arid deciduous open forests are remarkably varied and are primarily distinguished by basic edificators; they are often polydominant communities in which several species predominate in the same stand (for example, *Pistacia mutica* and *Punica granatum*, or *Amygdalus fenzliana* and *Celtis glabrata*, several species of *Pyrus*, etc.). There are more than 30 local endemic species growing in arid open forests, such as *Amygdalus nairica, Cousinia gabrielianae, Crataegus zangezura, Dianthus grossheimii, Pyrus chosrovica, Pyrus gergerana,* etc.

Very characteristic ecosystems from the mid-montane to the subalpine belt are tragacanth communities, in which cushion-shaped shrubs dominate, e.g. *Acantholimon bracteatum* (Fig. 8.5a), *Astragalus microcephalus* (Fig. 8.5b), *Astragalus lagurus, Astragalus uraniolimneus, Onobrychis cornuta* (Fig. 8.5c), *Gypsophila aretioides* and *Gundelia aragatsii*.

Juniper woodlands, dominated by various species of *Juniperus*, are very characteristic of the Transcaucasian Highlands from the lower to the subalpine belts. Dominants here are *Juniperus excelsa* and *J. foetidissima.*

8.6.3 Wetland Vegetation

These habitats are intrazonal and occur in all mountain belts. These are extremely diverse ecosystems occurring at lakes, rivers, streamlets and marsh areas, which vary dependent on environmental conditions and elevations (Barsegyan 1990; Fayvush and Aleksanyan 2016). Over the last centuries, the changes due to economic activities have resulted in the reduction of wetland areas and the extinction of

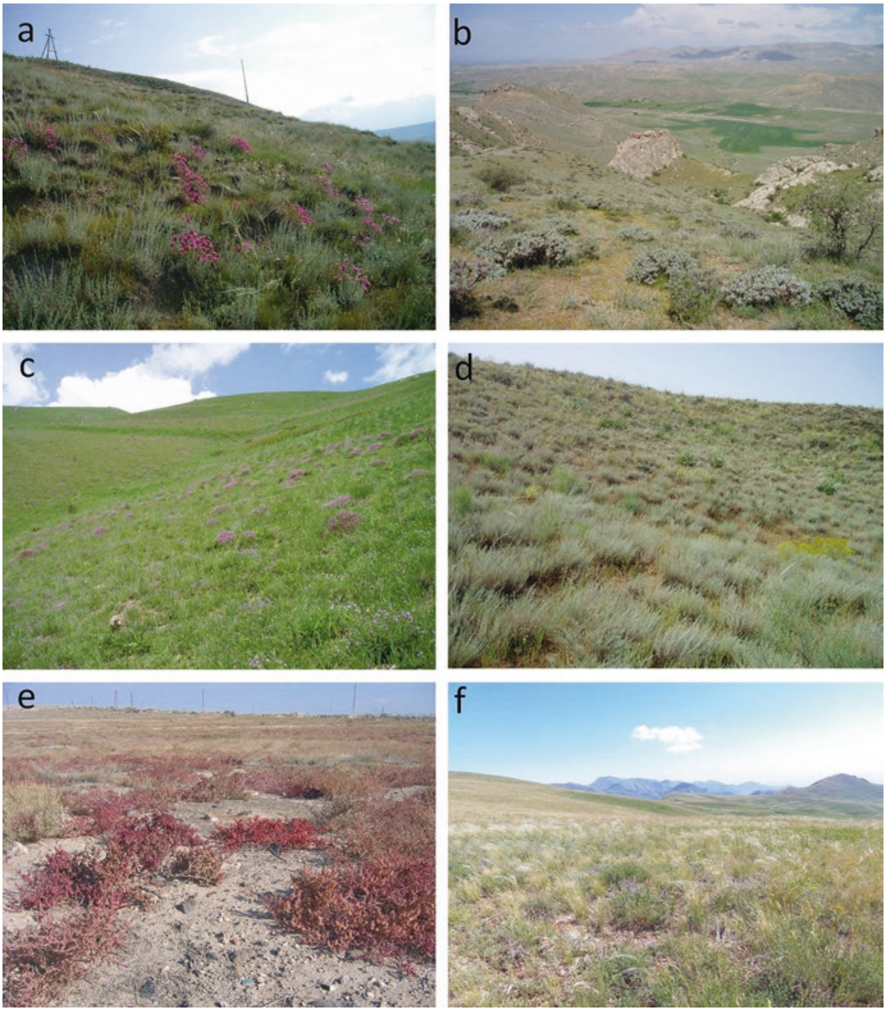

Fig. 8.5 (**a**) Tragacanth community with dominance of *Acantholimon bracteatum* (Sisian district, vicinity of Brnakot village, 1650 m a.s.l.); (**b**) Tragacanth community with dominance of *Astragalus microcephalus* (Vicinity of Hrasdan town, 1800 m a.s.l.); (**c**) Tragacanth community with dominance of *Onobrychis cornuta* (Vayots Dzor region, vicinity of Yelpin village, 1500 m a.s.l.); (**d**) Semi-desert with dominance of *Artemisia fragrans* (Vicinity of Tigranashen village, 1250 m a.s.l.); (**e**) Semi-desert with dominance of *Seidlitzia florida* (Vicinity of Merdzavan village, 900 m a.s.l.); (**f**) Steppes with a dominance of *Stipa arabica* (Vicinity of Tigranashen village, 1250 m a.s.l.; photos G. Fayvush)

some wetland species. Over the last years, the following processes have caused serious threats: the construction of small hydropower plants on rivers with scarce water resources, which changed the ecosystem; fluctuation of the water level of Lake Sevan, which resulted in the redistribution of water plants in the lake; as well as changes in the hydrological regime of rivers and lakes (for example, on the Lori Plateau) (The fifth … 2014).

8.6.4 Semi-Deserts

Semi-desert vegetation formations are found in the lower montane belt at altitudes of 375 to 1200 m a.s.l. Main dominants of this vegetation type are *Artemisia fragrans* (Fig. 8.5d), *Capparis herbacea, Camphorosma lessingii, Seidlitzia florida* (Fig. 8.5e) and *Acantholimon* spp. This formation contains the main variation in gypsophilic and halophilic vegetation in Armenia. The semi-desert vegetation of Armenia is very rich in endemic species, such as *Acantholimon vedicum, Allochrusa takhtadjanii, Astragalus holophylus, Bufonia takhtadjanii, Carthamus tamamschianae, Isatis buschiorum, Verbascum gabrielianae,* etc. Over the last 5 years, that have seen intensified processes of soil erosion and desertification, the expansion of the semi-desert belt in the elevational profile went up by about 50 m, as observed in the occurrence of several edificators; in particular the species *Artemisia fragrans*, *Capparis herbacea* and *Rhamnus pallasii* have been recorded some 200–300 m above their previous altitudinal limits (The fifth … 2014). Around 80–90% of the semi-desert belt is used for agricultural purposes, but often the rules of irrigation and soil cultivation are not followed, and that has resulted in soil erosion and secondary salination processes.

8.6.5 Mountain Steppes

Mountain steppes in the Transcaucasian Highlands in the recent past were, apparently, the most widespread type of vegetation. They occupied all the mountain plateaus and treeless slopes in the mid-montane belt. Researchers were strongly interested in the feather-grass steppes, which in their appearance are extremely similar to the steppes of Southern Russia. During the Soviet period, most steppe territories were plowed and used for agriculture. Presently, only small fragments of those steppes have been preserved on the steeper and stony slopes or in small pieces between fields on the mountain plateaus. The most common communities are steppes dominated by *Stipa tirsa, S. pennata, S. lessingiana, S. arabica* (Fig. 8.5f) and *Festuca valesiaca*, and also the so-called “tragacanth steppes” dominated by *Astragalus microcephalus, A. lagurus, A. auranthiacum* and *Onobrychis cornuta*. Steppes are the richest vegetation types in terms of species and they contain the largest number of endemic species in Armenia. Over the last 10 years, the lower part of the steppe belt has diminished in area due to the expansion of semi-desert vegetation. Typical steppe species have invaded into the meadow-steppe zone and have reduced its altitudinal limits (The fifth … 2014). The steppe vegetation is very rich in local endemic species and more than 40 local endemics are known, e.g. *Alcea* *grossheimii, Centaurea takhtadjanii, Merendera greuteri, Rhaponticoides hajastana, Rhaponticoides tamanianae, Tragopogon armeniacus,* etc.

Within the steppe zone the cultivation of soils and the establishment of protective forest belts around agricultural fields, as well as the use of areas for hay-making and also fires have had negative impacts on the plant cover and fauna. The natural plant cover is replaced by cultivated plants such as wheat, corn, sunflowers and fruit orchards as well as by the cultivation of vegetables in alluvial areas.

To date the benefits and services provided by steppe ecosystems have not been practically evaluated. The local population actively collects and uses numerous medicinal and edible steppe plants for personal consumption and for selling at local markets, and the steppes located on steep slopes are used as pastures and hay-making areas (in limited cases).

In the upper montane belt, between the steppes and subalpine meadows, there is a relatively narrow belt of meadow-steppes, in which both steppe and meadow plants dominate.

8.6.6 Subalpine and Alpine Vegetation

These ecosystems are typical for the upland zones and high altitudes (above 2200 m a.s.l.) in the Transcaucasian Highlands. These are subalpine meadows, subalpine tall grass vegetation and alpine meadows and carpets. Over the last years, probably due to the changes in the redistribution of pasture pressure, as well as a result of climatic changes, some successional changes have been observed, such as the shift of subalpine species into the alpine belt (in Syunik, Mount Aragats). Almost everywhere we see the expansion of species that are not suitable as fodder, especially of the species *Tripleurospermum transcaucasicum* (The fifth … 2014).

Subalpine The subalpine vegetation of the Transcaucasian Highlands is extremely diverse and is represented by a variety of ecosystems, including grasslands and lands dominated by forbs, mosses or lichens, heathland and scrub, and woody ecosystems.

The grasslands comprise subalpine meadows and subalpine tall grass communities and dominant species can be *Agrostis planifolia, Alopecurus armenus, Bromopsis variegata, Dactylis glomerata, Festuca ruprechtii, F. woronowii, Hordeum violaceum, Koeleria albovii, Phleum alpinum, Poa alpina, P. pratensis.* The dominant species in the subalpine forbs meadows can be *Anemone fasciculata* (Fig. 8.6a), *Astrantia maxima, Betonica macrantha, Carex brevicollis, Centaurea cheiranthifolia, Nepeta betonicifolia, Pimpinella saxifraga, Rhinanthus pectinatus, Scabiosa caucasica, Tanacetum coccineum* and *Veratrum album*). Sub-alpine tall-grass communities are Ponto-Caucasian dominated by *Aconitum orientale, Astrantia maxima, Campanula latifolia, Cephalaria gigantea, Dactylis glomerata, Delphinium flexuosum, Festuca gigantea, Galega orientalis, Lilium armenum, L. szovitsianum, Linum hypericifolium* and *Thalictrum minus*.

Subalpine heathland and scrub in the Transcaucasian Highlands include *Rhododendron caucasicum* heaths, and Southern Palaearctic mountain dwarf juniper scrub (*Juniperus sabina* and *Juniperus hemisphaerica*). Besides these, Steppe scrub with *Spiraea* spp. is well represented in the upper montane and subalpine belt.

In Northern Armenia, at the upper border of the forest, woody ecosystems are represented by so-called “Subalpine crook stem forest” (which are also called “Krummholz” or “Elfin Forest” in literature). *Acer trautvetteri, Betula litwinowii, Malus orientalis, Pyrus caucasica, Rubus idaeus, R. saxatilis, Sorbus aucuparia* and *Viburnum lantana* are dominants in these communities.

Alpine Alpine vegetation in the Lesser Caucasus is mainly dominated by alpine meadows and carpets, in which grasses dominate in meadows, and herbs in carpets. Alpine meadows can be dominated by *Festuca* spp., *Bromopsis variegata*, *Carex* spp. and/or *Kobresia schoenoides*. The same species can act as dominants in most cases for the Alpine carpets, in the Transcaucasian Highlands, both on volcanic and limestone substrata. These ecosystems include carpets dominated by *Alchemilla grossheimii*, *Campanula tridentata* (Fig. 8.6b), *Cirsium rhizocepalum*, *Plantago atrata*, *Potentilla raddeana*, *Ranunculus dissectus* subsp. *aragazi* (Fig. 8.6c),

Fig. 8.6 (**a**) Subalpine meadow dominated by *Anemone fasciculata* (Sevan pass., 2100 m a.s.l.; photo K. Tamanyan); (**b**) Alpine carpet dominated by *Campanula tridentata* (Aragats Mts., 3250 m a.s.l.; photo G. Fayvush); (**c**) Alpine carpet dominated by *Ranunculus dissectus* ssp. *aragatzi* (Aragats Mts., 3250 m a.s.l.; photo G. Fayvush); (**d**) Scree with *Coluteocarpus vesicaria* (Ughtasar Mts., 3250 m a.s.l.; photo G. Fayvush)

Sibbaldia parviflora, or *Taraxacum stevenii.* About 20 local endemic species are found in the meadows and carpets of the Transcaucasian Highlands (*Colchicum ninae, Erodium sosnowskianum, Gladiolus hajastanicus, Ornithogalum gabrielianae, Symphytum hajastanum,* etc.).

8.6.7 Petrophilous Vegetation

These habitats are intrazonal and very characteristic for mountainous areas. Petrophilic ecosystems are characterized by an abundance of rare, stenochorous and stenotopic plant species. In this regard, they are of great floristic and environmental interest. In the Transcaucasian Highlands, these ecosystems are distinguished on the basis of their substrate – screes and rocks on a volcanic or limestone basis. These ecosystems are predominantly included in the category "Inland unvegetated or sparsely vegetated habitats". Screes include temperate-montane acid siliceous screes (with *Amygdalus fenzliana, Cerasus incana, Coluteocarpus vesicaria* (Fig. 8.6d)*, Euphorbia gerardiana, E. szovitsii, Fumana procumbens, Potentilla argentea, Stachys lavandulaefolia, Stipa arabica, etc.*), temperate-montane calcareous and ultra-basic screes (with *Allium struzlianum, Helichrysum graveolens, Minuartia sclerantha, Tulipa biflora, T. julia,* etc.), acid siliceous screes of warm exposures (with *Amygdalus fenzliana, Athraphaxis spinosa, Bromus fibrosus, Cerasus incana, Ephedra procera, Nepeta mussinii, Poa bulbosa, Rhamnus pallasii,* etc.), and calcareous and ultra-basic screes of warm exposures (with *Allium materculae, Cleome ornithopodioides, Eremopyrum orientale, Eremostachys laciniata, Michauxia laevigata, Onosma sericea, Peganum harmala, Poa bulbosa, Rumex scutatus, Salvia dracocephaloides, Scrophularia thesioides, Serratula coriacea, Stachys inflata,* etc.). The category "Inland cliffs, rock pavements and outcrops" includes acid siliceous inland cliffs (with *Artemisia splendens, Dianthus raddeana, Erigeron venustus, Helichrysum graveolens, Minuartia imbricata, Saxifraga moschata, S. juniperifolia, S. kolenatiana, Sedum pilosum, Symphyandra zangezura, Tanacetum zangezuricum,* etc.), basic and ultra-basic inland cliffs (with *Amygdalus fenzliana, Cerasus incana*, *Hypericum formosissimum, H. eleonorae, Parietaria elliptica, Potentilla porphyrantha*, *Rhamnus pallasii,* etc.), wet inland cliffs (with *Adianthum capillus-veneris, Lycopodium selago,* etc.), and almost bare rock pavements, including limestone pavements, weathered rock and outcrop habitats (with species of *Sedum, Sempervivum, Parietaria* and other genera).

8.7 Conservation

Basically almost all of the hierarchical threats suggested by IUCN have some impact on the biodiversity and ecosystems of the Lesser Caucasus. Here we try to show the most important threats.

8.7.1 Threats

8.7.1.1 Open Mining

The underground resources of Armenia are very much exploited. It is estimated that in Armenia there are 613 mines with the value of 170 billion US dollars and 60 types of minerals are extracted. Armenia has 5.1% of the total world resources and 7.6% of the confirmed resources of molybdenum (The Fifth … 2014). There are also significant resources of copper, zinc, iron, lead, gold, silver, rhenium, cadmium, tellurium and others. Nowadays the mining industry has been declared by the RA Government as a priority sector of the economy. It is intensively developing and continues to have catastrophic consequences. Thousands of hectares of the territory of Armenia are covered by open mines and tailing ponds. The mines in Armenia are mainly concentrated in two regions – in the Alaverdi area of the Lori Region and the Kapan-Qajaran-Agarak area of the Syunik Region (Fig. 8.7).

The industry of construction materials has also caused damage to the natural environments of Armenia. Quarries of building materials (sand, stone, gravel, etc.) occupy ever larger areas, at the detriment of both natural ecosystems and agricultural lands. At present due to the extraction of construction materials more than 7000 ha of agricultural lands have become unsuitable for use.

8.7.1.2 Construction (Urban Development, Road Construction, Reservoir Construction)

Due to the reduction in the total volume of construction works during 2010–2011, at present the risk of their impact on ecosystems is not high. In recent years the expansion of existing inhabited areas and establishment of new settlements (in the form of summer-house communities) have been slower and almost without occupying new territories. Works on the road network are mainly aimed at widening and renovating existing roads.

8.7.1.3 Agriculture

After the independence of Armenia, the land privatization process has seriously changed the character and status of agriculture in the country. At present the main land users for agricultural production in the country are farms, which manage more than 82% of the arable lands, 75% of the perennial stands and 50% of the haymaking areas. In the sphere of agriculture the most serious problems connected with the environment are the losses of water due to ineffective irrigation, as well as salination of soils, and erosion and pollution by agricultural wastes. For the natural ecosystems being used as pastures the biggest threat is the disproportionate distribution of the pasture load: distant pastures suffer from under-grazing, which results in

Fig. 8.7 Open mining in the Syunik province of Armenia (Vicinity of Agarak village; photo G. Fayvush)

changes in ecosystems, in particular the replacement of alpine carpets with alpine meadows as well as the active penetration of subalpine weeds into alpine ecosystems. At present much of the land adjacent to pasture areas is overused and degraded to various degrees, varying from changes in plant cover to erosion, also as a result of land-slides and mudflows. Abandoned fields are a problem. After the privatization of land in the 1990s, peasants often received very small plots, which were not economically profitable. As a result, amidst the treated fields many sites remained abandoned and become a reservoir for weeds and other invasive and expanding species. They often form new monodominant communities (*Silybum marianum, Cirsium anatolicum, Cirsium incanum, Onopordum acanthium*, etc.), clogging the surrounding areas with their seeds.

8.7.1.4 Loggings

According to official data the volume of illegal loggings in Armenia has reduced during the last years. But nevertheless long-term negative changes in the ecological status are observed in areas, which have been subject to intensive loggings.

8.7.1.5 Hydropower Production

In Armenia, the construction of small hydropower plants (SHPP) is considered essential in development of the renewable energy sector. Construction of SHPPs is done according to the SHPP development scheme approved by the RA Government in 2009. According to this scheme it is planned to construct 115 SHPPs. As of 1 January 2014 licenses for hydropower production and HPP construction were issued by the RA Committee on Regulation of Public Services to 150 SHPPs. Parallel to the implementation of the scheme on development of small hydropower plants, Armenia has witnessed many problems related to the overuse of water resources and river ecosystems, biodiversity, specially protected areas, landscapes, the social status of the population and life quality. Studies implemented in recent years have analyzed the impact of SHPPs on the water regimes of a number of rivers, the loss of biodiversity, natural calamities, tourism development as well as on the socio-economic conditions of communities. The planning and implementation of SHPPs basically do not consider the needs of the water fauna, nor is the impact of the water regime of the mountainous rivers on littoral and aquatic ecosystems and biodiversity assessed or studied.

8.7.1.6 Recreation and Tourism

The impact of recreation and tourism on ecosystems is mainly connected with recreational trampling of the plant cover. On the other hand, underuse of forests for recreation has indirectly contributed to the increase of harvested volumes of wood. At the same time development of recreation and ecotourism may be more beneficial and advantageous from economic and environmental perspectives, but an appropriate policy and organization to manage these activities are still missing in Armenia.

8.7.1.7 Environmental Pollution

The changes in biodiversity and ecosystem services connected with pollution are mainly caused by accumulation of hazardous chemical substances in the soil, pollution of groundwater and rivers, accumulation of industrial wastes and landscape degradation. It disturbs the conditions for growth, development and reproduction, eliminates valuable, threatened and rare species in forest ecosystems, as well as causes declines in the productivity of agrocenoses and worsens the yield quality. At present there is no intensive industry functioning in the country. The main threat is caused by production, accumulation and storage of the wastes from the mining industry.

8.7.1.8 Impact of Invasive Alien and Expanding Species

In recent decades, both globally and in Armenia, the purposeful introduction of plants (species, varieties, forms) from different regions of the globe has been intensified. Unfortunately, risk assessment is not usually carried out and the invasive potential (the ability of penetration and establishment in natural ecosystems) of these plants is not taken into account. Intensification of the penetration of invasive species from neighboring countries is also not taken into account. Unfortunately, this problem in Armenia is still underestimated. No measures are taken either to prevent the invasion of invasive species, to strengthen quarantine rules, nor to eradicate already naturalized and intensively spreading species. An analysis of the dissemination of the most dangerous invasive plant species of Armenia shows that in recent years some of them have considerably widened their distribution (possibly connected with the change in climatic conditions and expansion of degraded habitats). The density of their populations has increased with their penetration and establishment in natural ecosystems. The list of these species includes such dangerous species as *Ambrosia artemisiifolia, Ailanthus altissima, Onopordum acanthium, Heracleum sosnovskyi, Cirsium incanum*, etc. (Fauvush and Tamanyan 2014).

The expanding species - native plants, which for some reason (often due to climate change) are beginning to spread intensively - are equally worrisome, changing the natural ecosystems and threatening biodiversity. Such species include *Astragalus galegiformis, Onopordum armenum*, various species of *Cirsium, Carduus, Clematis orientalis* and others. Biodiversity conservation in Armenia is implemented mainly in the specially protected nature areas, where 60–70% of the species composition of the flora and fauna is concentrated, including the overwhelming majority of rare, critically endangered, threatened and endemic species.

8.7.2 Nature Reserves

The Specially Protected Nature Areas (SNPAs) in Armenia are represented by state reserves, national parks, state sanctuaries and natural monuments. They have been established on lands of state property and are managed by state organizations. Natural monuments, which are located on the lands of both state and community property, are still not properly managed due to the absence of relevant management mechanisms.

At present, in Armenia the total territory covered by SPNAs amounts to 387,054 ha, which comprises 13.1% of the total territory of Armenia. These SPNAs are:

- 3 State Reserves (Khosrov forest, Shikahogh and Erebuni), which together cover a territory of 35439.6 ha or 1.19% of the total territory of Armenia;
- 4 National Parks (Sevan, Dilijan, Arpi Lake and Arevik), which together cover a territory of 236802.1 ha or 7.96% of the total territory of Armenia;

- 232 Natural Monuments;
- 27 State Sanctuaries, which together cover a territory of 114812.7 ha or 3.95% of the total territory of Armenia.

In addition, in the territory of the Nakhchivan Republic in the Zangezur Range there is a National Park "Zangezur" bordering on the Zangezur sanctuary in Armenia; and the Javakheti National Park was established in 2011 on the border with Armenia, in Javakheti (Georgia).

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Chapter 9
North-Western Caucasus

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Abstract This chapter characterizes the flora and vegetation of the North-Western Caucasus, taking the Karachaevo-Cherkessian Republic (a mountainous region in the southwestern Russia) and the Teberda State Biosphere Reserve (a protected nature area with restricted access located on the northern spurs of the Greater Caucasus Range) as examples. The Teberda State Biosphere Reserve is located in the southern part of the Karachaevo-Cherkessian Republic at the upper reaches of the Teberda and Kizgych rivers and their tributaries. The elevation in the Teberda State Biosphere Reserve varies from 1259 to 4046 m a.s.l. The treeline runs at 1700–2400 m a.s.l., and the upper limit of vascular plants is found at 3750 m a.s.l. About 83% of the Reserve area lies above 2000 m a.s.l. Rock and scree outcrops occupy 26% of the Reserve. The wide elevational range, complex topography, and sharp changes of microclimatic conditions determine a high species diversity and variety of plant communities. The flora of the Karachaevo-Cherkessian Republic currently comprises 1959 species of vascular plants. There are 10 floristic elements in the indigenous flora of the Republic, i.e. Holarctic, Palaearctic, Panboreal, Euro-Mediterranean, Mediterranean, Ancient Mediterranean, Irano-Turanian, Pontic-South-Siberian, Pluriregional, and Endemic. A total of 343 species (17.5%) are endemics. Six elevational belts (steppe, deciduous broad-leaved forest, coniferous forest, subalpine, alpine, and subnival) and major vegetation types, including steppes, deciduous and coniferous forests, crooked-stem elfin woods, tall grass communities, fens, alpine and subalpine meadows, snowbeds, lichen heaths, pioneer communities on rocks, screes and talus slopes are reviewed. The Caucasus is considered a biodiversity hotspot with significant levels of endemism at both species and ecosystem levels. Currently it is prioritized as one of the most vulnerable regions with a high irreplaceability.

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Abbreviations

KCR Karachaevo-Cherkessian Republic

9.1 Introduction

The Caucasus is a mountainous region situated between the Black and Caspian Seas and separated into two parts as Ciscaucasia and Transcaucasia, or the North and South Caucasus, respectively. The Greater Caucasus Range (Fig. 9.1a) is the largest and highest mountain range in the region. It is shared by Russia and Georgia, as well as with the northernmost parts of Azerbaijan and historically it is considered a natural barrier between Europe and Western Asia. The highest mountain peaks of the Caucasus, Elbrus (5642 m a.s.l.), Dykh-Tau (5205 m a.s.l.) and Shkhara (5193 m a.s.l.) are located along Greater Caucasus Range.

The Karachaevo-Cherkessian Republic (hereinafter KCR) is a region in south-western Russia adjacent to the Greater Caucasus Range. The KCR is bordered by Krasnodar Krai on the west, Stavropol Krai on the north-east, Kabardino-Balkar Republic on the south-east, and an international border with Georgia on the south-west. About 80% of the KCR's area is mountainous, excepting a small strip of low-land plains at the northern edge.

The Teberda State Biosphere Reserve (hereinafter referred to as the Reserve) is a protected nature area with restricted access; it is located in the south of the KCR on the northern spurs of the Greater Caucasus Range. The Reserve consists of two clusters, i.e. the eastern Teberdinsky (694 km^2), and the western Arkhyzsky (156 km^2). The Teberdinsky cluster is located at the upper reaches of the Teberda River and its tributaries from Teberda town in the north to the Greater Caucasus Range in the south; the Arkhyzsky cluster occupies the Kizgych River valley southward from Arkhyz village.

The wide elevational range (Onipchenko 2004), the complex topography (Pavlov et al. 1999), and the sharp changes of microclimatic conditions (Serebrjakov 1957; Onishchenko, Shilova 1985) determine the high species diversity and variety of plant communities in the study area. According to the latest revisions, the KCR flora comprises 1959 species of vascular plants, 1840 (94%) of which are indigenous and 119 (6%) are invasive (Zernov et al. 2015, 2018; Zernov 2016). The indigenous flora of the KCR includes 10 floristic elements, i.e. Holarctic, Palaearctic, Panboreal, Euro-Mediterranean, Mediterranean, Ancient Mediterranean, Irano-Turanian, Pontic-South-Siberian, Pluriregional, and Endemic. It is characterized by a relatively large portion of regional endemics (334 species, 17%) and a low number of local endemics (9 species, 0.5%) (Zernov et al. 2015).

The study of the flora and vegetation in the Caucasus has a relatively long history. The first Western European scientist who studied the Transcaucasian flora was the famous French botanist Joseph Pitton de Tournefort. In his expedition in

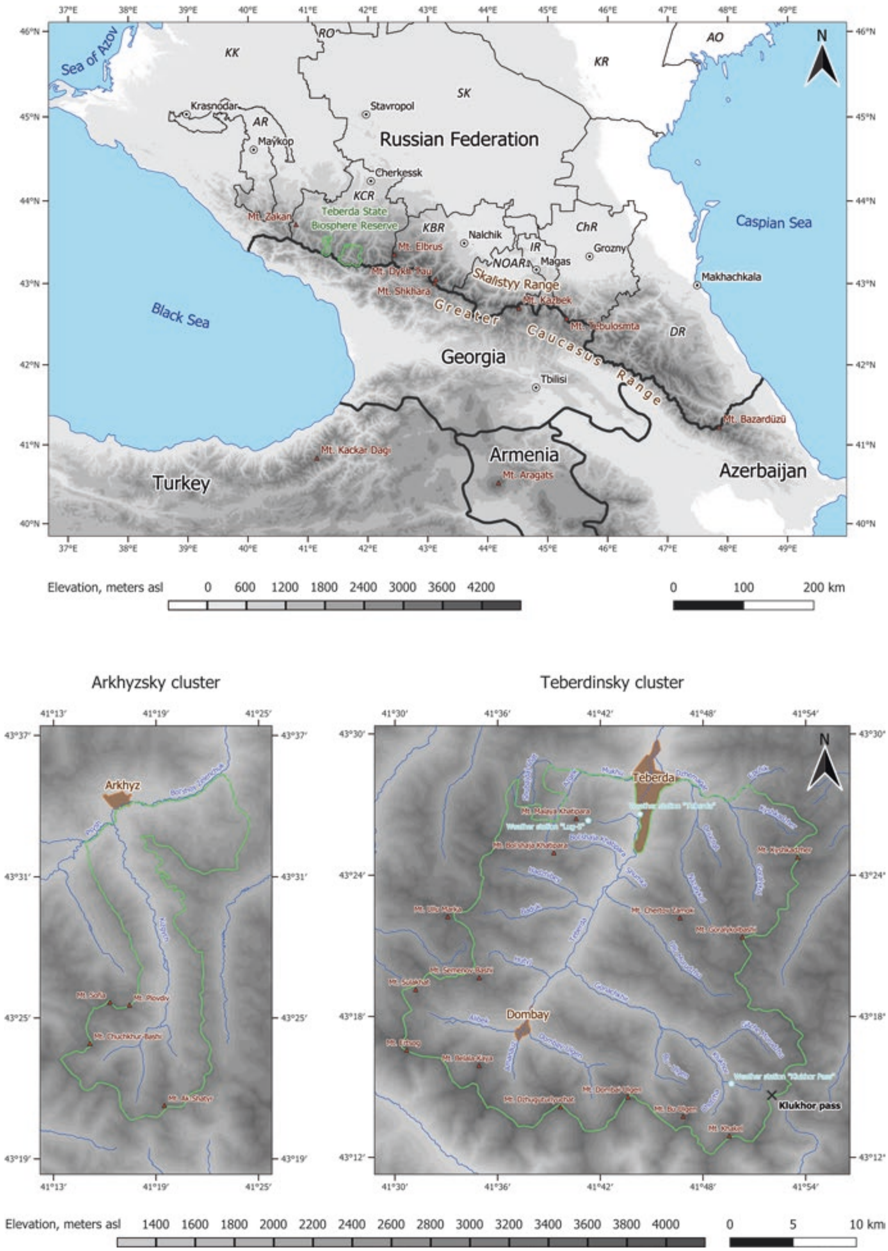

Fig. 9.1 (**a**) Overview map of the Caucasus Mountains and (**b**) detailed map of the Teberda State Biosphere Reserve (Cartographic database of federal nature protected areas 2004; SRTM 2015; Natural Earth 2019; OpenStreetMap 2019)

AR Adygeya Republic, *AO* Astrakhan Oblast, *ChR* Chechen Republic, *DR* Dagestan Republic, *IR* Ingushetia Republic, *KBR* Kabardino-Balkar Republic, *KR* Kalmykia Republic, *KCR* Karachaevo-Cherkessian Republic, *KK* Krasnodar Krai, *NOAR* North Ossetia-Alania Republic, *RO* Rostov Oblast, *SK* Stavropol Krai

1700–1702 he visited Tbilisi, Echmiadzin (Vagharshapat), the Arax River valley and he climbed Mount Ararat (Pavlov 2004). Tournefort was the *de facto* author of a significant number of taxa, subsequently accepted by C. Linnaeus. The first expedition of the Russian Academy of Sciences in the KCR took place in 1829–1830, when the famous Russian botanist, C. A. Meyer, first collected herbarium specimens of plants on the Elbrus (Zernov and Onipchenko 2011). Floristic researches in the Teberda Valley began in the end of the nineteenth century, when V.I. Lipsky, S. Sommier, E. Levier, I. Ya. Akinfiev, N.A. Bush, D.I. Litvinov, and other botanists visited this region (Vorobyova and Onipchenko 2001). The first floristic summary of the KCR contained 578 species (Bush 1909).

The Caucasian flora and vegetation are not deprived of the attention of scientists, but geobotanical, floristic and phytogeographic studies in the Caucasus are scattered and often devoted either to spatially limited regions (e.g., Tumadzhanov 1963; Elenevskij 1964; Prilipko 1970; Kimeridze 1985; Fajvush 1986; Khubieva 2001; Onipchenko 2002; Zernov 2002; Portenier 2012), or to narrow taxonomic groups (e.g., Alekseev 1980; Kolakovskij 1991; Elenevskij, Kuranova 2000; Dorofeev 2003; Skvortsov 2003; Punina and Mordak 2009; Pimenov and Klyujkov 2010), or to selected vegetation types (e.g., Mikeladze 1960; Narinyan 1961; Gagnidze 1974; Gadzhiev et al. 1986; Akatov 1991; Bondev 1993; Borlakov and Sablina 1985). There are a few phytogeographic researches of the entire Caucasus, conducted in the past century (e.g., Bush 1935), but to our knowledge, there are no recent phytogeographic studies on the Caucasus as a whole.

Nevertheless, the Caucasus is the only one of the 34 world biodiversity hotspots located in the Russian Federation (Mittermeier et al. 2005). Therefore, a floristic study of this region is very important for an inventory of the biological diversity. This chapter characterizes the flora and vegetation of the North-Western Caucasus taking the Karachaevo-Cherkessian Republic and Teberda State Biosphere Reserve as examples.

9.2 Geology

The elevation in the study area is varying from 1259 m a.s.l. (the water level of the Teberda River at the northern limit of the Reserve) to 4046 m a.s.l. (the highest peak of Mount Dombai-Ulgen) (Onipchenko 2004) with elevational range of 2787 m. About 83% of the Reserve area lies above 2000 m a.s.l. (Polivanova 1990). Several peaks exceed the elevation of 3750 m a.s.l., which is the upper limit of vascular plants in the study area (Onipchenko 2002), namely Bu-Ulgen (3917 m a.s.l.), Dzhuguturlyuchat (3896 m a.s.l.), Ertsog (3863 m a.s.l.), Belala-Kaya (3861 m a.s.l.), and Kyshkadzher (3822 m a.s.l.) (Onipchenko 2004).

A number of factors, such as erosion, weathering, ancient and modern glacial and hillslope processes (creep, avalanches, falls, slides, flows, etc) play an important role in shaping and changing the relief. Rock and scree outcrops are widespread at all elevations, but their role is most important in the alpine and subnival belts. Outcrops cover about 26% of the total area of the Reserve (Vorobyova and Onipchenko 2001). Jugged mountain tops and steep slopes are common, particularly in the southern part of the study area. The terrain in the northern part of the Reserve is smoother with more gentle slopes, especially in the upper part of the mountains, due to erosion and weathering, which soften exposed rock surfaces and cause fragments to fall or be dissolved (Onipchenko 2004).

The vast majority of valleys in the study area are U-shaped (trough valleys), which indicates their former glaciation (Onipchenko 2002). Currently there are 85 existing glaciers, occupying about 10% of the Reserve area (Vorobyova and Onipchenko 2001). Glaciers covered most of the mountains from their summits down to about 2400 m a.s.l. in the late Pleistocene. Separate glacier tongues extended further down to 1300 m a.s.l. during the Last Glaciation Maximum (that is the elevation of Teberda town) and even lower (Shcherbakova 1973). Since 1850 the glaciers have been steadily retreating. Former glaciers formed alpine cirques as depressions, which are currently occupied by small lakes and enclosed by frontal moraine deposits. Permafrost occurs here only at higher elevations (above 3400 m a.s.l.) and has a negligible influence on the vegetation (Onipchenko 2002).

Rivers in the Reserve are fed mainly by glaciers and snowfields, and all water streams in the study area belong to the Teberda River drainage basin. There are more than 130 lakes in the Reserve, and most of them have a glacial origin (Polivanova 1990). Water bodies cover about 0.7% of the Reserve area (Vorobyova and Onipchenko 2001).

Siliceous parent rocks predominate in the study area. Limestone outcrops are found two kilometers north of the Teberda town (Onipchenko 2004). Grey granite is the main parent rock type. Gneisses and various types of schists (biotite, chlorite, etc.) are also well represented and widely distributed across the Reserve (Makarov et al. 2002).

9.3 Climate

The climate of different parts of the Reserve varies dramatically. Sharp microclimatic changes are very typical in the study area due to the complex topography, and almost every valley is characterized by its local climatic peculiarities (Serebrjakov 1957; Onishchenko and Shilova 1985).

There are two permanent weather stations "Teberda" and "Klukhor Pass" in the Reserve (Fig. 9.1), located in Teberda town (43°26 '35.61"N, 41°44 '18.99″E, 1328 m a.s.l.) and near to the Klukhor Pass (43°15 '8.64"N, 41°49 '39.28″E, 2037 m a.s.l.) (Protsenko 1966). The temporary weather station "Lug-5″ was installed on the eastern spur of the Malaya Khatipara mountain in the alpine belt

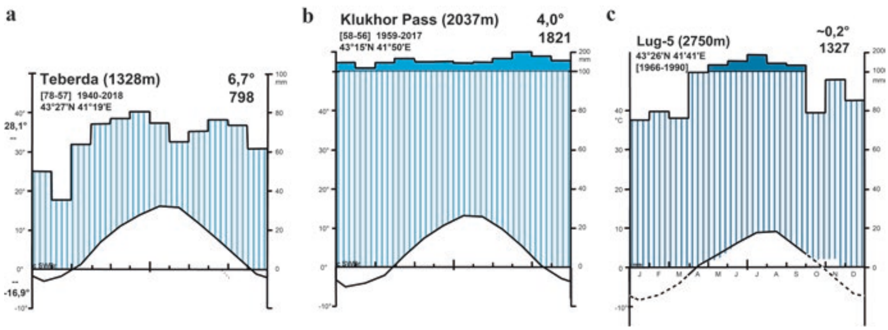

Fig. 9.2 Climate diagrams of three weather stations. (**a**) Teberda town, 1328 m a.s.l.; (**b**) Klukhor Pass near to Greater Caucasus Range, 2037 m a.s.l. (Federal Service for Hydrometeorology and Environmental Monitoring, 2019); (**c**) Malaya Khatipara research station, 2750 m a.s.l. (temperatures from April to September are average values of actual observations, collected from Lug-5 weather station and shown as a solid line; observations from Lug-5 station for remaining months are missing or scarce, and average temperatures for these months are derived from Teberda weather station data, applying the elevational correction −0.4° per 100 m and shown with a dashed line)

(43°26 ‘19.33"N, 41°41 ‘17.60″E, 2750 m a.s.l.) (Rabotnov 1987) and worked from 1966 to 1990. Climate diagrams of the stations are shown in Fig. 9.2.

The climate of the Teberda River valley is the typical climate of the inner mountain valleys — moderately warm with a cool summer and a relatively warm winter. The average annual temperature in Teberda is +6.9°C; in Dombay +4.3 °C (Tumadzhanov 1963).

Southern mediterranean winds, predominating in the study area, cross the Greater Caucasus Range and bring wet maritime air masses from the Black Sea (Tumadzhanov 1963; Pil ‘nikova 1990). Thus, the southern slopes are windward; the northern ones are leeward and characterized by heavy snow accumulations, which largely affect the vegetation pattern (Onipchenko 2002). The climate in the study area is primarily determined by two factors: elevation and distance from the Greater Caucasus Range. The greatest amount of precipitation falls at the southern boundary of the Reserve on some slopes of the Greater Caucasus Range — up to 3000 mm annualy. Precipitation declines markedly as the distance towards the north. The total annual precipitation in Dombay, located at the foot of the Greater Caucasus Range, is twice as much as in the Teberda resort area at 20 km northward — 1344 and 695 mm respectively. This contrast is especially sharp in winter, resulting in a relatively thin snow cover in the lowlands of the northern part of the Reserve (Tumadzhanov 1963).

The highlands of the Reserve are characterized by abundant rain- and snowfalls (the mean annual precipitation is about 1400 mm) and low temperatures (mean annual is −1.2 °C) (Rabotnov 1987). These numbers resemble those of some areas in the Swiss Alps, for example, Weissfluhjoch (2667 m a.s.l.) near Davos (Zingg 1961). The climate of the alpine belt in the study area can be considered as type X(VI) — a mountain climate of the temperate zone, according to Walter et al.

(1975). High precipitation ensures a significant snow accumulation in the highlands, a low position of the snow line, and the presence of young glaciers (Tumadzhanov 1963). At average, the temperature decreases by 0.4–0.8 °C per 100 m increase in elevation (Körner 1999); precipitation increases with elevation up to about 2200–2500 m a.s.l. (Onipchenko 2002). Air humidity averages about 79% during summer. The average duration of time with 100% air humidity is about 4 hours per day. Insolation at bare soil level is about one half of the potential[1] because of clouds (Grishina, Makarov 1986). August is the warmest month with a mean temperature of +8.3 °C, but frosts may occur in any month (Onishchenko and Onishchenko 1986). A typical climatic diagram for the alpine zone of the northern part of the Reserve is shown in Fig. 9.2c (Onipchenko 2004).

The highlands in the study area are characterized by quite stable daily dynamics in the cloud cover during the growing season, which, however, is a common phenomenon in mountainous regions (Körner 1999). Fog and clouds lie at the timberline level, and the sky is clear in the alpine belt in the morning (Fig. 9.4a), but the heating of mountain slopes after sunrise leads to anabatic currents, which move fog and clouds upslope. The clouds, brought by southern winds from the Black Sea, appear at noon and gradually increase in density during the rest of the day. The sky is usually overcast, with a thick fog descending into the highlands; precipitation often falls in the evening. Sunsets and nights are usually clear (Egorov et al. 2012).

9.4 Flora and Phytogeography

The phytogeography of the area is characterized by floristic elements, i.e., groups of species with largely similar distribution patterns (Hayek 1926; Meusel et al. 1964, 1965; Walter 1982; Zernov 2012). Currently, the flora of the KCR includes 1959 species of vascular plants (Zernov et al. 2015; Zernov 2016; Zernov et al. 2018). A total of 1840 species are indigenous; the remaining 119 species form an invasive (adventive) component. There are 10 main floristic elements in the indigenous flora of the KCR, i.e. Holarctic, Palaearctic, Panboreal, Euro-Mediterranean, Mediterranean, Ancient Mediterranean, Irano-Turanian, Pontic-South-Siberian, Pluriregional, and Endemic. The proportion of these 10 geographic floristic elements in the KCR is shown on Fig. 9.3. Their brief characteristics are given below.

1. The Holarctic floristic element of the KCR flora includes taxa that are found in all or almost all floristic regions across the Holarctic kingdom (Takhtajan 1986). 145 species (7.88% of the indigenous component of the KCR flora) belong to the Holarctic element. Some of these species, e.g., *Lloydia serotina*, *Polygonum viviparum*, *Sagina saginoides, Thalictrum alpinum*, etc., have arctic-mountainous holarctic distributions. The Holarctic species are nearly evenly

[1] Potential insolation refers to incoming solar radiation in the absence of an atmosphere.

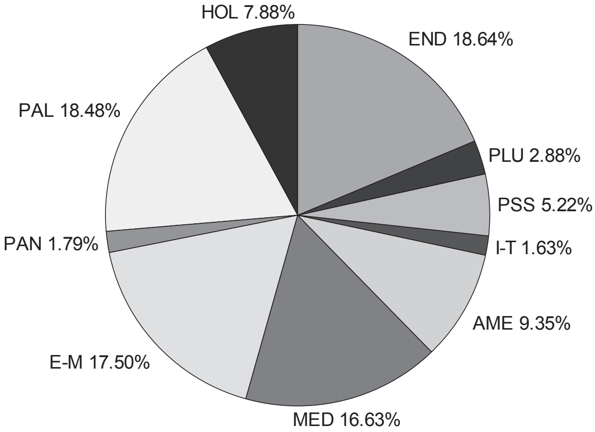

Fig. 9.3 The proportion of 10 geographic floristic elements in the KCR. *HOL* Holarctic, *PAL* Palaearctic, *PAN* Panboreal, *E-M* Euro-Mediterranean, *MED* Mediterranean, *AME* Ancient Mediterranean, *I-T* Irano-Turanian, *PSS* Pontic-South-Siberian, *PLU* Pluriregional, *END* Endemics

distributed in different habitats. This floristic element is represented by: (1) species of various sparse pioneer communities, growing on rocks, screes, pebbles and so on, (e.g., *Oxyria digyna*, *Polystichum lonchitis*, etc); (2) meadow species (*Origanum vulgare*, *Sanguisorba officinalis*, etc.); (3) forest species (*Dryopteris filix-mas*, *Moneses uniflora*, *Phyllitis scolopendrium*, etc.); (4) wetland species (*Eleocharis quinqueflora*, *Epilobium palustre*, *Equisetum palustre*, *Ranunculus sceleratus*, etc.); (5) steppe species (*Artemisia campestris, Koeleria cristata*, etc.). The Holarctic species as a whole are widely distributed across elevational belts, but only a few species grow along four elevational belts (*Gentiana aquatica*, *Hieracium umbellatum*, *Asplenium* spp., etc.), while most of them are confined to three, two or only one belt such as alpine belt, (e.g., arctic species), or to the deciduous broad-leaved forest belt.

2. The Palaearctic floristic element includes taxa whose ranges are encompassing the temperate and subtropical regions of the Holarctic floristic kingdom (Takhtajan 1986) within the Old World. We counted 340 such species in the KCR flora (18.48%). Most of them are confined to meadows (*Achillea millefolium*, *Agrostis tenuis*, *Alopecurus pratensis*, *Draba sibirica*, *Festuca pratensis*, *Helictotrichon pubescens*, *Leucanthemum vulgare*, *Luzula pallescens*, *Pimpinella saxifraga*, *Poa pratensis*, *Polygonum alpinum*, *Rumex alpestris*, *Stellaria graminea*, *Trifolium montanum*, *Trommsdorffia maculata*, etc.). Forest species are numerous as well (*Actaea spicata*, *Alliaria petiolata*, *Cardamine impatiens*, *Epipactis helleborine*, *Galium odoratum*, *Listera ovata*, *Matteuccia struthiopteris*, *Melica nutans*, *Paris quadrifolia*, *Rubus caesius*, *Sanicula europaea*, *Stachys sylvatica*, etc.); and wetland species are also common (*Alisma plantago-aquatica*, *Blysmus compressus*, *Calamagrostis pseudophragmites*, *Potamogeton lucens*, *Veronica beccabunga*, etc.). Xerophytic species, ecosys-

tem engineers[2] of steppe communities, also occupy a prominent place (*Festuca valesiaca*, *Medicago falcata*, *Phlomis tuberosa*, *Silene viscosa*, *Stipa capillata*, *S. pennata*, etc.). Synanthropes, i.e. species confined to anthropogenic habitats, are numerous as well (74 species), e.g., *Atriplex patula*, *Conium maculatum*, *Medicago lupulina*, *Plantago major*, *Polygonum convolvulus*, etc. The majority of Palaearctic species is concentrated in the coniferous and deciduous broad-leaved forest belts (175 species). The elevational range of the Palaearctic species is quite wide: almost 70% of them are found in two or three belts, and *Viola rupestris* occurs in four belts. But their number decreases rapidly with increasing elevation, and there are only 5 Palaearctic species in the alpine belt, e.g., *Potentilla gelida* and *Lomatogonium carinthiacum*.

3. The Panboreal floristic element (Kleopov 1990) includes taxa common in most regions of the Boreal subkingdom (Takhtajan 1986) of Holarctis in both the Western and Eastern hemispheres. There are 33 Panboreal species (1,79%) in the KCR flora, 8 of them having arctic-mountainous distributions (*Astragalus alpinus*, *Selaginella selaginoides*, *Woodsia alpina*, etc). Panboreal species are relatively stenotopic.[3] Almost half of them are plants of deciduous broad-leaved forests (*Chrysosplenium alternifolium*, *Gagea lutea*, *Polystichum braunii*, etc.) and mixed coniferous-deciduous forests (*Cinna latifolia*, *Pyrola chlorantha*, *P. minor*, etc.). A few meadow species (e.g., *Coeloglossum viride*) and hydrophytes (*Potentilla palustris*, *Scirpus lacustris*, etc.) also are Panboreal. Although the proportion of Panboreal species is insignificant in the flora of the KCR, they are more important in the alpine and deciduous broad-leaved forest belts. Some Panboreal species are very rare and exhibit relict features (*Cinna latifolia, Potentilla palustris*, *Viola selkirkii*, etc.). Only few Panboreal species play a significant role in plant communities (*Milium effusum*, *Myosotis alpestris*, *Scirpus lacustris,* etc.).
4. The Euro-Mediterranean floristic element is composed of taxa whose distribution is limited to the Mediterranean basin (including the Azov and Black Sea regions) and the European floristic provinces of the Circumboreal region (Takhtajan 1986). This floristic element includes 322 species, or 17.5% of the indigenous KCR flora. Euro-Mediterranean species are similar to the Palaearctic ones in terms of confinement to specific habitats and elevational belts. They are also predominantly forest mesophytes (*Anemone ranunculoides*, *Dentaria quinquefolia*, *Melica picta*, *Salvia glutinosa*, *Scilla siberica*, *Viola odorata*, etc.) and meadow species (*Anemone fasciculata*, *Carex huetiana*, *Cerinthe glabra*, *Phleum montanum*, etc.). Quite a lot of Euro-Mediterranean species (27) grow on rocks, screes and stony outcrops (*Cryptogramma crispa*, *Erigeron uniflorus*, *Festuca saxatilis*, *Saxifraga moschata*, etc.), whereas only 6 species prefer moist habitats (*Glyceria nemoralis*, *Petasites albus*, etc.). Species, confined

[2] Ecosystem engineers are organisms that create, significantly modify, maintain or destroy a habitat.

[3] Stenotopic species are able to tolerate or adapt to only a small range of environmental conditions.

to mountain meadow steppes are not numerous (*Dracocephalum austriacum*, *Helianthemum nummularium*, etc.). Almost half of the Euro-Mediterranean species occur in the deciduous broad-leaved forest belt. They also play a significant role in the composition of the subalpine flora (77 species), and they are even slightly more numerous than the Palaearctic species in the alpine belt.

5. The Mediterranean floristic element contains taxa whose range covers the Mediterranean basin in a broad sense, including the territory of the entire Caucasus. A total of 306 species (16.63%) belong to this floristic element. These species play a significant role in the composition of the KCR flora, and their importance is inferior only to the Palaearctic and Euro-Mediterranean floristic elements. Species of this floristic element are similar to the Palaearctic and Euro-Mediterranean ones in terms of confinement to habitats and elevational belts. They are mainly encountered in deciduous forests (*Ostrya carpinifolia*, *Potentilla micrantha*, *Tamus communis*, *Viola dehnhardii*, etc.); *Ornithogalum kochii* grows in steppe communities; *Amelanchier ovalis* occurs predominantly on rocks and stony slopes; *Sedum hispanicum* is common on disturbed sites. Most of the Mediterranean species occur in subalpine and deciduous broad-leaved forest belts. The elevational range of the Mediterranean species is comparable to that of the Euro-Mediterranean ones.
6. The Ancient Mediterranean floristic element is composed of taxa whose ranges cover the Mediterranean and Irano-Turanian regions of the Ancient Mediterranean subkingdom (Takhtajan 1986). A total of 172 species belong to this floristic element (9.35% of the indigenous flora). A significant part of the Ancient Mediterranean species occurs in steppe communities (*Ajuga chia*, *Convolvulus lineatus*, *Linum tenuifolium*, *Kochia prostrata, Teucrium polium*, *Zosima orientalis*, etc.). Ancient Mediterranean species are common in deciduous forests (*Cornus mas*, *C. australis, Polystichum aculeatum, Prunus cerasifera*), and on rocky and scree habitats (*Alopecurus vaginatus*, *Ceterach officinarum*, *Saxifraga cymbalaria*, etc.). This element also includes meadow species (*Doronicum oblongifolium*, *Orchis coriophora*, *Sanguisorba minor*, etc.). More than a third of the Ancient Mediterranean species are synanthropes (*Chenopodium botrys*, *Euphorbia falcata*, *Glaucium corniculatum*, *Kochia scoparia*, *Thymelaea passerina*, etc.). The majority of the Ancient Mediterranean species occur in mountain meadow steppe communities while their number is somewhat less in the deciduous broad-leaved forests. The range of elevational distribution of species representing the Ancient Mediterranean floristic element is very narrow. Most of these species exhibit stenotopic features and are confined to only one belt.
7. The Irano-Turanian floristic element is comprised of taxa that are found in both the Caucasus and in the Irano-Turanian floristic region (Takhtajan 1986). 30 species (1.63%) belong to this floristic element. Most of the Irano-Turanian species occur on rocky and scree habitats (*Caragana grandiflora*, *Ephedra procera*, *Jurinella moschus*, *Lamium tomentosum*, *Scrophularia orientalis*, *Sedum pilosum*, etc.), where they are numerically inferior only to the Caucasian species. Meadow species are also numerous (*Agrostis planifolia*, *Bromopsis varie-*

gata, *Cirsium rhizocephalum*, *Hordeum violaceum*, etc.). The role of the Irano-Turanian floristic element is most noticeable in the formation of mountain meadow steppes, where *Allium albidum*, *A. fuscoviolaceum*, *Asparagus verticillatus*, *Astragalus humilis*, *Cirsium echinus*, *Merendera trigyna*, *Silene chlorifolia*, etc. are common. The elevational range of the Irano-Turanian species is not wide, and most of species are found only in one elevational belt.

8. The Pontic-South-Siberian floristic element includes taxa which are common in the southern part of the Euro-Siberian floristic region (Takhtajan 1986). 96 species (5.22% of the indigenous KCR flora) belong to this element. Some species of this element are distributed almost throughout the Euro-Siberian region (*Astragalus austriacus*, *Galatella villosa*, *Inula aspera*, *Verbascum phoeniceum*, etc.). Many of them invade in the Northern province of the Ancient Mediterranean floristic subkingdom (*Artemisia armeniaca*, *Linum nervosum*, etc.) and in forested areas of the Euro-Siberian floristic region (*Achillea nobilis*, *Echinops sphaerocephalus*, *Potentilla arenaria*, *Salvia verticillata*, etc.). The distribution of some species, belonging to this element, is limited to the steppe and forest-steppe areas of the Eastern European floristic province (*Cirsium ciliatum*, *Elytrigia stipifolia*, *Galatella dracunculoides*, *Jurinea arachnoidea*, etc.). Pontic-South-Siberian species constitute the core of the foothill steppe vegetation.

   Almost all species of this element are either ecosystem engineers and dominants (*Artemisia austriaca*, *Bromopsis riparia*, *Festuca rupicola, Stipa pennata*, *S. pulcherrima*), or characteristic components of steppe communities (*Galatella linosyris*, *Goniolimon tataricum*, *Euphorbia stepposa*, *Silene densiflora*, *Verbascum phoeniceum*, etc.). Some of them are confined to rock outcrops (*Cleistogenes bulgarica, Peucedanum ruthenicum*). Almost all species of this floristic element occur in mountain meadow steppes. Numerous Pontic-South-Siberian species are found in the deciduous broad-leaved forest belt, where they invade from the steppe communities of Ciscaucasia, in particular the Pasbishchnyy, Skalistyy and Bokovoj Ridges, and where they occupy forest openings on dry south slopes. Some of these species are not found farther upslope (*Centaurea scabiosa* s.l., *Eryngium planum*, *Thymus marschallianus*, etc.), although a number of steppe species invade the subalpine belt on dry slopes (*Crocus reticulatus*, *Gagea pusilia*, *Spiraea crenata*, etc).

9. The Pluriregional floristic element contains taxa which are widespread outside the Holarctic floristic kingdom. 53 species (2.88% of the indigenous KCR flora) belong to this element. The proportion of water and wetland plants e.g., *Callitriche palustris*, *Phragmites australis*, *Potamogeton pectinatus*, *Typha angustifolia*, etc. is noticeable in this element. Only an insignificant part of the pluriregional species, mainly pteridophytes, are represented in the indigenous communities (*Athyrium filix-femina*, *Botrychium lunaria*). Ferns occur over the widest range of elevations, e.g. *Cystopteris fragilis* and *Polypodium vulgare* are found in four belts. More than a third of the pluriregional species are stenotopic, and their habitats are confined to only one belt. The overwhelming majority of these species are concentrated in the two lower belts. 15 species ascend into the

subalpine meadows (*Juncus bufonius*, *Poa annua*, etc.) and only 4 species reach the alpine belt (*Botrychium lunaria, Cystopteris fragilis*, *Huperzia selago*, *Polypodium vulgare*).

10. The Endemic geographic floristic element includes local and regional endemic taxa which are geographically restricted to the KCR or to a particular broader area respectively. A total of 343 species (18.64% of the indigenous KCR flora) belong to this group. An ecological analysis showed that the vast majority of endemics are meadow species (*Campanula collina*, *Helictotrichon adzharicum*, *Polygonum bistorta* subsp. *carneum*, *Ranunculus caucasicus* subsp. *subleiocarpus*, *Rhynchocorys orientalis*, *Scabiosa caucasica*, *Trollius ranunculinus*, etc.) and plants of rocky and scree habitats (*Chaerophyllum humile*, *Corydalis alpestris*, *Cruciata valentinae*, *Delphinium caucasicum*, *Dentaria bipinnata*, *Draba bryoides*, *Eunomia rotundifolia*, *Nepeta supina*, *Scrophularia olympica*, *Ziziphora puschkinii*, etc.). A large number of the regional endemics is concentrated in the subalpine and alpine belts. Endemism is discussed in more detail in the next section.

At the end of this brief review of the floristic elements of the KCR flora the following conclusions can be drawn: the flora of the deciduous broad-leaved forest belt consists mainly of the Palaearctic, Caucasian and Euro-Mediterranean floristic elements. Ancient Mediterranean, Irano-Turanian and Caucasian species have numerical superiority in the steppe belt, namely in mountain meadow steppes. The proportion of endemics dramatically increases in subalpine and alpine belts, while Palaearctic, Euro-Mediterranean and other floristic elements are significantly less represented there.

9.5 Endemism

The flora of the KCR is characterized by an extremely low level of local endemism and a relatively large number of subendemics (regional endemics). The meaning of local and regional endemics in the analysis of a flora is diametrically opposite: local endemics demonstrate the peculiarity of the studied flora, regional endemics estimate the similarity to neighboring floras.

In our opinion (Zernov et al. 2015) and following a broad interpretation of the species, without assigning species rank to many variations (“micro-species”) of *Alchemilla*, *Rosa*, *Hieracium*, 9 species can be classified as local endemics of the KCR: *Aquilegia kubanica*, *Calamagrostis balkarica, Festuca tzvelevii, Galium fistulosum, Haplophyllum ciscaucasicum*, *Primula renifolia, Silene kubanensis, Thymus elisabethae* (*T. teberdensis*) and *T. pseudopulegioides.*

A total of 334 species are classified as regional endemics of the KCR, occupying large, geographically isolated areas, including those outside the KCR. Regional endemics show ties between the flora of the KCR and floras of other Caucasian regions. These regional endemics can be divided into six groups:

- Pan-Caucasian regional endemics are common in the Greater and Lesser Caucasus — 182 species in total.
- West- and Central-Caucasian regional endemics are distributed in the Greater Caucasus, west of Mount Kazbek — 70 species.
- Central-Caucasian regional endemics are distributed mainly in the central part of the Greater Caucasus, from Mount Elbrus to Mount Kazbek — 10 species.
- West-Caucasian regional endemics are found west of Mount Elbrus — 43 species.
- Euxine-Colchis regional endemics are found on the southern slopes of the Greater Caucasus Range and invade the northern spurs of the Greater Caucasus, as well as Lazistan and Anatolia — 25 species.
- Crimean-Caucasian regional endemics are common in the mountainous regions of the Crimea and in the Greater Caucasus — 4 species.

Pan-Caucasian species have a numerical superiority in the endemic floristic element and constitute ca. 10% of the indigenous KCR flora.

The flora of the KCR has a transitional nature between the floras of the Western and Central Caucasus. This is clearly manifested in the presence of mutual West- and Central-Caucasian endemics. However, the analysis of regional endemics shows a greater affinity with the Western Caucasus flora: 43 West-Caucasian as against 10 Central-Caucasian endemic species.

Regional endemics do not form a single entity. The nature of this endemism is as variegated and diverse as the Caucasian isthmus area. A preliminary analysis of the related ties of Caucasian species in the KCR flora shows, that some of them are derived from the Ancient Mediterranean flora (*Draba supranivalis*, *D. scabra*, *Geranium platypetalum*, *Gypsophila tenuifolia, Minuartia imbricata*, *M. oreina*, *Petrocoma hoefftiana*, *Pseudovesicaria digitata*, *Saxifraga juniperifolia*, *Sedum oppositifolium*, *Veronica caucasica*, *V. minuta*, *Ziziphora puschkinii,* etc.). The remaining Caucasian species are closely related to boreal species (*Aconitum cymbulatum*, *Betula litwinowii*, *B. raddeana*, *Dryas octopetala* subsp. *caucasica*, *Empetrum caucasicum*, *Galium valantoides*, *Gentiana dechyana*, *Polemonium caeruleum* subsp. *caucasicum*, *Primula bayernii*, *Stellaria anagalloides*, *Thlaspi pumilum*, *Tilia begoniifolia*, *Woodsia fragilis*, etc.). Many regional endemics have close ties with the Euxine-Colchis flora (*Alopecurus ponticus*, *Cerastium undulatifolium*, *Minuartia circassica*, *Silene lacera*, *S. multifida*, *Pedicularis subrostrata*, *Potentilla brachypetala*, etc.).

9.6 Major Vegetation Types

9.6.1 History

The elevational belts of the North Caucasus were first described in the late nineteenth century by European and Russian researchers (Voeykov 1871; Medvedev 1882; Keppen 1885). They noted that steppes dominating in the lowland plains, are replaced with broad-leaved forests in the foothills and with coniferous forests at higher elevations. The forests, in turn, are replaced with treeless alpine ecosystems in the highlands. Kuznetsov (1909) specified four elevational belts: steppes, broad-leaved forests, coniferous forests, alpine grasslands. Kuznetsov 's elevational zonation was adopted as a basic scheme by many subsequent researchers (Elenevskii 1940; Stanyukovich 1955, 1973; Lavrenko 1964; Dolukhanov 1966; Gulisashvili et al. 1975; Grebenshchikov et al. 1980; Polivanova 1989). In the late twentieth century, a more detailed elevational zonation was developed for the Caucasus Mountains. E.g., Isachenko and Lavrenko (1980) specified seven native vegetation belts; Vedenin et al. (1980) and Ogureeva (1999) described 10 elevational belts: steppes, forest-steppes, oak-hornbeam forests, beech forests, fir-spruce forests, pine forests, subalpine meadows, alpine meadows, subnival vegetation.

Most of Russian botanists (Grossheim 1948; Shiffers 1953; Kononov 1957; Gulisashvili et al. 1975; Voskanyan 1977) traditionally divide the area above the timberline into three elevational belts in which vascular plants can grow: the subalpine, alpine and subnival belts. The subalpine belt occupies areas near and above the actual timberline. The alpine belt lays farther upslope and, in Caucasus Mountains, can be easily distinguished from the subalpine one by the type of plant communities developing in snowbed depressions[4] (Onipchenko 2002). Tall forb communities are typical of such habitats in the subalpine belt, while another type of vegetation, composed of undersized creeping perennial plants, occupies snowbed depressions in the alpine belt (Pavlov 2004).

We follow a traditional and commonly used scheme, which distinguishes six elevational belts for the vascular plants communities: steppe, deciduous broad-leaved forest, coniferous forest, subalpine, alpine, and subnival (Grossheim 1948; Shiffers 1953; Kononov 1957; Gulisashvili et al. 1975; Voskanyan 1977). These elevational belts are described in detail below, and the timberline is treated in a separate section.

[4] Snowbeds occur where beds of snow persist well into the growing season, usually weeks or months after snow in the immediate vicinity has melted away.

9.6.2 Steppe Belt

Steppe vegetation used to be widespread in the lowland plains along the northern foothills of the Northern Caucasus from Krasnodar to Grozny (Grossheim 1948), but at present most of the Northern Caucasian plains are cultivated, and only scattered fragments of steppe communities remain, primarily on the rocky slopes, unsuitable for the agriculture (Lavrenko 1940; Grossheim 1948; Dolukhanov 1966). These communities of the Northern Caucasus are classified as *Festuca-Stipa* dominated steppes (Lavrenko 1940), or southern steppes (Walter, Alekhin 1936; Agakhanyants 1986); they occur on dark and fertile soils (chernozem). Steppes in the lowland plains were absolutely treeless, while communities at foothills had a more mesic appearance and alternated with small *Quercus* woodlands, forming a forest-steppes subzone. Zonal lowland plain steppes are usually found northward from the Caucasus Mountains at elevations below 200 m a.s.l. The mesic mountain meadow steppes are mostly found between 200 and 500 m a.s.l. (Pavlov 2004), but these communities also occur at higher elevations on dryer and better insolated southern slopes, e.g. in the Dzhemagat valley and on the Skalistyy Range (up to 1450 m a.s.l.), and even higher (at almost 2000 m a.s.l.) on Mount Zakan at the border with the Krasnodarskiy Kray (Zernov, personal communication).

Zonal **lowland plain steppes** on the Northern Caucasus are characterized by the domination of xerophilous bunch grasses: *Stipa capillata, S. lessingiana, S. tirsa, S. zalesskii*, *Festuca valesiaca* and *Koeleria cristata*. Some common xeromesophilous forbs of the northern steppes (*Filipendula hexapetala, Myosotis sylvatica, Onobrychis arenaria, Stachys recta, Thymus marschallianus, Vicia tenuifolia*), as well as xerophilous ones of the southern steppes (*Crambe tatarica, Jurinea consanguine, Limonium platyphyllum, Salvia nutans, Veronica austriaca,* etc.) can be found here too. Forbs do not play a significant role in the relatively sparse and species-poor (12–15 species per m^2) herbaceous layer (Lavrenko 1940). Numerous species of ephemeral plants and spring geophytes, e.g., *Poa bulbosa,* terricolous lichens (*Cladonia convoluta, Parmelia vagans, P. ryssolea*)*,* cyanobacteria (*Stratonostoc commune*) and bryophytes (*Syntrichia caninervis, Tortula ruralis*) are common constituents (Pavlov 2004).

Mountain Meadow Steppes on the rocky southern slopes tend to be more xerophytic and often contain thorn cushions — *Astragalus aureus, A. denudatus,* as well as aromatic herbs — *Salvia canescens, Scutellaria orientalis, Teucrium polium, T. chamaedrys, Thymus marschallianus*. Some species of mountain xerophytic communities, such as *Astragalus denudatus, Salvia canescens, Scutellaria orientalis, Sideritis montana, Teucrium chamaedrys* and some others, occur on southern, highly insolated, rocky slopes in the Teberda River valley. Steppe communities on more mesic habitats, e.g. in forest clearings and on stream terraces include many xeromesophilous forbs, and feather grasses may be absent (Pavlov 2004). Forbs with the highest constancy in mountain meadow steppes are *Anthyllis vulneraria, Campanula sibirica, Galium verum, Medicago falcata (*incl. *M. romanica*)*, Onobrychis cyri, Potentilla arenaria, P. humifusa, Teucrium chamaedrys, T. polium,* *Trifolium alpestre, Veronica multifida,* etc. Spring geophytes, such as *Crocus reticulatus, Gagea pusilla, Merendera trigyna, Muscari muscarimi,* are abundant immediately after the snowmelt (Pavlov 2004). Mountain meadow steppes are floristically rich — 55-65 species per 100 m^2, or 30 species per 1 m^2. The same number of species per square meter is typical of the steppes in the Teberda River valley, where *Stipa capillata* dominates (Lavrenko 1940).

Steppe patches east of Teberda, in the upper part of the Kuban River basin, occupy foothills, where *Carex humilis, Festuca valesiaca, Koeleria cristata* and *Stipa caucasica* are common constituents. Steppe vegetation in this region are often intermixed with semidesert, open arid woodlands, thicket communities and shrublands with prickly and needle-leaved shrubs, such as *Berberis vulgaris, Juniperus communis, J. sabina, Rhamnus pallasii, Rosa pimpinellifolia* etc. (Pavlov 2004).

9.6.3 Deciduous Broad-Leaved Forest Belt

Broad-Leaved Forests form the next elevational belt upslope. They are commonly found as narrow stripes along the Kuban River and near the confluences of its tributaries. Presently, the lower part of the broad-leaved forest belt is severely altered by human activity, especially to the north of the Teberda River confluence, but deciduous forests usually remain intact on steep slopes due to their inaccessibility. The orientation of the slopes largely determines the species composition of forest stands. *Quercus petraea* is found mainly in the lower part of the Teberda and Kuban River valleys and primarily grows on dryer and well insolated southern slopes with rock outcrops. *Quercus robur* is widely distributed in the Teberda and Kuban river valleys and typical on wetter sites, e.g., on ravine bottoms and gentle slopes with well-developed loamy soils. *Fagus orientalis* dominates the broad-leaved forests on the river terraces in the upper reaches of the Teberda River, often forming nearly pure stands. Mixed broad-leaved forests are also quite common here (Fig. 9.4b) and extend along steep slopes at elevations of 1300–1500 m a.s.l. and higher (Pavlov 2004).

A diverse tree composition is a common feature of broad-leaved forests. *Carpinus betulus*, *Tilia begoniifolia*, *Acer platanoides, A. campestre*, *Fagus orientalis*, *Fraxinus excelsior*, *Cerasus avium*, *Malus sylvestris*, *Prunus divaricata* and *Pyrus communis* are common tree species at low-elevation on the steep slopes of the Kuban and Teberda River valleys (Pavlov 2004). The shrub layer can be well developed in some places and is represented by *Berberis vulgaris, Corylus avellana*, *Euonymus europaea*, *Lonicera orientalis* etc. *Rhododendron luteum* often dominates dry slopes, while *Prunus spinosa* is a characteristic shrub of forest edges. The shrub layer of the beech forests consists of *Corylus avellana*, *Lonicera orientalis*, *L. caprifolium*, *Ribes biebersteinii*, *Rosa canina*, *Sambucus nigra*, *Viburnum opulus*, etc. (Pavlov 2004). *Calamagrostis arundinacea* is often the dominant species in the herbaceous layer. Many forb species (*Aconitum orientale, Aruncus vulgaris*,

Fig. 9.4 (**a**) Cloud cover in the Teberda River valley, a view from the northern spur of Mount Malaya Khatipara in the early morning (2800 m a.s.l.); (**b**) Mixed broad-leaved forest along the Malyy Zelenchuk river (1780 m a.s.l.); (**c**) *Picea orientalis* forest, Gonachkhir valley (1750 m a.s.l.)

Circaea lutetiana, *Dryopteris filix-mas*, *Galium odoratum*, *Matteucia struthiopteris, Polygonatum verticillatum, Salvia glutinosa* etc), as well as typical nemoral species (*Festuca altissima*, *Hordelymus europaeus*, *Impatiens noli-tangere*, *Milium effusum*, *Paris incompleta*, *Stachys sylvatica*) are common. The presence of nemoral species in the understory of broad-leaved forests in the North-Western Caucasus was first noted by Kuznetsov (1909), who compared them with mountain forests of the Alps and other middle European mountains. The nemoral species of the Teberda beech forests were further discussed in number of publications (Sochava 1946, 1949; Tumadzhanov 1940, 1959, 1963; Lavrenko 1964). Broad-leaved stands are replaced with ***Betula pendula* forests** to the north of the Bokovoy Range and can also be found in patches at elevations between 1100 and 1700 m a.s.l., forming a peculiar "parkland" landscape in the upper part of the forest belt. Furthermore, *Betula pendula* forests are widespread on gently inclined plateaus (e.g. Dudaron, Bechasyn) surrounding the Kuban river valley. Numerous meadow grass and herb species, such as *Brachypodium sylvaticum*, *Bromus variegatus*, *Calamagrostis arundinacea*, *Rubus saxatilis*, occur under the canopies of light *Betula pendula* tree stands (Pavlov 2004).

Alnus **Forests** with a predominance of both *Alnus glutinosa* and *A. incana* often replace *Betula pendula* forests in depressions. Tall forbs (*Doronicum macrophyllum, Heracleum asperum, Senecio platyphylloides, S. nemorensis, Symphytum asperum*, *Telekia speciosa*) are characteristic species on these habitats. Nemoral species, such as *Aegopodium podagraria*, *Aruncus vulgaris, Filipendula ulmaria*, *Matteuccia struthiopteris* and *Petasites albus*, often dominate the herbaceous layer of wetter *Alnus* forests at lower elevations. Tall forbs, e.g., *Angelica purpurascens*, *Inula helenium*, *Cephalaria gigantea* and species of *Heracleum*, often dominate in forest openings and along forest edges (Pavlov 2004).

9.6.4 Coniferous Forest Belt

Three coniferous tree species are widely distributed in the Reserve. *Pinus silvestris*, *Abies nordmanniana* and *Picea orientalis* (Fig. 9.4c) occupy 34.7%, 12.6% and 8.4% of the forest area, respectively (Vorobyova et al. 1986). Thus, more than half of the forest area of the Reserve is covered by coniferous species, which replace broad-leaved stands at elevations above 1300–1400 m a.s.l. *Abies* forests completely cover slopes, regardless of their orientation, in the southern valleys (Dombai-Ulgen and Alibek), where the precipitation is more abundant. Forests in the central and northern parts of the Reserve are distributed according to the following pattern: wetter north-facing slopes are covered by fir forests with the admixture of spruce, whereas drier south-facing slopes are occupied by pure, or nearly pure pine stands (Pavlov 2004).

Abies **Forests** on the south-facing slopes along the Alibek and Dombai-Ulgen valleys are often characterized by a very high canopy density (nearly 100%) and tall tree stands (up to 35–40 m in height). Some other tree species (*Acer trautvetteri, Fagus orientalis, Populus tremula, Sorbus aucuparia,* etc.) are mixed with *Abies* in these communities. The understory is composed mainly of boreal species. At the same time relict Colchis[5] species, e.g., *Laurocerasus officinalis, Rhododendron ponticum, Vaccinium arctostaphylos,* as well as some species typical of the subalpine tall forb communities, such as *Campanula latifolia*, *Inula magnifica, Senecio platyphylloides, S. nemorensis, Telekia speciosa,* may also be present here (Pavlov 2004).

Pure ***Picea*** **forests** occur in the valleys of the Gonachkhir and other rivers on the northern margin of the Reserve (Fig. 9.4c) as a result of forest fires in the last century. There are no *Abies*- or *Picea*-dominated stands in the upper reaches of the Kuban River and its tributaries, but many forb species, typical of these communities (*Goodyera repens, Linnaea borealis, Vaccinium vitis-idaea*), still occur in the understory of *Pinus*-dominated forests (Pavlov 2004). The similarity in herbaceous components in *Pinus*-, *Picea*- and *Abies*-dominated coniferous forests in the North Caucasus was noted by Elenevskii (1940) and Sochava (1946).

North slopes are usually occupied by **fern** ***Abies*** **forests** — well-developed *Abies* stands with *Athyrium filix-femina, Dryopteris filix-mas, Matteuccia struthiopteris* and *Petasites albus* typifiyng the understory. Farther upslope, some subalpine meadow species (*Angelica purpurascens, Campanula lactiflora, C. latifolia, Heracleum asperum, Ligusticum alatum, Senecio platyphylloides, Telekia speciosa,* etc.) occur under the canopy, many of which can reach 2–2.5 m in height. The understory tends to disappear as the canopy density approaches 100%. In that case, the co-called **dead-*floor Abies*** **forests** are developed, where the understory is extremely sparse, and only few shade-tolerant species (e.g., boreal herbs such as *Goodyera repens* or *Linnaea borealis* or some bryophytes) are found in that community (Pavlov 2004).

Short-Forb *Abies* **Forests** are commonly found on gentle slopes and on the river terraces. *Picea orientalis* is a frequent additional associate in the overstory. The herbaceous layer contains both boreal (e.g., *Oxalis acetosella*) and nemoral (e.g., *Galium odoratum*) species. *Calamintha grandiflora, Geranium robertianum, Osmorhiza aristata, Paris incompleta, Salvia glutinosa, Senecio renifolius* and some other species are typical in the understory of these forests too (Pavlov 2004).

The *Pinus sylvestris* is the most widespread tree species in the Reserve. ***Pinus*** **forests** are found mainly in the northern half of the Reserve, where they usually occupy steep stony or rocky slopes along the Teberda River and its tributaries — Gonachkhir, Dzhemagat, Mukhu, Bol 'shaya and Malaya Khatiparas and some other rivers. The canopies of *Pinus* trees, in contrast to those of *Abies* and *Picea*, intercept less sunlight which favours the understory. *Calamagrostis arundinacea* is often the understory dominant. Other xerophilous species of grasses, sedges and forbs, such as *Anthyllis vulneraria, Brachypodium pinnatum, Carex humilis, Coronilla varia, Galega orientalis, Geranium sanguineum, Lathyrus roseus, Linaria*

[5] Species originating from the region on the coast of the Black Sea, centred in present-day western Georgia.

genistifolia, Moneses uniflora, Poa nemoralis, Potentilla argentea and *Trisetum rigidum*, typify the herbaceous layer (Pavlov 2004).

Since *Pinus silvestris* prefers drier habitats, and the precipitation declines markedly with distance from the Greater Caucasus Range, *Pinus* forests become increasingly common towards the north. A comparatively large tract of *Pinus* forest covers the slopes of the Teberda River valley to the north of the Reserve. East of the Reserve, in the Kuban river headwaters, *Abies* and *Picea* are also totally replaced with pine *Pinus silvestris* (Pavlov 2004).

9.6.5 Timberline

The timberline, consisting of open subalpine forests, crooked-stem and krummholz communities, can be considered as a transition zone between forest and the subalpine belts. Some studies (Vorobyova 1966; Gadzhiev 1970, 1990) include timberline communities in the subalpine vegetation; others (Grossheim 1948; Kononov 1957) consider them part of the forest belt. Crooked-stem and krummholz communities are widely distributed in the middle reaches of the Teberda River tributaries and occur predominantly on north-facing slopes and in glacial valley bottoms (Tumadzhanov 1960a, b). The average elevation of the timberline in the northern part of the Reserve, near to Teberda town, is 2100–2300 m a.s.l. (Elenevskii 1940; Grebenshchikov, Ozenda 1980), although the actual elevation of the timberline in the area varies widely — between 1700 and 2400 m a.s.l., depending on multiple factors, such as slope orientation, local topographical features, natural disasters and human activity (Tumadzhanov 1960a, b). Many researchers (Grossheim 1948; Yaroshenko 1956; Vorobyova 1966; Gadzhiev 1970, 1990) noted that the actual timberline in the Caucasus is lowered markedly due to human activities — clearing away trees and converting forest stands into meadows, used as hayfields and pastures for the domestic livestock. Haying and heavy grazing obviously prevent the restoration of the original timberline.

In the reserve, the timberline is generally lower towards the north on slopes facing the Teberda River valley. *Pinus* forests reach elevations up to about 2100 m a.s.l., and *Abies* and *Picea* forests attain 2100–2200 m a.s.l. in the upper reaches of the Teberda River and even higher (2450 m a.s.l.) on the northern slopes of the Greater Caucasus Range (Fig. 9.5a). At their upper limit, coniferous forests sometimes are restricted to convex parts of the slopes, where concave portions serve as chutes for avalanches, damaging tall trees. In those cases elevational belts interfinger, i. e. the timberline attains its lower limits in valleys and its highest limits on ridges. As a consequence, belts along the slopes of valleys can be reversed from their otherwise normal elevational relationship, varying in the range ± 500–700 m (Pavlov 2004).

Natural disasters are quite common in the study area, as well as in many other mountainous regions. Avalanches, rockfalls, landslides and mudslides dramatically

Fig. 9.5 (**a**) Timberline, Dombay-Ulgen and Alibek valleys. A view from the Chuchkhur valley (2200 m a.s.l); (**b**) Crooked-stem *Betula litwinowii* elfin forest, Arkhyz valley (1850 m a.s.l.); (**c**) *Rhododendron caucasicum* scrub, eastern spur of Mount Malaya Khatipara (1480 m a.s.l)

change the landscape, destroying forests and lowering the timberline (Körner 1999). Large vertical swaths along steep slopes down the face of a mountain, free from coniferous forests, are often signs of recurrent snow avalanches, sweeping away tall trees. Elfin *Betula litwinowii* and *Fagus orientalis* trees with strongly bowed stems, however, remain undamaged and often invade lower zones along avalanche chutes.

Crooked-Stem Elfin Forests are widespread in the Caucasus in general (Grossheim 1949; Tumadzhanov 1960a; Gulisashvili et al. 1975) and in the Reserve in particular, occupying 27.1% of its forested area (Vorobyova et al. 1986). The height of the trees in these communities is about 2–3.5 m, and both the shrub and herbaceous layers are usually well developed beneath their canopy. The upper limit of crooked-stem forests is comparatively low (1700–1900 m a.s.l.), especially along the bottoms of the glacial valleys of the Alibek, Bu-Ulgen, Dombai-Ulgen and Amanauz rivers (Pavlov 2004). These communities occupy sites subject to heavy winter snow accumulation (several meters) and extensive snow creep (Yashina 1981). The trunks of the flexible elfin trees are often pressed to the ground by snow, but they easily spring up again after the snowmelt (Fig. 9.5b). Abundant water supply combined with good drainage leads to the development of poor acidic soils under these communities (Onipchenko 2002).

Crooked-stem elfin forests on colder northern slopes are overwhelmingly dominated by *Betula litwinowii* in the overstory with *Sorbus aucuparia* as a constant admixture. *Betula* forests on northern slopes are often characterized by dense bush of *Rhododendron caucasicum* (Leskov 1932; Tumadzhanov 1960a, b). Spiny shrubs (*Juniperus communis, Rubus idaeus)*, subalpine and forest herbs (*Oxalis acetosella, Senecio renifolius*), bryophytes (*Barbilophozia barbata, Hypnum pallescens, Sanionia uncinata*) and lichens (*Cetraria islandica, Cetraria pinastri*) have high constancies and typify the understory (Onipchenko 2002). Besides these, constituents of subalpine tall herb communities, such as *Heracleum asperum*, *H. freynianum*, *Valeriana alliariifolia,* as well as a large variety of typical boreal forbs and shrublets, e.g., *Calamagrostis arundinacea*, *Dryopteris filix-mas*, *Goodyera repens, Gymnocarpium dryopteriss*, *Pyrola media, Vaccinium myrtillus*, *Vaccinium vitis-idaea,* often occur under elfin birch canopies. The moss layer, also consisting of characteristic forest species, such as *Dicranum scoparium*, *Hylocomium splendens*, *Pleurozium schreberi*, *Polytrichum commune*, etc., is usually well developed (Pavlov 2004). Rhododendron can extend beyond the edge of the birch‘s canopies and form large patches upslope, adjacent to the elfin crooked-stem forests on wetter and cooler northern slopes (Fig. 9.5c).

Similar communities, dominated by elfin *Betula litwinowii* trees with *Sorbus aucuparia* as a constant associate, also occur on steep southern slopes. Higher insolation and less winter snow accumulation on windward slopes result in a prolonged growing season. Snow creep is less frequent there, and thus young *Abies nordmanniana* trees can grow in these communities. In contrast to the northern variant just mentioned, *Rhododendron caucasicum* is completely absent in this shrub layer, and boreal species, e.g., *Dicranum scoparium* and *Pyrola minor* are poorly represented. However, some frequent species, e.g., *Rubus idaeus* and *Sanionia uncinata*, are shared with the previous association. On the other hand, several subalpine species (*Aconitum nasutum, Astrantia maxima, Bupleurum falcatum, Calamagrostis arundinacea, Campanula latifolia, Geranium sylvaticum, Millium effusum, Silene vulgaris,* etc.) are well represented, and tall forbs play a significant role in the herbaceous layer. The moss layer is often well developed and can cover up to 80% of the ground (Onipchenko 2002).

Another type of crooked-stem forests, i.e. ***Fagus*-dominated communities** are not very widespread in the Reserve and occupy the lower parts of slopes. All *Fagus* forests together (including both the broad-leaved *Fagus* forests at the base of the slopes and the crooked-stem elfin communities at the timberline) occupy only 3.3% of the forested area in the Reserve (Vorobyova et al. 1986). Evergreen *Rhododendron caucasicum* is the most typical shrub in the understory. Besides rhododendron, two other ericaceous shrubs — *Rhododendron luteum* and *Vaccinium arctostaphylos* are also very common here. Certain species of tall forbs, such as *Campanula lactiflora, Inula magnifica, Ligusticum alatum*, *Senecio platyphylloides*, *Telekia speciosa*, sometimes attaining 2–2.5 m in height, and typical forest grasses and herbs, e.g., *Calamagrostis arundinacea, Calamintha grandiflora*, *Galium odoratum*, etc., are usually found in the herbaceous layer of beech-dominated crooked-stem forests (Pavlov 2004).

The gently sloping plateaus Dudaron and Bechasyn, surrounding the Kuban River valley, are characterized by a lowered timberline. *Betula* and *Alnus* forests, located at elevations of 1600–1800 m a.s.l., border on wet and sometimes peaty subalpine meadows, composed mainly by tall grasses. Mountain wet meadows are most frequently dominated by *Molinia coerulea*; *Calamagrostis arundinacea* is the second most frequent dominant species. Meadows alternate with *Hypnum*-sedge or, less frequently, *Sphagnum*-sedge moors; peaty meadows with *Deschampsia caespitosa* are widespread as well. *Carex cespitosa*, *C. hartmanii*, *C. lasiocarpa*, *C. limosa*, *C. muricata*, *C. vesicaria* and some others are the most common sedges. Rushes are represented by *Juncus articulatus*, *J. effusus* and *J. filiormis*. *Eryophorum polystachyon* and *E. vaginatum* are also typical of moors (Pavlov 2004).

9.6.6 Subalpine Belt

The subalpine elevational belt, laying near and above the timberline, is characterized by presence of treeless, mainly herbaceous communities. Subalpine meadows, grasslands and tall-herb communities occur on well-drained soils in the middle reaches of the Teberda River ‘s tributaries and are well represented in the study area (Pavlov 2004). Among the common constituents *Astrantia maxima*, *Campanula latifolia*, *Geranium sylvaticum*, *Millium effusum*, *Rumex alpestris* can be found in the Caucasian herbaceous subalpine communities (Buslik 1990; Karner and Mucina 1993). *Rhododendron* and *Juniperus* dominated scrub, subalpine fens, plant communities on siliceous rocks and unstable stony substrates are less widely distributed in the study area (Onipchenko 2002).

Calamagrostis arundinacea **Dominated Subalpine Meadows** are widespread in the subalpine belt of the study area at elevations from 1950 to 2650 m a.s.l. and occur mainly on southern, relatively steep (7–35°) slopes. These communities are characterized by a dense herbaceous layer (up to 100% cover) and a low percentage of bare ground and exposed stones. Bryophytes play a minor role; terricolous lichens are absent. Subalpine meadows are rather productive, but, due to their slope positions, plants sometimes may suffer from lack of moisture (Onipchenko 2002). The soils under the subalpine meadows are characterized by a relatively high content of exchangeable cations, organic matter and mobile phosphorus (Volkov 1999). These communities are floristically rich and composed mainly of characteristic subalpine species, e.g., *Anemone narcissiflora, Anthemis macroglossa, Betonica macrantha, Bupleurum falcatum, Silene vulgaris, Thesium alpinum, Tragopogon reticulatus, Trifolium canescens*, as well as species with wide ecological ranges, such as *Anthoxanthum odoratum* and *Deschampsia flexuosa* (Onipchenko 2002). There are other grass species (e.g., *Bromus variegatus*, *Festuca varia*, *Helictotrichon versicolor*, and *Agrostis vinealis*) that can dominate in the subalpine belt, though they are not widespread in the Reserve (Pavlov 2004).

Bromus variegatus **Dominated Grasslands** are typically encountered at ridgetops and upper parts of windward slopes. These communities occupy nearly snow-free habitats with deep soils that are freezing in winter and are characterized by a low production and low mineralization rates. They are relatively rich in lichens, and their vascular plant composition is similar to that of alpine lichen heaths, described below (Shiffers 1953; Vorobyova 1977; Onipchenko 2002).

Festuca varia **Subalpine Grasslands** occupy mainly warm and dry southern steep slopes with many xeromorphic and succulent species, e.g. *Ajuga orientalis, Sempervivum caucasicum, Sedum purpurascens, Helictotrichon versicolor*, *Festuca djimilensis*, *F. ovina*, *Koeleria eriostachya* and *Phleum phleoides* (Onipchenko 2002).

Due to the rich floristic composition of the subalpine meadows with their large number of plants with luxuriant, conspicuous wildflowers, such as *Psephellus vvedenskii, Anemone narcissiflora, Betonica macrantha, Lilium monadelphum, Pulsatilla aurea* and *Pyrethrum coccineum,* the communities have a high aesthetic value (Fig. 9.6a).

Tall Herb Communities are another peculiar vegetation type, common in the subalpine belt in the Caucasus. They usually occupy river valley bottoms, snowbed depressions, flat or concave sites and are characterized by heavy snow accumulation and moistened, but well-drained soils. A warm temperature regime in the subalpine belt leads to intensive spring snowmelt, which in turn results in a prolonged growing season and an adequate water and nutrient supply, brought from the upper slopes by meltwater flows (Onipchenko 2002). All this creates extremely favorable conditions for the growth of exuberant thickets of enormous herbs, attaining 1.5–2 m in height and 90–100% density (Fig. 9.6b).

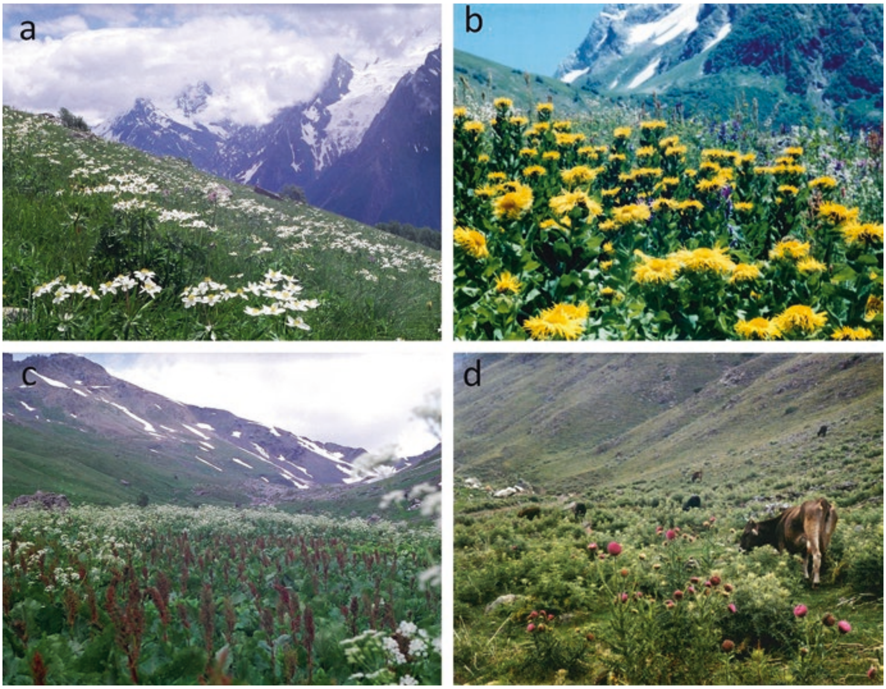

Fig. 9.6 (**a**) Subalpine meadow with blooming *Anemone narcissiflora*, south-facing slope in the Alibek valley (2300 m a.s.l); (**b**) Native subalpine tall herb communities with *Inula orientalis* in the foreground, bottom of the Hadzhibey valley (2300 m a.s.l.); (**c**) Ruderal tall herb communities dominated by *Rumex alpinus* and *Anthriscus sylvestris*, bottom of the Azgek valley (2200 m a.s.l.); (**d**) Thorny non-palatable Asteraceae *Carduus nutans* and *Cirsium pugnax* in overgrazed pastures, bottom of the Mukhu valley (2150 m a.s.l.)

Tall herb communities are often referred to as a distinctive vegetation type, very different from meadows (Grossheim 1948; Gadzhiev 1970). As pointed out by Grossheim (1948), Caucasian tall herb communities have three distinctive features, that distinguish them from meadows: (1) an almost complete absence of turf in the soils; (2) implicit layers; (3) a low species diversity. Soils, developed under these communities, are characterized by moderate quantities of exchangeable cations, a relatively high concentration of soluble phosphorus, and a well developed humus layer that is rich in organic matter (Volkov 1999).

Often only a restricted number of superior competitors dominate this vegetation, preventing smaller species from growing in the deep shade of giant herbs. The role of bryophytes is negligible, and lichens are completely absent. *Aconitum orientale, Cephalaria gigantea, Dactylis glomerata, Lapsana communis, Ligusticum alatum, Vicia cracca* represent diagnostic species (Onipchenko 2002). *Anthriscus sylvestris, Campanula lactiflora*, *Campanula latifolia, Heracleum asperum*, *Millium effusum*, *Rumex alpinus*, *Senecio platyphylloides, S. macrophyllus*, *Valeriana alliariifolia* are also common in the subalpine tall herb communities in the Reserve (Pavlov 2004).

Ruderal Tall Herb Communities can be found in the subalpine zone of the Reserve even now, more than 75 years after the cessation of grazing. They occupy nearly the same habitats as native tall herb communities, but on sites of former cattle farms, shepherd‘s summer dwellings, sheepfolds, corrals, livestock trails, drinking points, etc., where vegetation cover had been drastically changed and soils were once well manured and moistened. According to our observations, these communities do not occur in places where cattle are currently grazing, and likely develop only after the cessation of cattle trampling and foraging. A few tall and highly productive species invade these sites after the grazing is stopped (Fig. 9.6c). The community seems very stable due to the high competitive ability of the dominants (Onipchenko 2002). The soils under the ruderal tall herb communities are characterized by a higher soil acidity and a lower carbon to nitrogen (C/N) ratio compared with soils under the native subalpine tall herb communities (Volkov 1999).

Generaly these communities are floristically very poor. The tall and dense vascular plant cover, dominated by a few competitive dominant species, prevents the establishment of other plants in this community. Lichens are completely absent, and the role of bryophytes is negligible. *Rumex alpinus* often is the sole dominant; a few ruderal species, e.g., *Anthriscus sylvestris* and *Urtica dioica* are also very common components (Onipchenko 2002). Wild ungulates very rarely use this community as a pasture, if at all. From the large mammals only bears often feed on some plants, e.g., *Millium effusum*, *Heracleum asperum* and *Anthriscus sylvestris*, especially in spring. Bear activity creates gaps in the dence herbaceous layer, and this plays an important role in the establishment of native subalpine species, and therefore increases the floristic richness of the community (Onipchenko 2002).

Tall Grasslands Dominated By *Poa longifolia* develop on recently or currently grazed sites and can serve as another example of human-altered vegetation within the Reserve. The grazing impact is evident: slopes are traversed by terracettes (cattle tracks), which often form dense interlacing networks; cattle dung is common on currently grazed pastures; non-palatable plants, e.g., *Alchemilla vulgaris* aggr., *Achillea millefolium*, *Lamium album*, *Urtica dioica*, etc., are constant and abundant. These grasslands occupy gentle (2°–10°) slopes within the subalpine zone near the timberline (2150–2420 m a.s.l.). Heavy snow accumulation and abundant water supply, brought from the upper slopes, create a favourable water regime. Tall bluegrass (*Poa longifolia*) is often the sole dominant. *Alopecurus pratensis* and *Senecio subflocossus* are common constituents. The floristic richness is intermediate between that of the previous two associations. The coverage of herbs is high (up to 90%); the role of bryophytes and lichens is low (Onipchenko 2002).

Polygonum **Dominated Ruderal Communities** occur on gentle (3°–5°) slopes within the subalpine zone (2150–2450 m a.s.l.) in dry northern, currently grazed valleys (Azgek, Mukhu) near acting cattle farms, sheepfolds, corrals, i.e., at sites with a high stock density, where the vegetation is altered drastically under the severe grazing stress. The communities, developing in such habitats, have almost nothing to do with natural subalpine vegetation. Native subalpine species are almost completely displaced by ruderal lowland invaders, e.g., *Alopecurus pratensis, Capsella bursa-pastoris, Elytrigia repens, Lamium album, Plantago major, Stellaria media, Thlaspi arvensis* and *Urtica dioica*. These communities are often dominated by *Polygonum aviculare*. Thorny Asteraceae *Carduus nutans* and *Cirsium pugnax* also often abound and may serve as a refuge for some palatable species, which benefit from growing nearby (Fig. 9.6d). The communities are floristically poor. Lichens are completely absent, and the role of bryophytes is negligible (Egorov, Onipchenko 2002).

Mesotrophic *Small-sedge* Subalpine Fens are generally widespread in the Caucasus (Akatov 1991), although they are quite rare in the Reserve and occupy only small areas due to the rugged mountain topography and well-drained soils. Mesotrophic small-sedge fens occur in the subalpine belt at elevations of 1900 to 2600 m a.s.l. They develop in habitats with a permanently abundant, but slow-moving water supply on alluvial fans near streams, on slopes of various steepness and orientation near springs and watercourses, or on horizontal flooded areas in U-shaped valley bottoms. The underground water table can be found at 5–15 cm depth (Onipchenko 2002). The soils developed under subalpine fens are distinguished by the well-developed peat horizon and extreme values of soil characteristics under other subalpine and alpine communities — the fen soils have the highest nitrogen and carbon amounts; the largest quantities of exchangeable cations Na^+, K^+, Ca^+, Mg^+; the highest levels of pH and the lowest hydrolytic acidity (Volkov 1999). Typical species of moist habitats, such as *Campylium stellatum, Dactylorhiza urvilleana, Pinguicula vulgaris, Potentilla erecta, Swertia iberica* (Fig. 9.7a), etc., as well as some species of subalpine tall herb communities, e.g. *Geranium sylvaticum* and V*eratrum album,* occur at high constancy here. Graminoids, typical of the alpine belt (*Anthoxanthum odoratum, Luzula multiflora, Nardus stricta*), are common in mesotrophic small-sedge subalpine fens. The vascular plant cover is well developed (50–90%); the moss layer is moderately dense (up to 50%) (Onipchenko 2002).

A similar association, ***sedge* subalpine fen,** occurs on very gentle (up to 5°) slopes on water-saturated soils with a poor drainage, causing peat formation. The water table lies near the soil surface and open water may be present in these habitats. Stones are completely absent from the surface. This association are floristically similar to the previous one. The presence of *Carex rostrata* and *C. limosa* are the main diagnostic feature. The role of graminoids is minor. The moss layer is better developed than the vascular plant cover — up to 100% and 20–75% respectively (Onipchenko 2002). These communities are widespread in the Western Caucasus (Akatov 1991), but very rare in the Reserve.

Other vegetation types, e.g., *Rhododendron caucasicum* and *Juniperus communis* dominated scrub, communities on siliceous rocks and unstable stony substrates (screes, rock streams, pebbles along rivers etc.), are less widely distributed in the subalpine belt in the study area and described in details elsewhere (Onipchenko 2002).

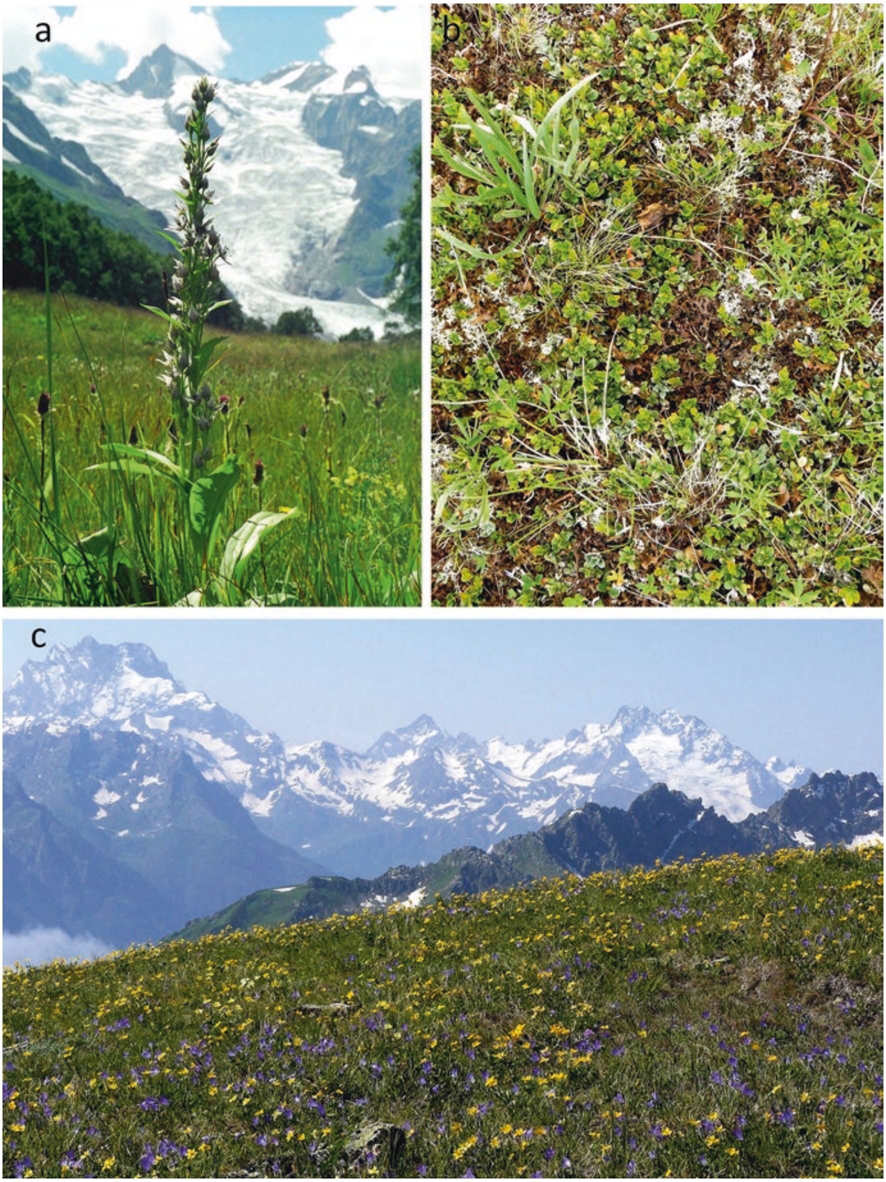

Fig. 9.7 (**a**) *Swertia iberica* in a subalpine fen on the south-facing slope of the Alibek valley (2000 m a.s.l.); (**b**) The structure of alpine lichen heath, Mount Malaya Khatipara (2810 m a.s.l.); (**c**) Alpine lichen heath in peak bloom on the eastern spur of Mount Malaya Khatipara (2810 m a.s.l.)

9.6.7 *Alpine Belt*

The subalpine belt gives way to the alpine one at elevations above approximately 2300 m a.s.l. The actual elevation of the transition zone in the study area varies widely depending on many factors, primarily slope orientation and distance from the Greater Caucasus Range. For example in the southern half of the Reserve it lies at elevations of about 2600–2700 m a.s.l. on south-facing slopes, and at 2250–2300 m a.s.l. on the north-facing ones (Pavlov 2004). The alpine belt encompasses extensive areas roughly from 2500 to 3000 m a.s.l. northward from the Greater Caucasus Range, occupying about 35% of the total area of the Reserve (Utyakov 1960).

A rich diversity of plant communities can be observed in the alpine belt. The following main physiognomic types of the alpine vegetation are distinguished in the Caucasian highlands: alpine meadows, alpine heaths, dwarf shrub heaths, snowbed communities, *Kobresia* grasslands, cold water spring communities, dwarf scrub, alpine fens, and vegetation on screes, pebbles and rocks (Bush 1935; Grossheim 1948; Shiffers 1953; Kononov 1957; Tumadzhanov 1963, 1980; Gulisashvili 1964; Dolukhanov 1966; Gulisashvili et al. 1975; Vorobyova 1977; Rabotnov 1987). A few hundred vascular species have been recorded from this belt (Onipchenko et al. 2011; Zernov, Onipchenko 2011; Zernov et al. 2015).

Snow accumulation is the main factor, which determines the structure and species composition of the plant communities in the highlands of the Reserve (Rabotnov 1987; Walter 1975). Depth and duration of the snow pack vary widely in the alpine belt depending on multiple factors, primarily on slope orientation and steepness (Schröter 1926; Walter and Breckle 1994; Franz 1979; Reisigl and Keller 1987; Körner 1999; Onipchenko 2002; Onipchenko 1994a). Depending on the depth of the snow cover in winter, the most widespread Caucasian alpine plant communities can be arranged in the sequence shown in Fig. 9.8 and described in details below.

The term "heaths" commonly refers to tundra-like communities dominated by non-herb psychrophytes — lichens, bryophytes and dwarf shrubs (Shiffers 1953, 1960). In the study area **alpine lichen heaths** occupy windward slopes and crests in the alpine belt and develop in habitats with insignificant winter snow accumulation (Onipchenko 2002). Extremely low temperatures, deep (over 40 cm) soil freezing in winter and frequent drought in summer are the key factors affecting structure and

Fig. 9.8 Distribution of the widespread Caucasian alpine plant communities as related to the accumulation of snow (Generalized from Rabotnov 1987; Onipchenko 1994a; Onipchenko 1994b; Volkov 1999; Onipchenko et al., 2009)

species composition of the alpine lichen heaths (Onipchenko and Onishchenko 1986), which in turn cause a low level of nutrients, an extremely slow nutrients circulation (Voronina et al. 1986), a low productivity and a low aboveground biomass (Onipchenko 1985). These communities develop on thin or moderately thick alpine meadow soils and on skeletal stony or gravelly soils, formed predominantly (77%) from biotite schist parent rock (Vertelina et al. 1996), and characterized by a low cation exchange capacity, an average level of organic matter, the lowest level of water-soluble phosphorus and the highest pH among the studied subalpine and alpine plant communities (Volkov 1999).

The spatial structure of alpine lichen heaths is very peculiar: small lichen patches alternate with graminoid bunches or isolated shoots of vascular plants and bryophytes (Fig. 9.7b), thus, these communities have physiognomic characteristics of both tundra and meadows (Pavlov 2004). Onipchenko (1985, 1994b) and Grabherr (1989) put forward the following hypothesis to explain this structure: in poor shallow soils, the roots of vascular plants occupy a larger area than their aboveground shoots; therefore, above ground vacant space becomes available for the fruticose lichens, since they compete very little for nutrients with vascular plants.

A conspicuous abundance of fruticose lichens, covering up to 55% (mean 28%) and indicating low accumulation of winter snow, distinguishes alpine heaths from other Caucasian highland communities. Coverages of vascular plants and bryophytes are 15–80% (mean 47%) and < 1–25% (mean 4%), respectively. As a rule, the exposed stone cover is insignificant (0–30%; mean 5%). There is no sole dominant, although the fruticose lichens *Cetraria islandica, C. laevigata, Cladonia gracilis, C. furcata, C. mitis, C. pyxidata, Flavocetraria cucullata, F. nivalis* and *Thamnolia vermicularis* are the most typical species and play an important role in the community. Among the flowering plants, *Carex sempervirens, C. umbrosa, Festuca ovina* and *Trifolium polyphyllum* are the most abundant; *Carum caucasicum, Gentiana pyrenaica, Rhytidium rugosum* and *Vaccinium vitis-idaea* have a high constancy; *Anemone speciosa, Aster alpinus, Eritrichium caucasicum* and *Oxytropis cubanensis* are also common constituents (Onipchenko 2002). The floristic richness of the alpine lichen heaths is 39.8 species per 100 m^2 (Onipchenko, Semenova 1995). In total, 102 species of vascular plants, 27 bryophytes and 20 lichens were recorded in 28 relevés of the association (Onipchenko 2002; Onipchenko and Pavlov 2009).

Alpine heaths serve as winter pastures for wild ungulates. Due to the generally very severe environment, the recovery process after the disturbance of alpine heaths is very slow. For example, revegetation after mild digging by wild boar (*Sus scrofa*) on a single occasion took at least 15 years (Onipchenko and Golikov 1996). Pine voles (*Pitymus majory*), a very common rodent species in the Caucasian highlands that characteristically shows an intensive digging activity (Fomin et al. 1989), has a relatively low population density in the alpine lichen heaths (129 animals per hectare were registered in peak years). These rodents dig 390 ± 180 holes and produce 330 ± 180 soil disturbances per hectare per year (Fomin and Onipchenko 1986).

Domestic livestock grazing in alpine heaths results in a rapid loss of the lichen cover and a change to sparse dry scree-type communities (Egorov and Onipchenko

2002). Strict restrictions, especially the banning of grazing, are absolutely necessary to preserve these fragile, species-rich communities whith an exceptional aesthetic value (Fig. 9.7c).

Festuca varia **Dominated Grasslands** are widespread in the Caucasus (Grossheim 1948; Shiffers 1953; Gulisashvili et al. 1975; Bedoshvili 1988; Pysek and Srutek 1989) and occupy relatively dry habitats with an insignificant accumulation of winter snow (0.5–1.5 m). The snow cover stays until the end of May or the first half of June, and thus the duration of the vegetation period lasts 3.5–4.5 months (Onipchenko 1994b). The tussock grass *Festuca varia* is the sole dominant, and it occurs over a wide elevational range from the steppe to the subnival belt (Egorov et al. 2012). However, it does not tolerate excessive moisture, so it dominates only on dry, moderate to steep, mainly southern slopes. Soils under these communities are thick, well developed and formed predominantly (72%) from biotite schist parent rock (Vertelina et al. 1996); they have an intermediate pH value compared to the other studied alpine communities (Volkov 1999). The depth of the humus layer is 20–24 cm; the content of soil skeleton in the upper 10 cm is 10% by volume (Grishina et al. 1993).

The high productivity of *Festuca varia* combined with the low decomposition rates of dead leaves of firm bunch grasses (Leinsoo et al. 1991) lead to a substantial litter accumulation. The aboveground necromass in *Festuca varia* dominated grasslands is nearly 3 times greater than the aboveground biomass (Onipchenko 1990). Abundant litter produced mainly by the sole dominant, *Festuca varia*, suppresses other species. As result, the role of bryophytes and lichens is low in terms of species richness, plant cover and biomass. Vascular plant cover ranges between 40% and 90% (mean 64%). Bare soil and stones cover only limited area within the community (0–20%; mean 4%). *Festuca brunnescens* and *Nardus stricta* are constant associates, though they are usually less abundant than the major dominant. Common constituents include *Ajuga orientalis, Calamagrostis arundinacea, Campanula collina, Centaurea cheiranthifolia* (Fig. 9.9a)*, Galium verum, Scorzonera cana, Sempervivum caucasicum, Silene saxatilis, Viola altaica* and others, many of which have xeromorphic traits (succulence and leaf pubescence). Also, species typical of the alpine lichen heaths often occur — *Alchemilla caucasica, Carex umbrosa, Helictotrichon versicolor, Minuartia circassica* (Onipchenko 2002).

Although most of constituents can grow only in the intervening space between dense bunches of grasses and do not play any significant role in the community, *Festuca varia* dominated grasslands are floristically the richest community in the alpine belt of the Reserve (56.8 species per 100 m^2; Onipchenko and Semenova 1995). In total, we recorded 161 species of vascular plants, 38 bryophytes and 8 lichens in 30 relevés of this association (Onipchenko 2002; Onipchenko and Pavlov 2009). The population density of pine voles in *Festuca varia* grasslands reaches 170 animals per hectare. During peak years rodents dig 1780 ± 500 holes and produce 4780 ± 730 soil disturbances per hectare per year (Fomin and Onipchenko 1986). *Festuca varia* grasslands are relatively resistant to anthropogenic disturbances. Moderate domestic livestock grazing does not have a negative effect on the

Fig. 9.9 (**a**) *Centaurea cheiranthifolia*, a common constituent of the *Festuca varia* dominated grasslands, on the eastern spur of Mount Malaya Khatipara (2800 m a.s.l.); (**b**) *Geranium gymnocaulon*, the codominant in a dryer variant of *Geranium-Hedysarum* meadows, Mount Malaya Khatipara (2800 m a.s.l.); (**c**) *Taraxacum stevenii* in the snowbed community, Arkhyz valley (2640 m a.s.l.); (**d**) *Draba rigida* in the Ullu Murudzhu valley (3100 m a.s.l.); (**e**) *Veronica telephiifolia* in the subnival community, Mt. Semenov-Bashi (3050 m a.s.l.); The (**f**) cushion plant *Gypsophila tenuifolia* on subnival rock outcrops in the Bol 'shaja Khatipara valley (2800 m a.s.l.)

composition and floristic richness of this grassland (Onipchenko 2002). Severe grazing, however, leads to the exclusion of *Festuca varia* and the dominance of *Nardus stricta* on gentle slopes, or the development of bare spots and sparse dry scree-type communities on steep slopes (Egorov and Onipchenko 2002).

Geranium-Hedysarum **Meadows** are widespread in the Western and Central Caucasus (Vorobyova 1977; Kimeridze and Mardaleshvili 1980; Kimeridze 1985). In the study area, they occupy habitats with a relatively gentle topography, local depressions and lower parts of slopes at elevations of about 2600–3000 m a.s.l. (Onipchenko 2002). Confined to habitats with moderate snow accumulation

(2–4 m), these communities are well protected from wind and low temperatures in winter. At the same time, the growing season is relatively long (2.5–3.5 months; Onipchenko 1994b). Thus, *Geranium-Hedysarum* meadows occupy the most favorable habitats and are the most productive communities among the studied vegetation types in the alpine belt of the Reserve (Onipchenko 1989). Soils under *Geranium-Hedysarum* meadows are formed predominantly (57%) from granite parent rock (Vertelina et al. 1996) and characterized by a low level of exchangeable cations and organic matter, a medium or high level of exchangeable phosphorus and an intermediate pH (Volkov 1999). The vascular plant cover in this community is relatively dense (50–97%; mean 81%), and the main dominants (*Geranium gymnocaulon* and *Hedysarum caucasicum*) usually provide far most of the cover in the herbaceous layer. Coverage and the overall role of lichens and bryophytes is negligible. Besides the major dominants, three other forb species are constant constituents in these meadows — *Carum meifolium, Pedicularis condensata* and *Pulsatilla aurea*. Some bunch grasses, e.g., *Festuca brunnescens, F. varia* and *Nardus stricta,* are frequent associates, though they are usually not abundant in the community (Onipchenko 2002). A moister variant of *Geranium-Hedysarum* meadows can be found along watercourses and brooks, where *Geranium gymnocaulon* plays the role of the sole dominant. It can reach cover values of about 75% or even more, which causes a low floristic richness of such meadows. Only few species can grow in the lush *Geranium gymnocaulon* layer: *Carex atrata, Carum meifolium, Luzula multiflora, Matricaria caucasica, Phleum alpinum* and some others are often represented by single individuals and play a minor role in the community. A dryer variant of *Geranium-Hedysarum* meadows often occurs in small depressions on gentle slopes and is usually dominated by more than one species (Fig. 9.9b). Sometimes *Hedysarum caucasicum* is the sole dominant. Such communities are floristically richer than the moister variant (Onipchenko 2002). The floristic richnes of *Geranium-Hedysarum* meadows is 35 species per 100 m^2 (Onipchenko and Semenova 1995), and the species pool includes 112 species of vascular plants, 23 bryophytes and 5 lichens, recorded in 20 relevés of the association (Onipchenko 2002; Onipchenko and Pavlov 2009).

Among the studied alpine plant communities *Geranium-Hedysarum* meadows are the most attractive habitats for pine voles (*Pitymus majory*). Up to 940 animals per hectare were registered in peak years, when rodents dig 5500 ± 590 holes and produce 14,300 ± 2850 soil disturbances per hectare per year (Fomin and Onipchenko 1986). Voles consume approximately 15% of the annual net production in such years and leave clearly visible gaps in the structure of the communities (Fomin et al. 1989). Vascular plant species differ in their reaction to the different sizes of gaps (Onipchenko and Rabotnova 1994). Moderate consumption of the aboveground biomass and burrowing activity does not lead to significant changes in the structure and species composition of the community, but the rodents play an important role in maintaining the soil structure, in particular its water and air permeability and they intensify soil biological processes (Onipchenko 1989; Fomin et al. 1989). *Geranium-Hedysarum* meadows, just as *Festuca varia* grasslands, change into *Nardus stricta* dominated grasslands under heavy domestic livestock grazing (Egorov and Onipchenko 2002). Thus, overgrazing leads to the physiognomical convergence of these two associations. But the species composition, in contrast to the abundance of the species, seems a more stable characteristic and often remains similar to that of the original community, despite the fact that the major dominant is replaced by *Nardus stricta*.

Snowbed Communities are more common in wetter southern valleys (Murudzhu, Klukhor, Alibek, Chuchkhur) near the Main Caucasian Range, although they also can be found in the dryer northern part of the Reserve in habitats with a deep winter snowpack. They occur in the alpine and subnival belts at elevations from 2700 to 3200 m a.s.l., predominantly on leeward northern and eastern slopes. These communities grow under conditions of significant accumulation of winter snow (5 m and even more), e.g. in local depressions, at valley foothills, and at bottoms of nival and glacial corries under long-lived snowfields. Accordingly, they have an ample melt water supply during the whole or the main part of the vegetation season (Onipchenko 2002). Snow melting ends in late July or the first half of August, thus snowbed communities have the shortest vegetation season among closed alpine communities (1.5–2.5 months; Onipchenko 1994b). The length of the growing period is the main factor limiting plant development in these habitats (Onipchenko 1989). Soils, developing under snow bed communities, are the most acidic and unsaturated and have the highest amount of available N (Grishina et al. 1993; Makarov et al. 1997), but a medium or high level of exchangeable phosphorus, a low level of exchangeable cations and a relatively low organic matter content compared to the other studied alpine communities (Volkov 1999).

These communities are composed mainly of low-growing (2–3 cm) short-rosette or creeping plants with taproot or creeping rootstocks, predominantly dicotyledons, forming a dense herbaceous cover without pronounced layers. Diagnostic species for the snowbed communities are *Carex pyrenaica, C. atrata, Luzula multiflora, Minuartia aizoides, Pedicularis nordmanniana, Potentilla crantzii*, many of which are often abundant and have high constancy values. *Ranunculus brachilobus* dominated snowbed communities are most commonly found in the southern part of the study area near the Main Caucasian Range (Murudzhu, Klukhor, Alibek, Chuchkhur valleys), where the precipitation and snow accumulation are especially abundant. These communities occur predominantly on leeward (mostly northern and eastern), slopes under long-lived snowfields. The communities are characterized by a relatively dense vascular plant cover (45–80%; mean 65%), and a poorly developed bryophyte layer (<1% to 30%; mean 7%). The role of lichens is negligible. Besides the major dominant, two forbs, *Corydalis conorhiza* and *Geranium gymnocaulon,* are the diagnostic species and common associates in *Ranunculus brachilobus* dominated snowbed communities (Onipchenko 2002).

Snowbed communities in the northern part of the Reserve occupy depressions and bottoms of nival and glacial circuses (corries) with a heavy winter snow accumulation (4 meters and more), and *Ranunculus brachilobus* does not occur in this association. In the absence of the main dominant, other forbs, e.g. *Minuartia* *aizoides*, *Sibbaldia procumbens*, *Taraxacum stevenii* (Fig. 9.9c) as well as tussocky *Nardus stricta* increase their abundance. The diagnostic species set includes *Desmatodon latifolius, Carex oreophila, Catabrosella variegata*, *Nardus stricta* and *Stereocaulon alpinum*. Also, *Gnaphalium supinum, Hyalopoa pontica*, *Sedum tenellum* and *Sibbaldia procumbens* are characteristic flowering plants. Among the bryophytes *Polytrichastrum alpinum, Polytrichum juniperinum* and *P. piliferum* are common. Terricolous lichen species occur sporadically and only *Stereocaulon alpinum* is a typical constituent, though its role in the community is not important. Coverages of herbs and mosses are somewhat denser than in the previous association, i.e. 25–95% (mean 68%) and 1–60% (mean 22%), respectively. Bare soil and the cover of boulders is low (Onipchenko et al. 2001; Onipchenko 2002).

The overall floristic richness of the *Sibbaldia*-dominated snowbeds is the lowest among the investigated closed alpine communities, i.e. 18 species per 25 m^2 (Onipchenko and Semenova 1995). Based on 10 relevés in each association, the species pool includes 36 species of vascular plants, 13 bryophytes and 6 lichens for *Sibbaldia*-dominated snowbeds; and 39 species of vascular plants, 15 bryophytes and 4 lichens in *Ranunculus*-dominated communities (Onipchenko 2002). The snowbed communities are the most unfavorable habitats for pine voles, mainly due to the very low protective quality offered by the short plant cover in summer. Accordingly, the numbers of voles inhabiting snowbeds is negligible (Fomin et al. 2004). Their burrowing activity is the least among the studied alpine plant communities. Rodents dig 60 ± 60 holes and produce 780 ± 210 soil disturbances per hectare during peak years (Fomin et al. 1989). Snowbed communities remain relatively stable under grazing. However, the abundance of *Sibbaldia procumbens* and the percentage bare soil cover increase on grazed sites compared with intact communities (Egorov, Onipchenko 2002).

Other vegetation types of the alpine belt, e.g., *Juniperus communis* scrub, alpine fens, *Kobresia* grasslands, open communities on unstable stony substrates, communities on large stone-stabilized mounds, communities on siliceous rocks, communities on north-facing cliffs, dwarf shrub heaths, and communities along cold streams and springs are also quite common in the Reserve, though they do not occupy large areas. They are described in details elsewhere (Onipchenko 2002; Pavlov 2004).

9.6.8 Subnival Belt

The alpine belt gives way to the subnival belt at elevations of 2900–3000 m a.s.l., where the permanent snowline runs (Tushinskii 1957). A continuous vegetation cover is absent and only scattered individual plants or small islands of poorly developed, sparse, pioneer communities on rocks, screes and talus slopes, interspersed with glaciers and snowfields, occur here. Plants, growing above the permanent snowline, have to be tolerant of the extremely harsh environmental conditions at high elevations, such as strong winds, low temperatures, a short vegetation season, poor soils and a high intensity. The spatial distribution of vegetation in the subnival belt is determined mainly by availability of shelters, e.g., niches and crevices in rocks and screes, which are suitable for plants establishment and survival, and only few species can grow here (Pavlov 2004). The last census revealed only 168 species of vascular plants growing above 3000 m a.s.l. The upper limit of vascular plant distribution in the Reserve is at approximately 3750 m a.s.l. A very small number of species, e.g., *Carum caucasicum, Draba rigida* (Fig. 9.9d)*, D. siliquosa, Hyalopoa pontica, Minuartia imbricata, Potentilla gelida*, *Primula amoena, Saxifraga exarata, S. sibirica, Senecio karjaginii,* were found at this elevation on the southern slope of Mt. Kyshkadzher (Egorov and Onipchenko 2003).

Pioneer Communities on Dry Screes and Fellfields commonly occur in the upper alpine and subnival belts at elevations of 2750–3540 m a.s.l. on loose substrate. Their herbaceous cover is very scarce (about 10%), and boulders of siliceous parent rocks (granites, gneises, shists) cover 50–95% of the area (Onipchenko 2002).

These communities are relatively poor floristically, but are peculiar in species composition, and they comprise many Caucasian endemics (Vorobyova 1977). The diagnostic species set of this association includes the dwarf crucifers (*Dentaria bipinnata, Draba scabra, D. siliquosa, Eunomia rotundifolia, Noccaea pumila*) and other low-growing forb species (*Alopecurus dasyanthus, Chaerophyllum humile, Corydalis alpestris, Delphinium caucasicum, Potentilla gelida*). Most of the species are perennial polycarpics[6] with special adaptations to grow on an unstable substrate, such as deep roots, creeping shoots and stolons. The species composition varies considerably. The role of bryophytes and terricolous lichens is low in both species number and cover (Onipchenko 2002).

Subnival Communities on Moist Screes and Rocks occur at elevations of 2700–3750 m a.s.l. on slopes of different steepnes (up to 80°) and orientation. High elevations and a significant accumulation of winter snow shorten the vegetation season. On the other hand, there is no moisture shortage in these habitats and plants can develop quickly during the snow-free period. The coverage of bare ground, rocks and boulders is substantial (50–99%; Onipchenko 2002). Some researchers (Vorobyova 1977; Kononov 1957) consider subnival communities on moist screes and rocks as an early successional stage of closed highland communities in habitats with a significant accumulation of winter snow.

These communities share many species with alpine snowbeds such as *Cerastium cerastoides, Gnaphalium supinum, Hyalopoa pontica, Kiaeria starkei, Polytrichastrum sexangulare, Polytrichum piliferum, Sedum tenellum, Sibbaldia procumbens* and *Taraxacum stevenii*. Species of cold, wet and open habitats have high constancy values here, e.g., *Draba scabra, Matricaria caucasica, Minuartia imbricata, Murbeckiella huetii, Saxifraga sibirica* and *Veronica telephiifolia* (Fig. 9.9.e).

[6] Polycarpic plants are those that flower and set seeds many times before dying.

A variant of this community, developing on steep (30–80°) talus slopes and screes with a predominantly northern orientation, is characterized by a sparse (<20%) herbaceous cover. The diagnostic species are adapted to temporary freezing: *Anemone speciosa, Festuca ovina, Lloydia serotina, Luzula spicata, Polytrichastrum alpinum* and *Primula amoena* have high constancy values here. Bryophytes play an important role in such habitats and their coverage is sometimes comparable to that of the flowering plants.

Another variant of this association, co-called subnival snowbed communities, occurs as small fragments on gentle and moderate (<45°) slopes. An extremely sparse vegetation cover (1–5%) and a substantial stone cover (up to 99%) are typical of these communities. The species composition indicates that the substrate is rather stable. *Potentilla gelida, Saxifraga moschata* and *Senecio karjaginii* form the diagnostic set. The role of bryophytes and terricolous lichens is negligible (Onipchenko 2002).

Subnival Communities on South-Facing Rocks occur in the upper alpine and subnival belts at elevations from 2750 to 3100 m a.s.l. on siliceous, predominantly south-facing outcrops. Though these communities develop on very steep (70–90°) slopes, significant humus accumulation in fissures allows many species to occupy these habitats. The species typical of these habitats grow under conditions of a high sunlight intensity and drought stress, and thus many species in these communities have xeromorphic features, namely long-lived hard leaves (*Saxifraga juniperifolia, S. kolenatiana*), abundant pubescence (*Eritrichium caucasicum, Potentilla divina*) or succulent leaves (*Sempervivum pumilum*). The typical rock plant *Potentilla divina* and several alpine species of windward snow-free habitats, e.g., *Anemone speciosa, Empetrum nigrum, Eritrichium caucasicum, Helictotrichon versicolor, Luzula spicata*, form the diagnostic set of the association. Cushion plants, e.g., *Arenaria lychnidea, Gypsophila tenuifolia* (Fig. 9.9f) and *Saxifraga juniperifolia* are well-represented here. The herbaceous cover is sparse (from 2 to 15%) (Onipchenko 2002).

9.7 Conservation

The Caucasus has been inhabited since ancient times, and the anthropogenic impact in this region has a long history. The earliest proven period of livestock grazing dates back to 4000–2000 cal. B.P., when pig raising became common in the lowlands (Semenov and Petelin 2004). The knowledge on early periods of human activity in the Caucasus is based on peat, dung and fossil analyses from a few sites in North Ossetia and Karachaevo-Cherkessiya (Savinetskyy 1992). Currently the Caucasus is characterized by a complex alternation of natural and human-modified landscapes, and modern trends in industrial, agricultural and cultural development make the Caucasus one of the most changed regions in our planet (Polivanova 1990). Several kinds of anthropogenic factors altered the highland ecosystems, mainly grazing, building of roads, and summer recreation and winter sport activities by tourists (Lukschanderl 1983). At the same time, the Caucasus is considered a hotspot with significant levels of endemism and a high biodiversity at both species and ecosystem levels (Myers et al. 2000; Krever et al. 2001). Thus, in the global biodiversity conservation context the Caucasus is prioritized as one of the most vulnerable regions with a high irreplaceability (Brooks et al. 2010).

Traditionally, the following administrative units belong to the Caucasus: the Krasnodarskiy and Stavropolskyy regions, the republics Kabardino-Balkaria, Karachaevo-Cherkessia, North Ossetia, Chechnja, Ingushetia, and Dagestan (within modern Russia) as well as the countries Georgia, Azerbaijan and Armenia. In the era of the Soviet Union 37 nature reserves, i.e. protected areas with restricted access («zapovednik» in Russian), were created in the Caucasus. A nature reserve in the former Soviet Union and in modern Russia is a protected area, where ecosystems are preserved in their original, intact condition. As a rule, reserves are managed for the conservation of nature phenomena, such as endangered and threatened species, rare ecosystems and unique geological features, and provide special opportunities for scientists for their study and research. The area of nature reserves is withdrawn from any form of land use, and any destructive human activity, such as hunting, fishing, mining, wood harvesting, mowing, grazing, etc., is prohibited. In contrast to national parks, reserves generally are also closed to tourism, although some of them allow a limited access to visitors. To visit a reserve, a permit from the Ministry of Natural Resources of the Russian Federation or the direct management of a reserve is required.

Established methods of land use were the main challenge in organizing reserves in the Caucasus. Ubiquitously spread traditional agriculture used nearly all available herbaceous communities in the highlands and steppes in the lowland plains for stock raising. Most of the Caucasian reserves have boundaries sharply ending at the lower edge of the forest belt and are deprived of buffer zones. Thus, reserves are directly adjacent to farmer lands (Fig. 9.10), which leads to regular violations of the protection regime. E.g., seasonal cattle drive, moving large herds of livestock through the territories of nature reserves, remain the norm (Polivanova 1990).

In addition, conservation strategies in the Caucasus have to take into account the high population density and long history of traditional extensive land use, and should not veer away from the three fundamental objectives required for the conservation of biodiversity: (i) to ensure the representation of the full range of native ecosystem diversity; (ii) to maintain viable populations of plants and animals with adequate space, suitable habitats and available resources; and (iii) to sustain ecological processes, such as natural disturbance regimes, nutrient cycling, and predation. As for the Karachaevo-Cherkessian Republic, and the Teberda Reserve in particular, local cultural and economic aspects also have to be considered and taken into account in implementing conservation strategies. There are six main conservation priorities in Karachaevo-Cherkessia:

- Institutional strengthening and capacity building;
- Improving the network of protected areas;

Fig. 9.10 Overgrazed *Nardus stricta* dominated pasture in the Shubajdaj-chat (Mukhu tributary) valley, directly adjacent to the Reserve (2550 m a.s.l.)

- Conserving endangered species and species of special concern;
- Conserving priority biomes, i.e. forests and alpine ecosystems;
- Promoting sustainable resource use;
- Promoting public awareness and environmental education (Petelin 2004).

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