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

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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

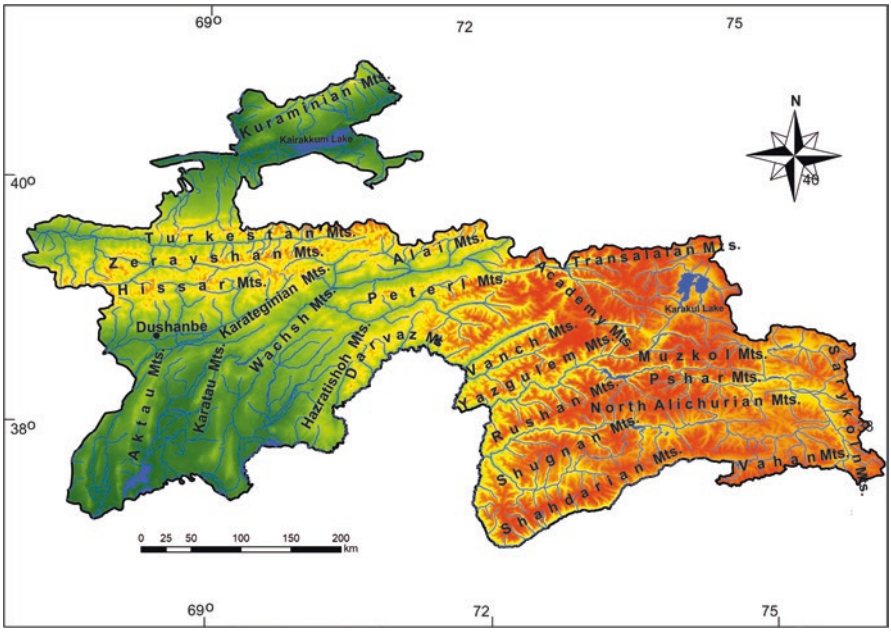

Fig. 1.1 Topographic map of the Pamir-Alai within Tajikistan showing the main ranges, cities and rivers

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

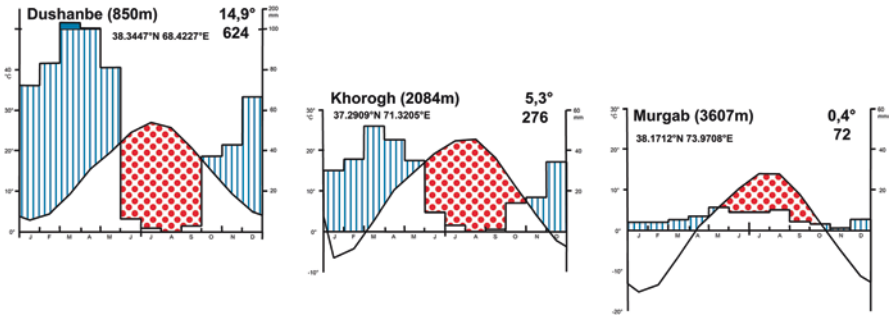

Fig. 1.2 Climatograms of the main bioclimatic provinces in Tajikistan: south-western Pamir-Alai (Dushanbe), western Pamir (Khorogh) and Eastern Pamir (Murghab)

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

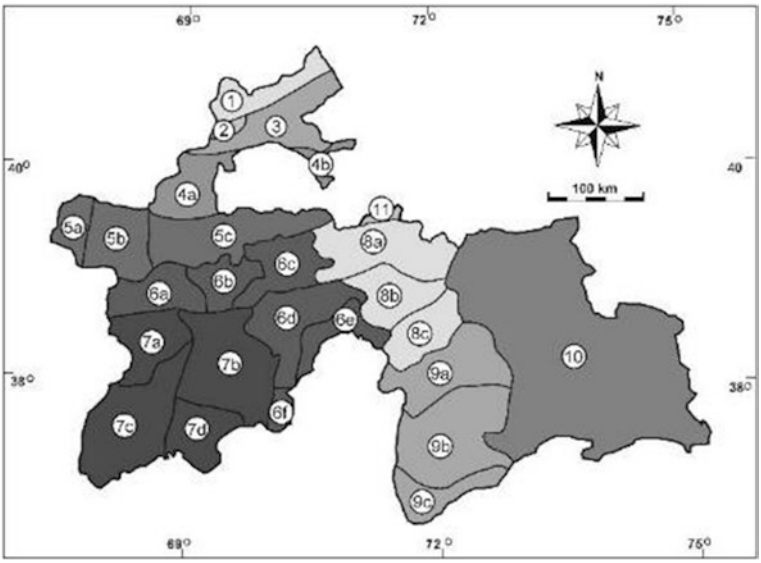

Fig. 1.3 Geobotanical division of Tajikistan: *1* – Kuraminian; *2* – Mogoltausian; *3* – Prisyrdarian; *4a* – Turkestanian A, *4b* – Turkestanian B; *5a* – Zeravshanian A, *5b* – Zeravshanian B, *5c* – Zeravshanian C; *6a* – Hissar-Darvasian A, *6b* – Hissar-Darvasian B, *6c* – Hissar-Darvasian C, *6d* – 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

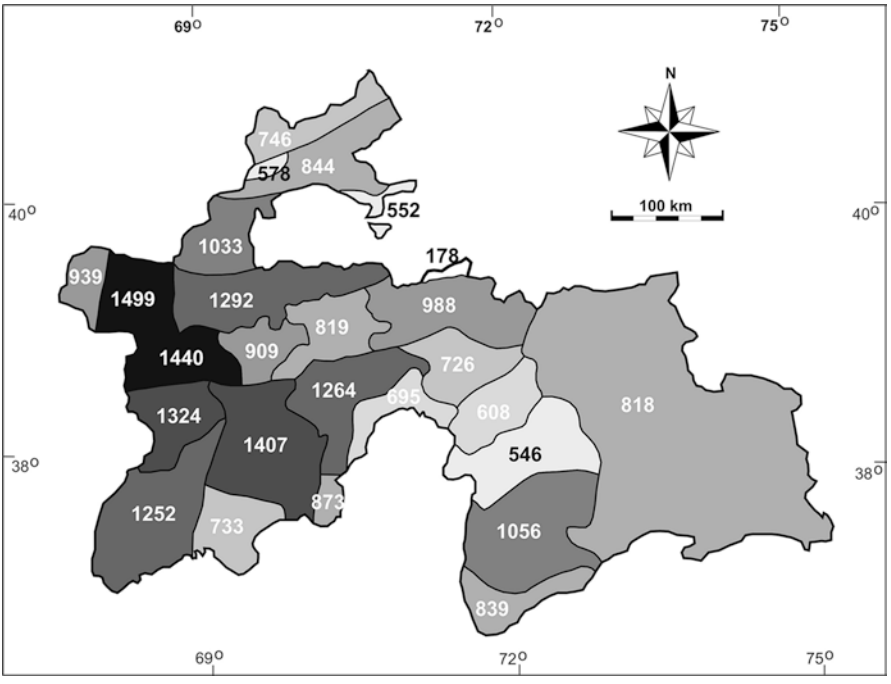

Fig. 1.4 Floristic richness of the phytogeographic subregions of Tajikistan – number of vascular plant species per subregion

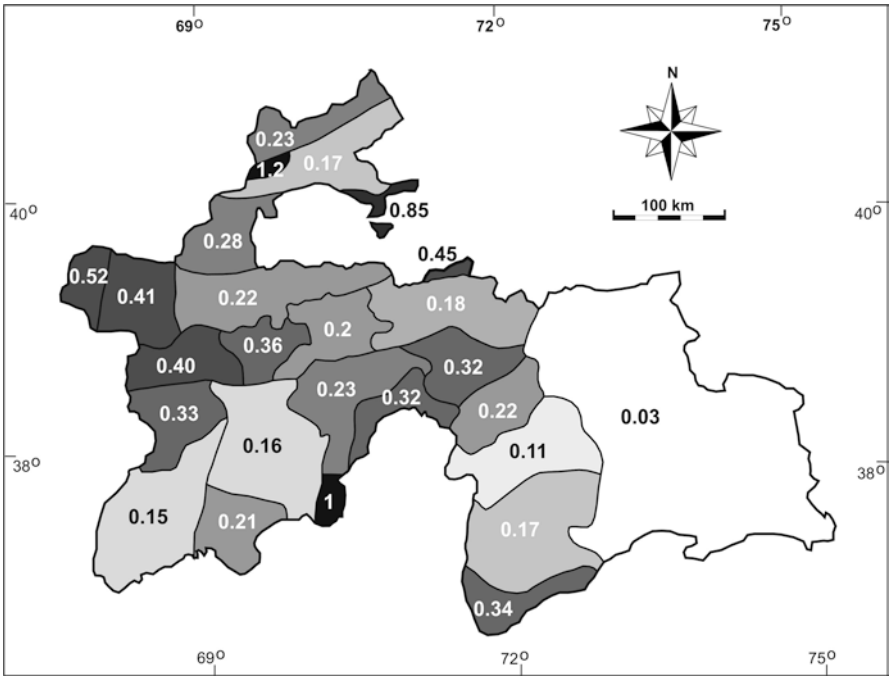

Fig. 1.5 Relative floristic richness of the phytogeographic subregions of Tajikistan

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.

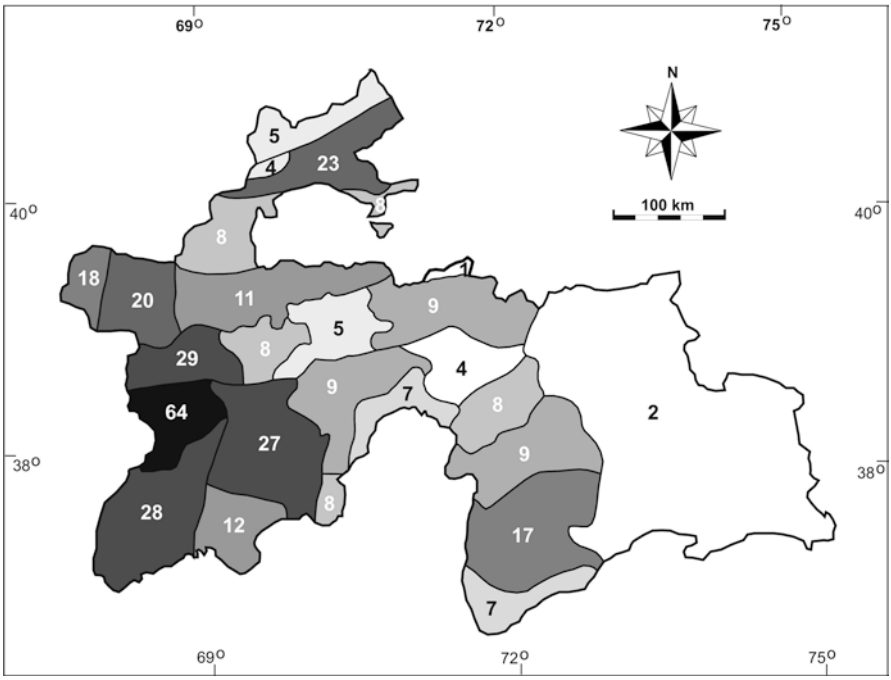

Fig. 1.6 Frequency of alien species established in Tajikistan across the geobotanical subregions

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*.

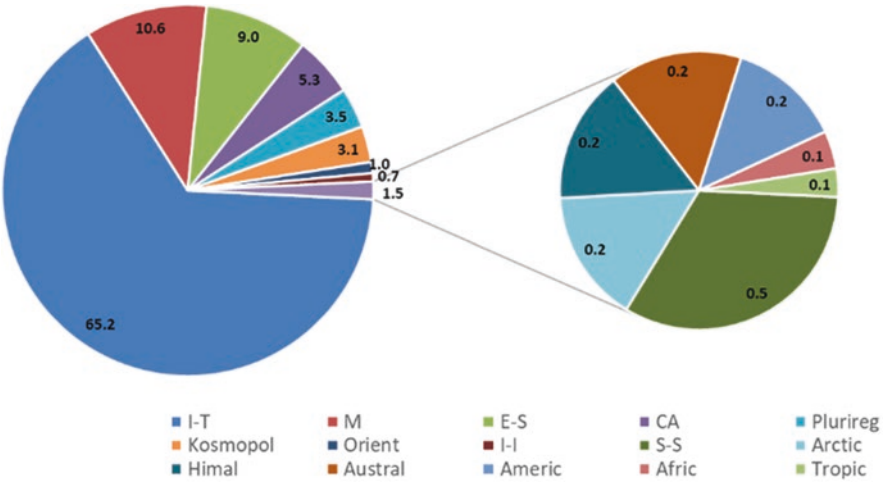

Fig. 1.7 Phytogeographical composition of the flora of Tajikistan. Explanations: *I-T* Irano-Turanian, *M* Mediterranean, *E-S* Euro-Siberian, *CA* Central Asian, *Plurireg* pluriregional, *Kosmopol* cosmopolitan, *Orient* Oriental, *I-I* Indo-Indochinese, *S-S* Saharo-Sindian, *Himal* Himalayan, *Austral*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

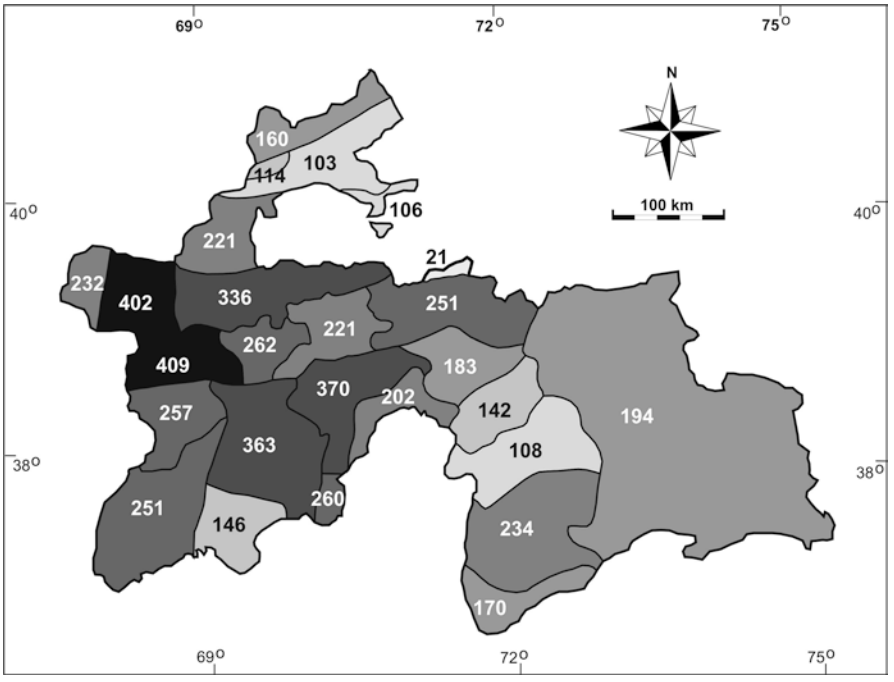

Fig. 1.8 Distribution of endemic vascular taxa in geobotanical regions

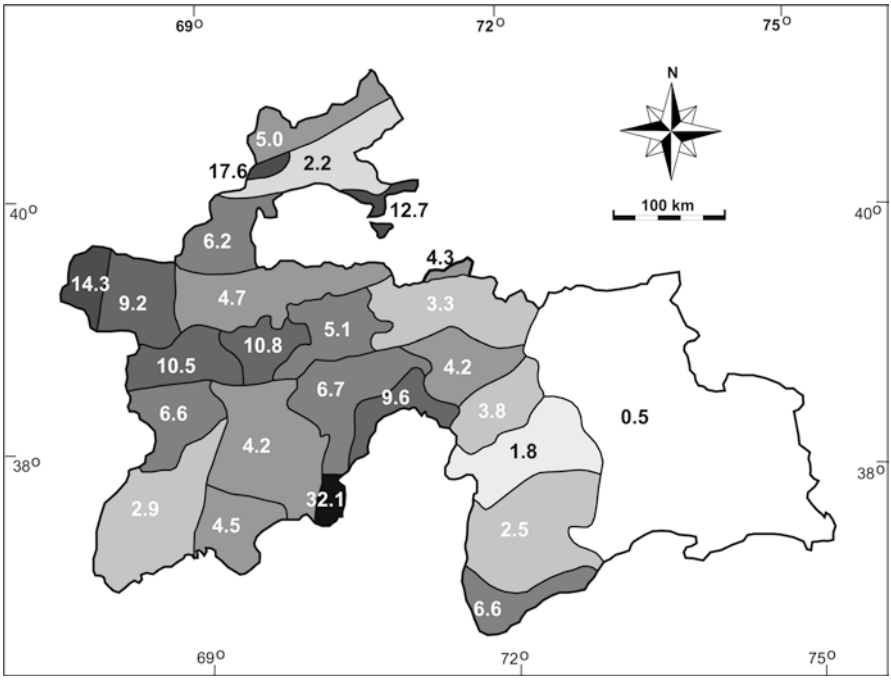

Fig. 1.9 Endemic species per 100 km^2 in each of the geobotanical regions of Tajikistan

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).

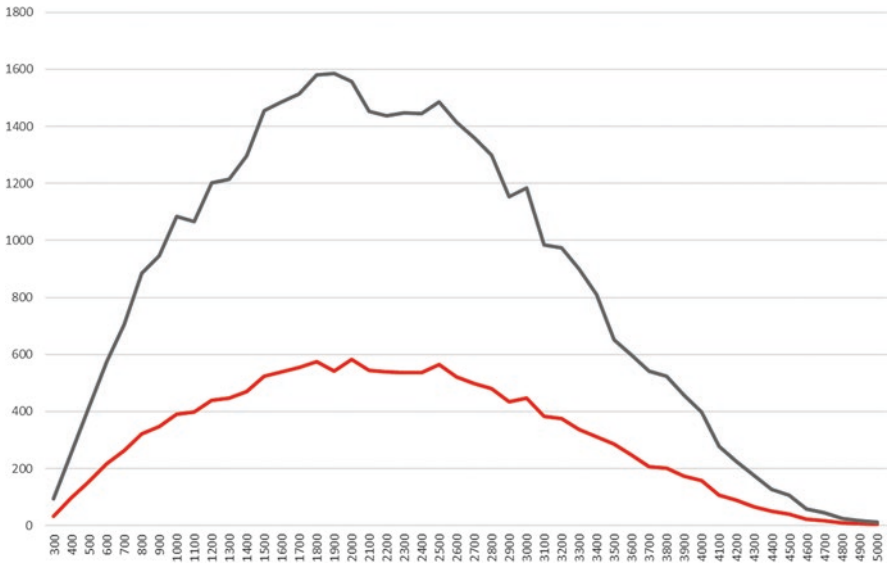

Fig. 1.10 Altitudinal distribution of endemism as the number of endemics occurring in belts of 100 m altitude (red line) shown against the background of the total plant richness (black line)

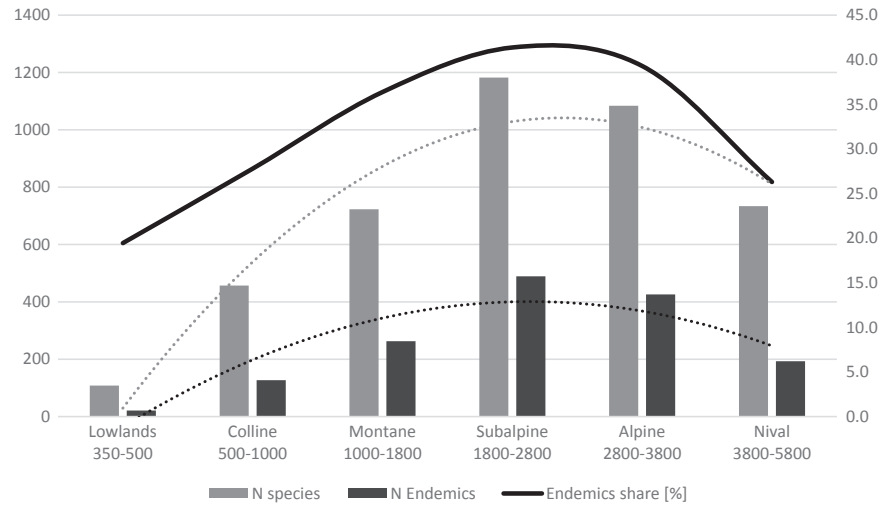

Fig. 1.11 The endemism in the Pamir-Alai in relation to altitudinal zonation and total flora richness

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 underinvestigated 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

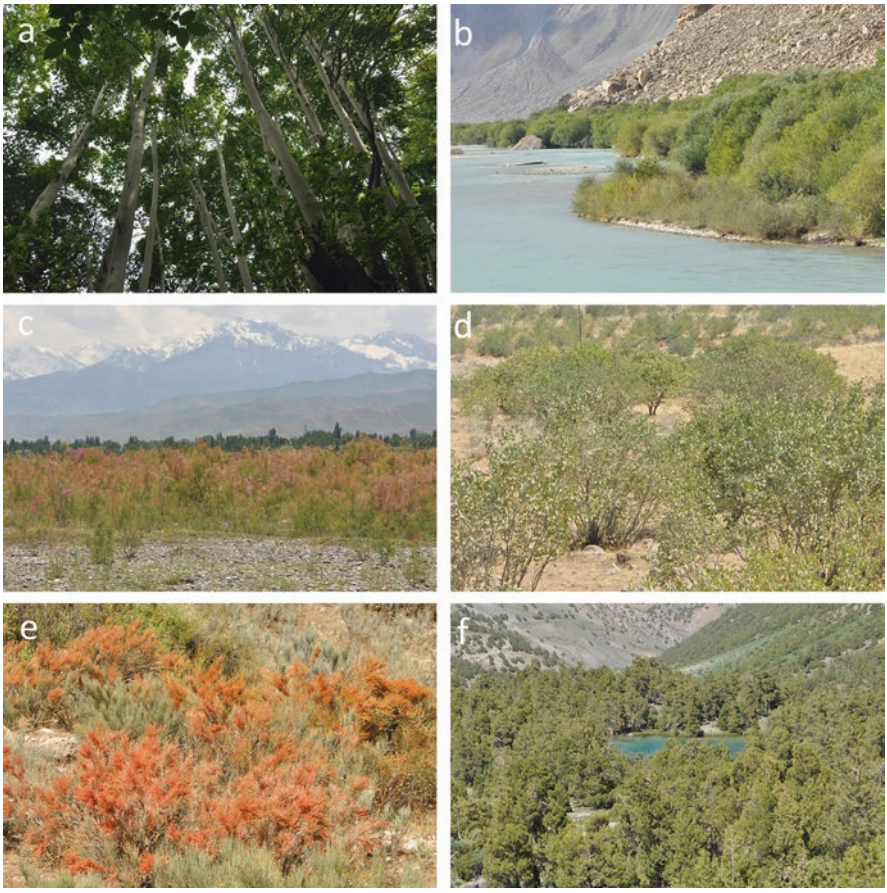

Fig. 1.12 (**a**) Stand of *Platanus orientalis* in the Panj River Valley near Qualaykhum, 2100 m a.s.l.; (**b**) *Populetum pamiricae* along the Ghunt River north of Khorogh, 3200 m a.s.l.; (**c**) Community with *Tamarix ramosissima* in the Zeravshan Valley near Sudzhina, 800 m a.s.l.; (**d**) Thermophilous 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

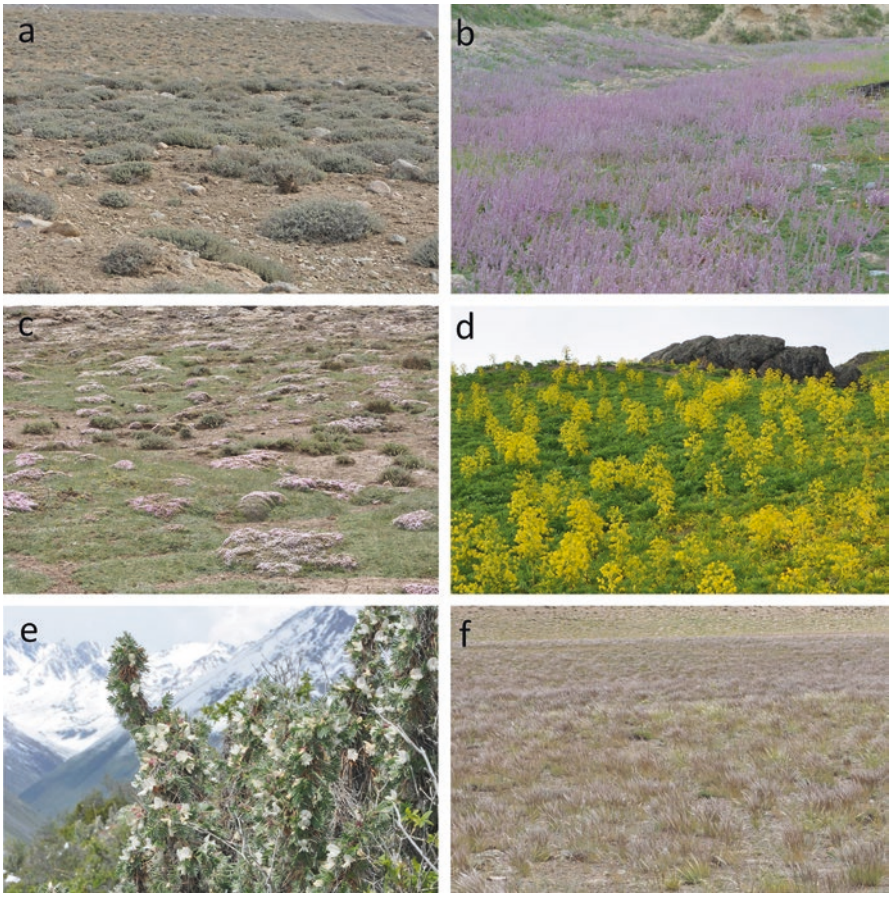

Fig. 1.13 (**a**) High altitude semi-deserts dominated by *Krasheninnikovia ceratoides* and *Oxytropis chiliophylla* in Eastern Pamir near Murghab, 4300 m a.s.l.; (**b**) Lowland salt marsh with dominance of *Psylliostachys leptostachya* near Vase in SW Tajikistan, 500 m a.s.l.; (**c**) Cushion community 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.

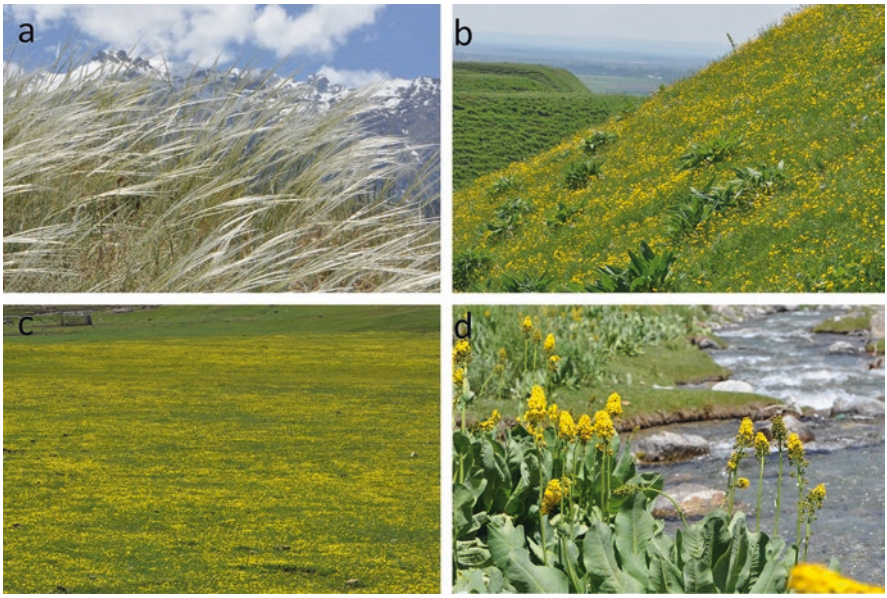

Fig. 1.14 (**a**) *Stipetum lipskyi* on northern slopes of the Zeravshan Mts. near Urmetan, 1750 m a.s.l.; (**b**) Meadow with *Koelpinia macrantha* (yellow) and *Arctium leiospermum* near Panj, 500 m a.s.l.; (**c**) Pastures with *Ranunculus alaicus* in the alpine belt of Hissar Mts., 3500 m a.s.l.; (**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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