Folia Geobot
DOI 10.1007/s12224-012-9147-8

Vegetation Patterns of the Irano-Turanian Steppe along a 3,000 m Altitudinal Gradient in the Alborz Mountains of Northern Iran

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Abstract The Irano-Turanian floristic region is a major center of endemism in the Holarctic of Eurasia. The Alborz Mountains of northern Iran are a complex and heterogeneous environmental system with rich water resources and great habitat diversity. We have investigated steppe plant communities along an altitudinal gradient ranging from approximately 1,000 m a.s.l. in the semi-desert steppes near Tehran to a height of 3,966 m a.s.l. at the summit of Mount Tochal. Our two-way indicator species analysis of 1,069 vegetation samples resulted in classification of five major vegetation zones: (1) a semi-desert *Artemisia* steppe near Tehran, (2) a *Stipa* grassland in the alluvial undulating hills north and west of Tehran, (3) a submontane and steppe zone, (4) a subalpine cushion formation zone and (5) an alpine meadow and subnival zone of Mount Tochal. Annuals and ephemerals in the semi-desert vegetation decline as altitude increases and almost disappear in the alpine zone. Past human impacts of ancient Persian civilization and a traditional pastoral economy have affected the physiognomy of plant communities; thorny dwarf shrubs now dominate the treeless vegetation of the region. Lower competition for space, different phenology and the presence of edaphic and hydrological layers associated with anthropogenic impacts are major reasons for entanglement of different plant communities in the arid- and semi-arid steppe. The phytogeography of the region changes from omni-

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Published online: 05 April 2013

Irano-Turanian and Saharo-Sindian transgressive species at lower altitudes to a more limited range of western Irano-Turanian species and local endemics at higher altitudes.

Keywords Alborz Mountains · Alpine meadow · Altitudinal gradient · Biodiversity · Cushion-Form vegetation · Grazing · Semi-desert steppe · TWINSPAN

Plant nomenclature Rechinger (1963–2010)

Introduction

Iran is a large country (1.6 million km^2) with a diverse range of plant species resulting from a high degree of variability in climate and topography and a complex tectonic history. The Alborz and Zagros mountain ranges in the northern and western regions of the country are part of an extensive tectonic uplift system in which the greatest diversity of flora and plant communities occurs. The lowest region in the country lies 28 meters below sea level along the shore of the Caspian Sea with the terrain rising to a height of 5,671 m at the Demavand Volcano in the Alborz Mountains. This is the highest peak in Eurasia west of the Himalayas. Phytogeographically, large parts of Iran are characterized by inclusion of Irano-Turanian floristic elements. The only exceptions are the northern forests south of the Caspian Sea harboring Euro-Siberian species, and the pseudo-savanna vegetation of southern Iran where many Saharo-Sindian elements occur (Zohary 1973; Hedge and Wendelbo 1978; Léonard 1981–1992; Akhani 2007; Akhani et al. 2010).

Despite many efforts during the last half-century to document and study the flora of Iran (Rechinger 1963–2010), our understanding of many vegetational zones and plant communities remains incomplete. Two major factors account for this deficiency in our knowledge: First, very few vegetation scientists have the expertise necessary to identify the diverse range of flora in Iran, particularly the species-rich communities of the steppe and mountain regions. Secondly, use of the widely accepted Braun-Blanquet methodology (Braun-Blanquet 1964) for describing and classifying types of vegetation on the Iranian steppe is very time consuming. For example, the two most important works on the subject (Klein 1994; Léonard 1981–1992) were published nearly twenty years after field work was completed with both authors employing the Zürich-Montpellier classification school of plant sociology and working almost exclusively on their respective projects.

The Alborz Mountains are geomorphologically and climatologically the most heterogeneous mountain system in southwestern Asia. The northern slopes face towards humid air masses of the southern Caspian Sea governing the forest vegetation of predominantly Euro-Siberian phytochoria of the Hyrcanian province (Akhani et al. 2010). However, above the treeline and on the southern slopes the semi-arid Irano-Turanian phytochorion is dominated by many endemic species (Frey and Probst 1974; Klein 1991; Akhani 1998; Noroozi et al. 2008, 2011). Floristic and vegetation studies in the Alborz range date to Bunge (1860) followed by Buhse and Boissier (1860), Buhse (1861), Kotschy (1861), Buhse and Winkler (1899), Gilli (1939, 1941), Gilli et al. (1941), Akhani and Ziegler (2002) and Kamrani et al. (2010). The alpine zone of Alborz has been investigated phytosociologically by Klein (Klein 1982a,b, 1984, 1987, 1988, 1994; Klein and Lacoste 1989, 1994).

In 2000, this paper's lead author (HA) began documenting the flora and vegetation types of several regions in and around Tehran, including the Tochal (written alternatively Tuchal) massif north of the city, the remnant vegetation in the center of Tehran itself in the Pardisan Nature Park and the *Artemisia* steppes located to the south in the Kuh-e Arad range. This work was undertaken in part through supervision of a series of masters theses at the University of Tehran. In this paper a general overview of the vegetation of these regions is presented. Our research goals were: *i*) to document and describe the vegetation units along a transect from the semi-desert vegetation south of Tehran to the alpine zone of the Tochal massif; *ii*) to collect floristic, vegetation and relevant GPS data of the area of intensive human activities and urbanization; and *iii*) to present the distribution of plant communities and major community groups along this 3,000 m transect. Species diversity, life-form patterns and phytosociology of the high alpine zone are not included in this study, but are the subjects of two related works (Noroozi et al. 2010; Mahdavi et al. 2013).

Material and Methods

Study Area

The study area is situated in southern slopes of central Alborz in Tehran province (35°20–55′ N, 51°15–26′ E) with elevations ranging from 1,000 m a.s.l. south of Tehran to the peak of Mount Tochal (3,966 m a.s.l.) in the central Alborz range (Fig. 1a–b).

Geomorphologically the study area can be classified into three main regions:

1) The Kuh-e Arad or Arad Range (35°20–30′ N, 51°15–20′ E) is located 20 km south of Tehran, near the town of Hassan-abad (1,000–1,428 m a.s.l.). Its gentle slopes are composed of Eocene volcanic and volcaniclastic rocks with inclusions of andesitic lava, tuff and zeolite-rich beds (Bazargani-Guilani and Rabbani 2004). Sedimentary formations composed of gypsiferous marls and detritic sandstones are also in small outcrops at the mountain's base. These older formations are replaced by Quaternary alluvium in the nearby flat plain.
2) Pardisan Nature Park or Pardisan Eco-Park (35°44–45′ N, 51°20–24′ E) is located in northwestern Tehran (1,300–1,450 m a.s.l.) with a surface area of approximately 300 hectares. The geomorphology of the park and surrounding neighborhoods is comprised of several Quaternary alluvial fans dissected by valleys and gullies of varying depths oriented on a north-south axis. Geologically, the park is located on top of C formation conglomerates composed mainly of clastic sediments of Eocene volcanic and volcaniclastic rock (Berberian et al. 1985). These fans are assumed to date to the last glacial periods when the fan formation process would have been more active than today (Beaumont 1972). The major water resource is Farahzad River located at the westernmost border of the park where several springs emerge from aquifers along the valley flanks and

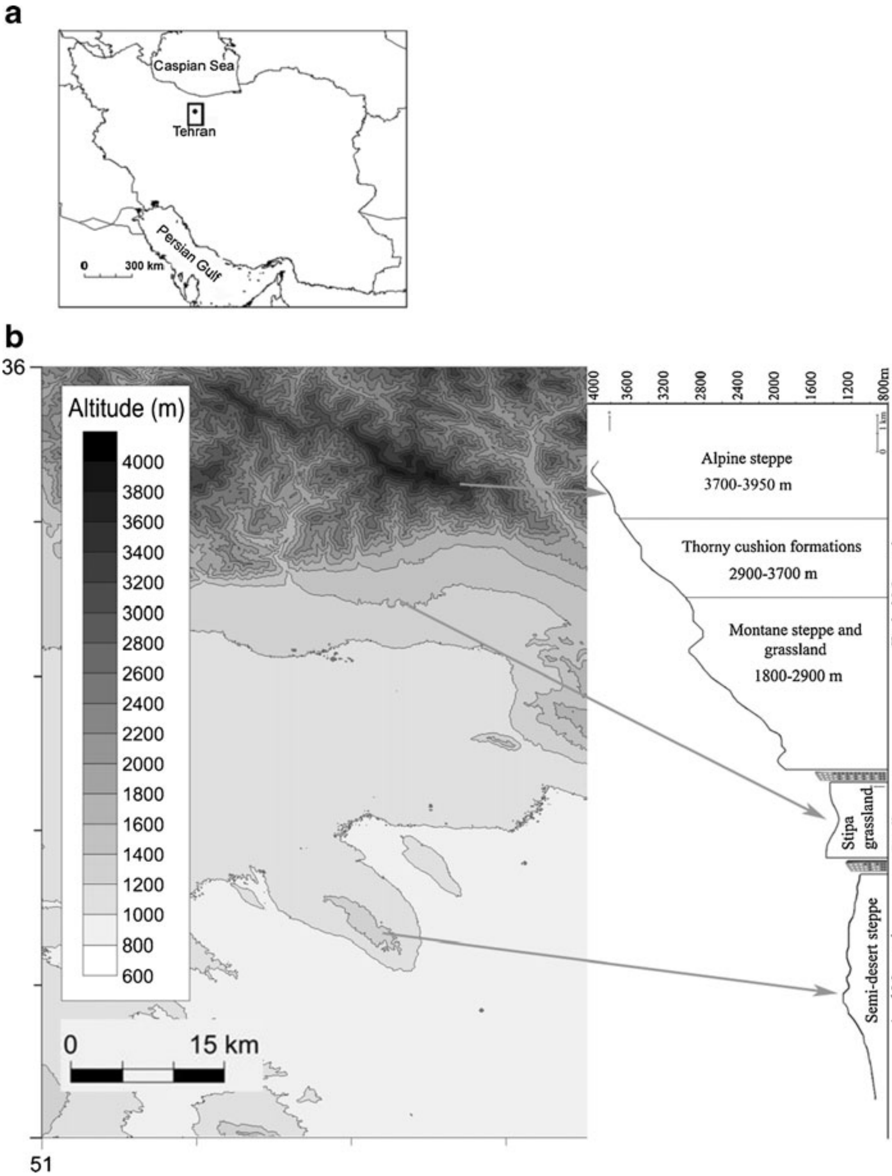

Fig. 1 **a** Location of the investigation area in Iran. **b** Topographic map of the study area showing main vegetation zones along altitudinal range

Qanat system along the Farahzad and other valley floors. Although there had been a plan to construct an environmental park in this area before the Islamic Revolution (McHarg 1975), it was not carried out and instead many parts of the Park were planted with exotic trees. Soon after the field studies of this paper – many construction activities changed the physiognomy of the park and the natural landscapes (particularly the Farahzad valley) have been completely destroyed.

3) Mount Tochal (35°49–55′ N, 51°22–26′ E) located north of Tehran reaches 3,966 m a.s.l. at its summit. This steeply sloped mountain is dissected in many places by deep valleys and rock cliffs. The average slope is 25–30° but can be as steep as 90° in many of its vertical rock formation. The northern slopes display a range of eroded features and deposits indicating that thick layers of ice covered Mount Tochal during the last glacial period. Geologically, the mountains north of Tehran consist of a complex of Palaeozoic, Mesozoic, and Tertiary formations. Mount Tochal is composed predominately of Eocene tuffs, andesites, pyroclastics and basalts (Emami et al. 1993). As a consequence of complex topography, and the merging of many rocky outcrops with natural and human-made erosional deposits, soils are extremely heterogeneous – from fine silts to stony gravels. These soils are fed from melting snow and many springs that flow through steep, deep valleys.

Climate

The climate of Tehran and surrounding regions is recorded in several stations (Fig. 2a–c). It ranges from a Mediterranean desert continental climate (Varamin and Mamazan) in the southernmost part of the region to a Mediterranean xeric continental climate in the central part of Tehran (Mehrabad and Geophysic) to a Mediterranean pluviseasonal continental climate in Tajrish on the northern edge of the city (Djamali et al. 2011). Although there is no station at higher altitudes on Mount Tochal, the Abali station located 50 km to the east at an altitude of 2,465 m a.s.l. also indicates a Mediterranean pluviseasonal continental climate. The very low precipitation in the south (145 mm at elevation of 1,021 m a.s.l) gradually increases to average annual of 233 mm at the elevation of 1,190 m a.s.l. and rapidly increases to 423 mm at an elevation

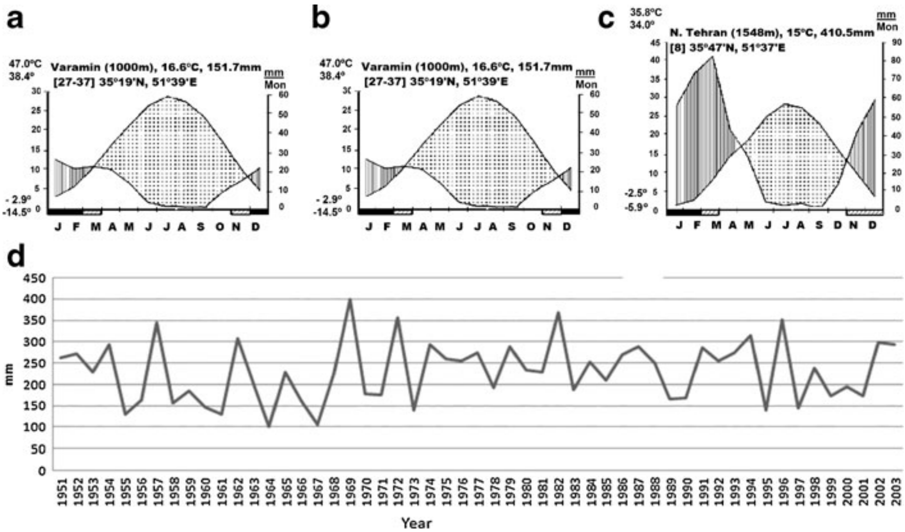

Fig. 2 Climatic diagrams of three stations: **a** Varamin, **b** Tehran (Mehrabad), and **c** N. Tehran. **d** Rainfall fluctuation over 52 years recorded at Tehran climatic station. Temperature values in y-axis from bottom to top show: absolute recorded minimum temperature, average minimum temperature of the coldest month, average maximum temperature of the warmest month and absolute maximum recorded temperature. Climatic data courtesy of Iranian meteorological stations

of 1,548 m a.s.l. (Fig. 2a–c). Precipitation mainly occurs in late autumn, winter and early spring. Much snow falls during the winter, and persists in the alpine zone until mid-summer. Summers are arid, hot and sunny with intensive radiation. Dry season (Precipitation<2Temperature) lasts at least five months (Fig. 2a–c). The mean annual temperature is between 15°C to 17°C but with a great range of variation in seasonal temperatures. Continentality index (Ic) is a good approximation for these variations and is calculated as the difference between mean temperatures of the warmest month (Tmax) and coldest month (Tmin). In Tehran meteorological stations, the Ic ranges from 26.6 to 27.3. The inter-annual precipitation variation in the region is also very high. Based on climatic data recorded at the Tehran station since 1952, precipitation varies from a minimum of 100 mm to a maximum of 400 mm, fluctuating from an average of 230 mm by a very high standard deviation of 71.9 (Fig. 2d).

Data Collection

Vegetation sampling was carried out during the springs and summers of 2000–2006. Following Braun-Blanquet's method of phytosociological sampling (Braun-Blanquet 1964), 1,069 relevés were recorded along altitudinal gradients from lower steppes at 1,000 m a.s.l. to the peak of Mount Tochal at 3,966 m a.s.l. Plots were recorded in relatively homogeneous units covering the whole altitudinal gradient. A surface area of 25 m^2 was applied to 80 % of relevés. The size of the remaining relevés varies from 4 to 100 m^2 depending on the physiognomy and habitat of the stand. The 25-m^2 surface area was obtained based on species-area curve (Cain 1938) and tested in many parts of Iran. All vascular plants, environmental and quantitative data (latitude, longitude, altitude, aspect, inclination, bedrock, total cover, coverage-abundance classes) and anthropogenic activities were recorded in each relevé before vascular plants were collected and subsequently identified in the laboratory. Voucher specimens and related original relevés are preserved in the Halophytes and C_4 Plants Research Laboratory at the School of Biology at the University of Tehran (Hb. Akhani). Nomenclature follows Flora Iranica (Rechinger 1963–2010) that in some cases has been updated based on information from more recent taxonomic literature.

Data Analysis

All data collected in the field was input into a local TURBOVEG database (Hennekens and Schaminée 2001) and analyzed using multivariate analysis. Two-way indicator species analysis (TWINSPAN) was used to separate major groups and species characteristics (Hill 1979) using JUICE software, ver. 7.0 (Tichý 2002). The program's default settings were employed except for minimum size of group that was set to 200 to clarify the main vegetation groupings. The cut-level was set on three and the values of cut-level were 0, 2, and 5. This resulted in six groups in which two subgroups of the alpine area were merged into one. The synoptic table is provided showing the categorical frequencies and fidelity values calculated by JUICE, ver. 7.0. In this version only the positive values multiplied by 100 are calculated. Distinction of plant communities within each community group is based mainly on cluster analysis by applying Euclidean distance and Ward's linkage method (data not shown) using PC-ORD (McCune and Mefford 1999). The resulting phytosociological tables have been then manually edited considering field data. A total of 1,069 relevés were analyzed and hygrophilous plant communities were excluded from this study.

Classification and Characterization of Communities

Although our work uses Braun-Blanquet's criteria for description and characterization of plant communities, we have not applied its formal nomenclature in this paper due to the absence of a phytosociological system in our study area and the high degree of complexity in anthropogenic influenced vegetation types of the montane steppes. Plant communities of the high alpine vegetation zones have been previously described in a separate paper using phytosociological nomenclature (Noroozi et al. 2010).

The lower vegetation units 'here communities' are equivalent with formal name 'association' and 'sub association'. Wherever possible, we have employed a two-name species approach in naming plant communities: the first species is most abundant characteristic species followed by a second species with a pronounced role in the coverage and physiognomy of the community. One name has been used for those communities where the dominant and characteristic species are the same. This approach conforms to the formal naming of plant communities following ICPN conventions (Weber et al. 2000).

Results

The synoptic table of vegetation (Table 1 in Appendix) presents five major groups and the most important diagnostic species resulting from our TWINSPAN analysis. Each community group is further divided to show most important diagnostic species and altitude range. The frequency of categories and related fidelity value is shown for each species based on analysis of the whole dataset. Figures 3, 4 and 5 show selected photographs of plant communities and landscapes along the altitudinal transect within the study area. A brief description for each major group is presented herewith:

A. Semi-desert steppe: *Artemisia sieberi* community group in Kuh-e Arad and Hasan abad flats (Table 1, A.1–10; Fig. 3a,b; 1,000–1,400 m a.s.l.)

The southernmost end of the transect in the Kuh-e Arad mountains and surrounding alluvial plain is dominated by semi-desert *Artemisia* steppe forms – a vegetation type that also characterizes large areas of semi-desert steppes of central Iran that are dominated by *Artemisia sieberi* on flat plains and undulating slopes. In the study area, ten different plant communities were observed (Table 1). Uniform communities of *Artemisia sieberi* are generally found in flat plain with alluvial soil, mostly associated with many ephemerals if there is sufficient rainfall (Table 1, A.1; Fig. 3a). *Amygdalus eburnea-Artemisia sieberi* (Table 1, A.2) occurs in rocky outcrops close to this *Artemisia* community. Towards the undulating slopes, rocky outcrops and valleys *Artemisia sieberi* associates with several other perennial species. The sodium content of andesitic bedrock apparently plays a major role in developing semi-halophytic communities, such as *Caroxylon orientale-Artemisia sieberi* and *Salsola kerneri-Artemisia sieberi* in stony and rocky areas (Table 1, A.3, A.4; Fig. 3b,). Thorn-cushion *Acantholimon* cf. *hohenackeri* forms a very rich community type characterized by the occurrence of the local endemic species *Kalakia marginata*

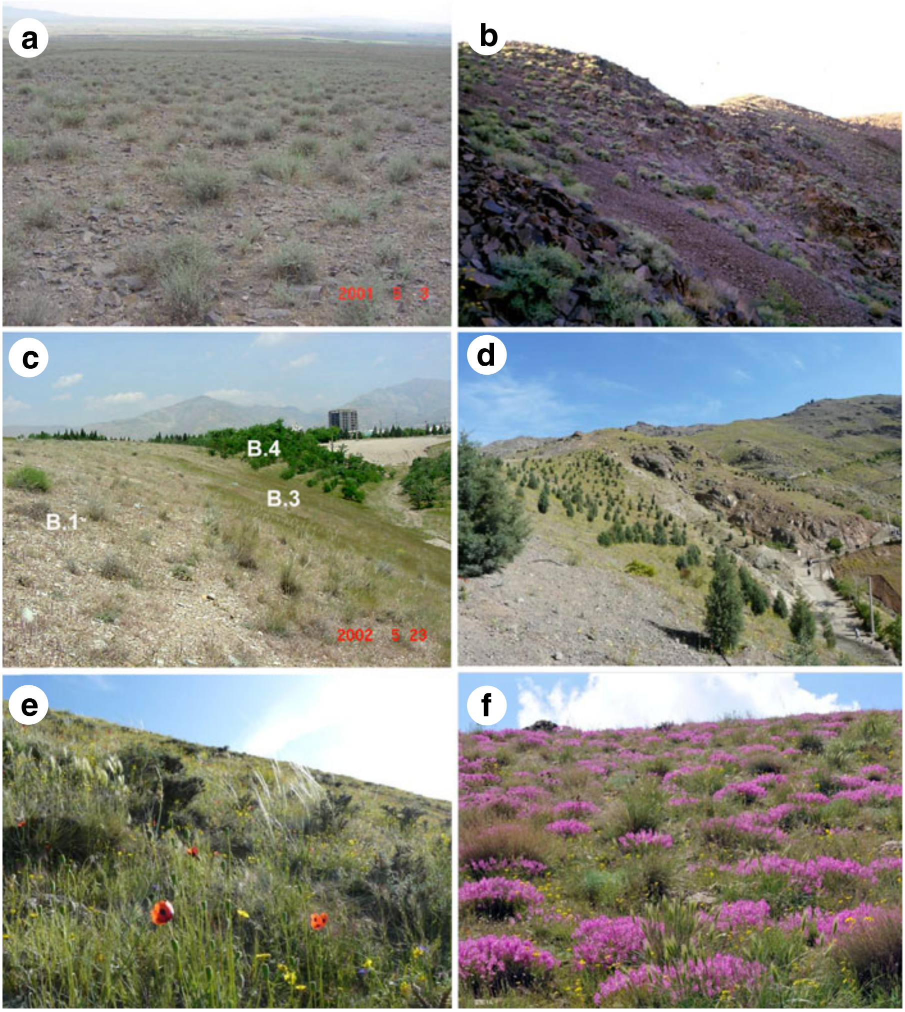

Fig. 3 Selected photographs from plant communities. Number after the name of each community (comm.) refers to respective number in Table 1. **a** *Artemisia sieberi* comm., Hassanabad (A.1); **b** *Salsola kerneri-Artemisia sieberi* comm. Arad mountain (A.4); **c** *Polygonum paronychioides-Stipa hohenackeriana* comm. (B.1) in foreground and *Medicago-monspeliaca-Aegilops columnaris* comm. in center (B.3) and *Cupressus arizonica-Ribinia pseudoacacia* in background (B.4), Pardisan Eco-Park; **d** *Cupressus arizonica* cultivated zone originally *Astragalus macropelmatus-Onosma microcarpum* comm. (BCa.4)., **e** *Astragalus mesoleios-Psathyrostachys fragilis* comm. in Tochal (Ca.1); and **f** *Aethionema gradiflorum-Stipa arabica* comm. (Ca.2)

in scree soils of rocky outcrops (Table 1, A.5). *Ephedra intermedia* occurs either as small patches in the *Artemisia* community or as a community at the top of undulating hills (Table 1, A.6). Artificial plantations of non-native *Atriplex canescens* caused formation of an anthropogenic community (Table 1, A.7) and colonization by many ruderals and annual species benefiting from artificial irrigation. Shrubby species of *Pteropyrum aucheri* (Table 1, A.8) develop in shallow dry seasonal water runnels and gullies in the study area and in similar habitats in many parts of central and southern Iran.

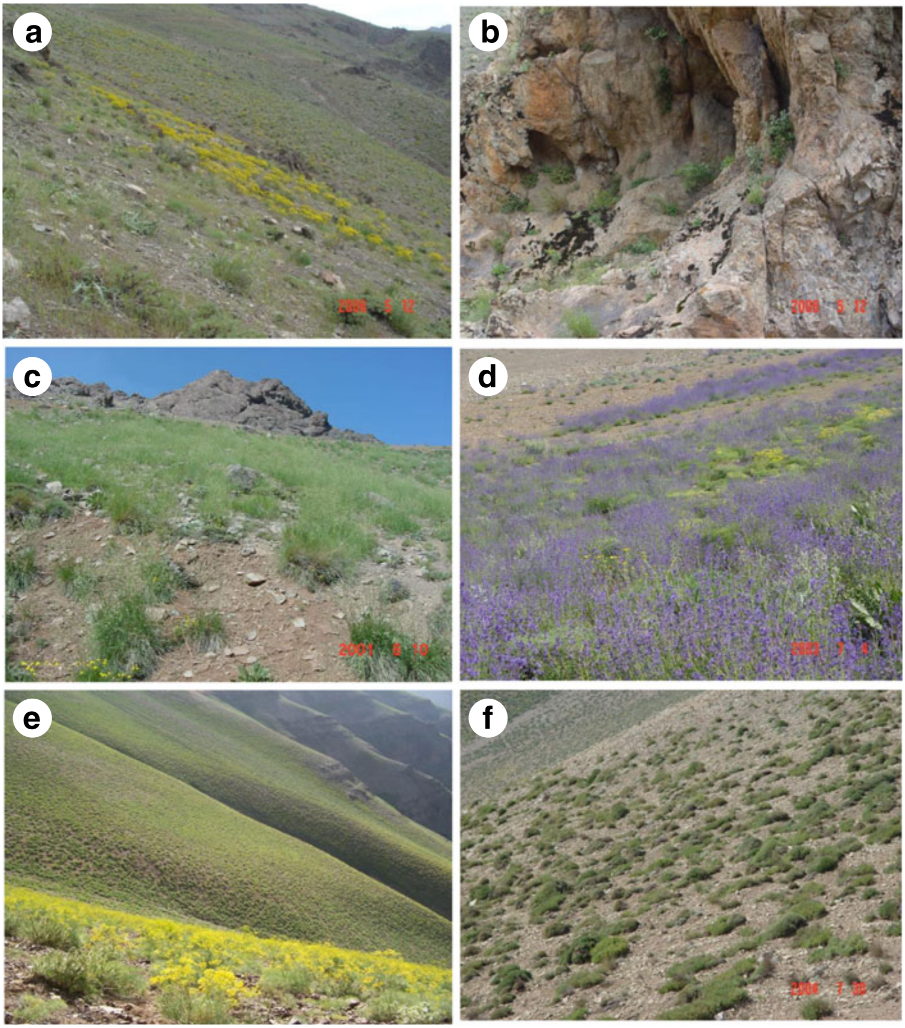

Fig. 4 Selected photographs from plant communities in Mont Tochal. Number after the name of each community (comm.) refers to respective number in Table 1. **a** *Gundelia tournefortii-Bupleurum exaltatum* comm. (Ca.8); **b** *Graelsia stylosa* comm. (Ca.11–13); **c** *Aethionema virgatum-Festuca sclerophylla* (CaCb.1); **d** *Nepeta racemosa-Eryngium billardieri* (CaCb.3); **e** physiognomy and view of *Prangos uloptera-Cousinia adensticta* community group (C); **f** *Onobrychis cornuta* comm. (Cb.2)

Both salinity and intense disturbance have adverse effects on the diversity in semi-desert vegetation. *Launaea acanthodes* and *Centaurea brugieriana* are typical ruderal desert species that replace *Artemisia sieberi*-dominated areas, especially along roadsides (Table 1, A.9). Disturbance in *Artemisia sieberi* community may cause increased soil salinity indicated by invasion of *Salsola annua* (=*Anabasis setifera*) in such habitats (Table 1, A.10).

B. *Stipa* grassland: *Stipa hohenackeriana* community group in undulating alluvial hills of Pardisan Eco-Park, area near Koye Faraz and Evin Prison (Table 1, B1–B8, Bca. 1–4; Fig. 3c, 1,400–1,800 m a.s.l.)

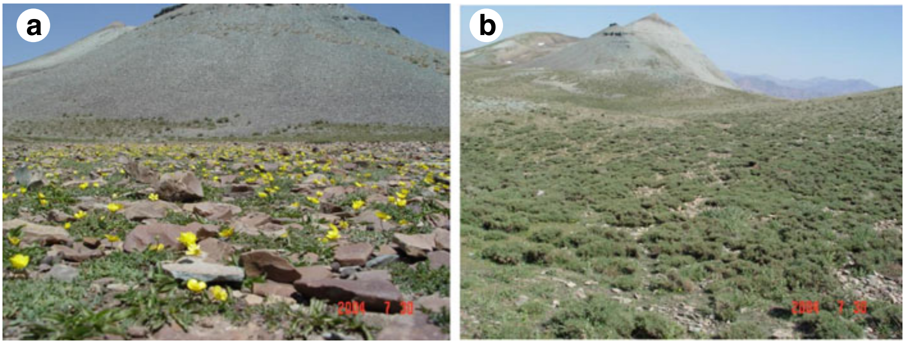

Fig. 5 Selected pictures from alpine and subnival plant communities of Tochal. Number after the name of each community (comm.) refers to respective number in Table 1. **a** *Ranunculus crymophilus* comm. (D.9) in foreground and scree communities in sloping background; **b** *Astragalus iodotropis* comm. (D.7)

This is a small zone of remnant vegetation in a highly urbanized area of Tehran. The absence of grazing allows for the development of grass communities (Fig. 3c). Vegetation is predominately *Stipa hohenackeriana* that originally was found with *Polygonum paronychioides* (Table 1, B.1; Fig. 3c), in slightly disturbed areas with *Cnicus benedictus* and *Tragopogon pterocarpus* (Table 1, B.2) and in gullies and shaded moist parts with *Aegilops columnaris* (Table 1, B.3; Fig. 3c). An artificial plantation of *Pinus eldarica*, *Robinia pseudoacacia* and *Cupressus arizonica* (Table 1, B.4, 5; Fig. 3c, d) and several disturbed and ruderal community types were found along roads and adjacent to park facilities (Table 1, B. 6, 7). Similar types of vegetation are found in the foothills of Mount Tochal near Evin Prison, Koye Faraz, and Velenjak. A small thicket of *Halimodendron halodendron* was observed on the steep western slopes of the Farahzad valley (Table 1, B. 8) but has now completely disappeared as the result of urbanization activities.

The *Stipa* grassland changes to submontane and montane plant communities along a narrow transition zone in the altitude range between 1,800 to 2,000 ma.s.l. on the foothills of Mount Tochal near Koye Faraz and Velenjak (Table 1, B, Ca). The heterogeneity of this habitat has resulted in formation of several diverse plant communities. Thorny *Astragalus* species play a major role in the physiognomy of this zone (Table 1, BCa.1–2). We observed a highly rich plant community in the area surrounding Evin Prison with an average α-diversity of 40.5.

C. Submontane, montane and subalpine zone of Mount Tochal: *Prangos uloptera* community group (Table 1, Ca, Cb; Figs. 3e–f, 4a–f, 2,000–3,700 m a.s.l.)

The characteristic species of this large group consists of several perennial Irano-Turanian elements with wide distribution in montane and subalpine zone of the Zagros and Alborz Mountains (Table 1). The most important physiognomic feature of this type of vegetation is the presence of grasses and tall umbelliferous plants growing together with thorn-cushion species. Species like *Stipa arabica*, *Prangos uloptera*, *Hypericum scabrum*, *Psathyrostachys fragilis*, *Festuca sclerophylla* and *Melica persica* play a major role in the physiognomy of this region.

Long-term grazing is apparently the major reason for domination of thorn-cushions and spiny species belonging to diverse Irano-Turanian genera such as thorny *Astragalus, Acantholimon, Acanthophyllum, Cousinia* and *Onobrychis cornuta* and poisonous and unpalatable species such as *Hypericum scabrum* and *Euphorbia* spp. in this region.

This region is further divided into two large submontane-montane (C_a), and subalpine groups (C_b), supported by TWINSPAN analysis (Table 1).

> C_a) Submontane and montane zones: *Prangos uloptera-Psathyrostachys fragilis* community subgroup (2,000–3,000 m a.s.l.)

The submontane and montane zone is the most species-rich region in our study with 14 plant communities. The grasses (such as *Psathyrostachys fragilis*, *Arrhenatherum kotschyi*, *Taeniatherum caput-medusae* subsp. *crinitum*, *Stipa arabica*, *Festuca sclerophylla* and *Melica persica*) show a remarkable role in physiognomy and

Fig. 6 **a** Relict stand of *Juniperus excelsa* on the northern slopes of Mount Tochal, located just 3 km east of the study area; **b** A herd showing intensive grazing in the alpine zone of the Tuchal Mountains. **c** Steep slopes of Velenjak, where the slopes are being dug to plant exotic trees

species combination of many plant communities (Table 1, C; Figs. 3d,e, 4c). This zone is subject to various soil and erosion disturbances caused by road construction, artificial plantations, overgrazing, trampling, ski trails in addition to natural erosion disturbances, such as moving scree (Table 1).

Astragalus mesoleios is a thorny subshrub occurring in the foothills (1,900–2,000 m a.s.l.) mixed with *Onobrychis michauxii* in finer soils and occurring with scattered shrubs such as *Amygdalus lycioides* on rocky ground (Table 1, Ca.1). *Aethionema grandiflorum* occupies stony ground and with its beautiful flowers is among the most showy vegetation units in the area (Table 1, Ca.2; Fig. 3f). The steep slopes with loose sandy and gravel soils are covered by *Nepeta denudata*, *Pseudocamelina glaucophylla* and *Hesperis persica* species (Table 1, Ca.3).

Astragalus macropelmatus, *Onosma microcarpum*, *Salvia limbata*, *Nepeta fissa*, *Asperula glomerata* are common species of the rocky scree and sand of the submontane zone (2,000 to 2,400 m a.s.l.). *Gundelia tournefortii* is found on more gentle slopes affected by overgrazing (Table 1, Ca.5–8, Fig. 4a). This latter species is a grazing indicator in many steppic rangelands of Iran (Tatian et al. 2010).

The montane zone (2,500–2,900 m a.s.l.) shows greater variation in microhabitat and microclimate. Dry, gravely slopes are covered by *Elymus libanoticus*, *Astragalus compactus*, *Hordeum bulbosum* and *Stipa pulcherima*, and dry steeper slopes by *Dianthus orientalis* (Table 1, Ca.9, 10). Rock cliffs in this zone are common habitats for chasmophytic species such as: *Eriocycla olivieri*, *Parietaria judaica*, *Graelsia stylosa* and *Rosularia persica* (Table 1, Ca.11–13, Fig. 4b). Temperatures decrease and wind becomes more severe in the upper altitudes of this zone, with communities of *Aethionema virgatum-Festuca sclerophylla*, *Pterocephalus canus-Thymus kotschyanus* and *Nepeta racemosa-Eryngium billadieri* found in the transitional region between this zone and the subalpine zone (Cb) (Table 1, CaCb.1–3; Figs. 4c, d).

C_b) Subalpine zone: *Prangos uloptera-Cousinia adenosticta* community subgroup (3,000–3,700 m a.s.l.)

The subalpine zone (Table 1, Cb.1–2) lies at altitudes between 3,000–3,500(–3,700) m a.s.l. and is comprised of two plant communities. In contrast to the montane zone with a strong grass representation, the subalpine zone is physiognomically represented by many thorn-cushion and xerophytic species (Fig. 4f). This is due to harsher conditions and exposure of these communities to strong wind and poor soil conditions. Tall umbelliferous species (*Prangos uloptera*) cover large areas of this zone (Table 1, Cb.2; Fig. 4e), but the subalpine communities show a clear decline in species diversity (Table 1, see also Mahdavi et al. 2013).

Piptatherum laterale and *Elymus longearistatus* are two linking species between subalpine zone and the alpine and subnival zones (Table 1, CbD). The cliff community of *Arabis caucasica-Silene odontopetala* community occurs in this transitional zone with very few other species (Table 1, CbD.1).

D. The alpine and subnival zone: *Oxytropis persica* community group (Table 1, D.1–17; Fig. 5a,b, 3,500–3,966 m a.s.l.)

The alpine and subnival zone of Mount Tochal provides a diverse range of ecological niches including scree, rocky, xerophytic and hygrophilous habitats.

Cousinia multiloba is the most widespread species of this zone and several units can be distinguished (Table 1, D.1–3). *Semenovia tragioides* forms a small community in south-facing, exposed, stony ground (Table 1, D.4). The south-facing slopes also benefit from the moisture provided in deeper soils covered by the community of *Rumex elbursensis-Cirsium lappaceum* and the presence of tall herbaceous species and elements of the subalpine zone such as *Prangos uloptera* (Table 1, D.5). The stony ground on northern slopes is preferred by *Galium decumbens* and *Thymus pubescens* comm. (Table 1, D.6). In the area with well-developed soil layers, *Astragalus iodotropis* develops well (Table 1, D.7; Fig. 5b). In small wetlands and areas fed by melting snow, *Polygonum serpyllaceum*, *Ranunculus crymophilus*, *Taraxacum brevirostre*, *Potentilla* sp, *Cerastium persicum*, *Trifolium radicosum* (Table 1, D.8-10; Fig. 5a) occur. All of these communities are well adapted to scree and/or partly stony habitat with an open cover, except for *Trifolium radicosum*, which is almost exclusively found in swampy fine soils. The cliff, stabilized and moving scree habitats have very few species (Table 1, D.11–14; Fig. 5a). The most xerophytic community in the alpine zone is the *Jurinella frigida-Astragalus capito* comm. (Table 1, D.15) that occurs on exposed, stony ground and in scree soils. The uppermost alpine communities occurring between 3,900–3,966 m a.s.l. on the southern slopes consist of *Astragalus macrosemius-Asperula glomerata* (Table 1, D.16).

Discussion

Phytosociological Outlook and Phytogeography

Because of the absence of a phytosociological system for our study area, we have avoided formal naming of plant communities and instead propose main groups (comparable to classes, orders and alliances) and smaller units (comparable to associations and subassociations) (Table 1). There are several constraints in using such a system for highly diverse and anthropogenically impacted vegetation of the montane and submonate zones. The only available overview of Iran's vegetation is from Zohary (1963, 1973), who proposed several invalid classes and associations (Léonard 1993). Before implementation of a practical system, some basic questions and issues need to be clarified.

A. The steppic vegetation of Iran is subjected to extreme fluctuations in climate (see climatic diagrams in Fig. 2c,d), and the number of species changes drastically in different years. Consequently, it is extremely time consuming and impractical to conduct phytosociological sampling and analyze data collected over several years. Most floristic changes related to the presence or absence of ephemerals, ephemeroides (geophytes) and annuals, and even hemicryptophytic perennials are highly dependent on the amount of annual rainfall (see Mahdavi et al. 2013).
B. Based on observations in many parts of Iran and many southwestern and central Asian countries, problems with analysis of multi-layered vegetation in arid zones are clearly much stronger than in mesic regions. Open vegetation and rainfall fluctuations result in a type of community in which larger perennials (small trees, shrubs, dwarf-shrubs) share their habitat with ephemerals, long-living annuals, hemicryptophytes and geophytes independently. This condition provides a

'stable mosaic' of two or more components, already a well-known phenomenon in arid regions of Australia and Africa (Pignatti et al. 1995). Habitat compartmentation leads to co-occurrence of several 'synusiae' in the same stand (Cain 1936; Gleason 1936; Montaña 1992). Such 'synusiae' form under various conditions: spatial compartmentation arises from open coverage in steppe vegetation where different life forms occupy available spaces with low interference; temporal compartmentation is related to different phenology of species in arid areas; and finally, edaphic and hydrological compartmentations cause co-occurrence of different communities that profit from existing edaphic and hydrological layers. In closed canopies such as forests, maquis, dense thickets and scrub, the dominating life form plays a strong role in determining the underlying layers. However, in arid and semi-arid regions with open vegetation, these four levels of compartmentation largely inhibit simultaneous competition and consequently lead to independent functioning and formation of different 'synusiae' side by side, except probably below-ground competition. This results in the formation of many micro- and overlapping communities that causes a great deal of confusion in sampling in the field and data analysis using criteria developed by the Zürich-Montpellier school of phytosociology. We might need some measures to overcome this complexity such as using only perennial species in classification.

C. It is often quite difficult to define a homogeneous plant community in the field. This is due, in part, to long-term land use and pastoralism in the montane and submontane zones that lead to formation of a steppe potentially composed of shrubby woodland vegetation.

In light of these issues, we have avoided proposing formal names prior to analysis of more comparative data. The following five major groupings resulting from our TWINSPAN analysis (Table **1**A) are the basis for further refinement and proposal of new phytosociological classes of Irano-Turanian semi-desert and montane steppe vegetation:

1. The *Artemisia sieberi* community (Table **1**, column A) includes many species of the semi-desert steppes of Iran, and matches with invalid classes *Artemisietea herba-alba iranica* (Zohary 1973) and *Artemisietea sieberi* (Asri 2003). The species with the highest degree of fidelity (>50) within this group are annuals, except two species of *Artemisia sieberi* and *Poa sinaica*. Three species (*Poa sinaica*, *Astragalus tribuloides* and *Neotorularia torulosa*) have an Irano-Turanian/Saharo-Sindian range. The remaining species are generally omni-Irano-Turanian, found in the deserts of Iran and deserts and semi-desert regions to the north and east in Afghanistan, Pakistan, central Asia and in the Aralo-Caspian area. The taxonomic ambiguity of *Artemisia* species (Podlech 1986) is a main problem for formal naming of these plant communities in Iran.
2. The *Stipa hohenackeriana* community group (Table **1**, column B) grows in soft, fine alluvial soils with sufficient water availability on the undulating foothills and gentle slopes of the Alborz range. As in other parts of Iran, these communities occur mostly in transitional areas between the semi-desert *Artemisia* steppe and various montane steppes with mesophytic vegetation (see Akhani 1998). *Stipa* seeds are fast germinating and their long awns penetrate into soft soils and germinate only when there is enough water (Ronnenberg et al. 2008). Due to overgrazing,

grass-dominated communities are replaced by thorn-cushion formations in mountain slopes, or ruderal species in the plains and valley trains in many regions in Iran. Four of nine species with the highest fidelity (>50) in our TWINSPAN analysis (Table **1**) are perennials. *S. hohenackeriana* occupies a large area of the Irano-Turanian region from Iraq to central Asia with core distributions in Iran and Afghanistan (Bor 1970; Freitag 1985). *Euphorbia teheranica* is an endemic species of central Iran. *Astragalus iranicus* is a common hemicryptophytic species of the section *Malacothrix*, endemic in the Zagros and Alborz Mountains (Podlech and Maassoumi 2010). *Teucrium polium* s.l. is widely distributed in the Irano-Turanian, Mediterranean and Saharo-Sindian regions (Rechinger 1982). *Filago desertorum* is a typical Saharo-Sindian annual species occurring transgressively in the Irano-Turanian area (Wagenitz 1980b). *Rhizocephalus orientalis* is a very tiny lesser-known therophytic Irano-Turanian grass species (Bor 1970). Although *Aegilops columnaris* has the highest fidelity within this group, its range is poorly documented in Iran, due to its similarity (and confusion with) *A. triuncialis*.

The transitional position of *Stipa* communities between semi-deserts, montane steppes, scrub and woodlands results in many difficulties in designating their syntaxonomic status. While the data in Table **1** clearly show the strong links with lower and upper zones, much more comparative data is required to clarify them (see DCA plot in Mahdavi et al. 2013).

3. The *Prangos uloptera-Astragalus* community group encompassing most large areas within the submontane, montane and subalpine zones is dominated by different species of tragacanthic *Astragalus* and many other thorn-cushion and herbaceous species and tall umbelliferous life forms. The subalpine zone of central Alborz has been studied by Klein (Klein 1987, 1988) who identified two invalid classes, *Prangetea ulopterae* and *Onobrychidetea cornutae*. It seems to us that the boundaries between these classes are indistinguishable and therefore could fall into provisional orders belonging to the larger *Prangeto-Astragaletea* class. The invalid order *Astragaletea iranica* suggested by Zohary (1973) should also receive careful consideration in any future attempts to validate these units.

   In our TWINSPAN analysis (Table **1**, column Ca, Cb) *Prangos uloptera*, *Hypericum scabrum* and *Stipa arabica* show the highest fidelity and highest frequency as well. These species are widely distributed in the Iranian mountain steppes as omni-Irano-Turanian elements (Robson 1968; Herrnstadt and Heyn 1977; Freitag 1985). Various thorny species of the genus *Astragalus* occur in this zone including *A. compactus*, *A. microcephalus* and *A. mesoleios*. The *Prangos uloptera-Psathyrostachys fragilis* community subgroup (1,800–3,000 m a.s.l.) is a lower altitude expression of the *Prangos-Astragalus* community group. *Psathyrostachys fragilis* and *Arrhenatherum kotschyi* are the two most frequent grass species in the western part of the Irano-Turanian range (Bor 1970; Baden 1991). This zone is characterized by a presence of many ruderal and semi-ruderal species (Table **1**, Ca). *Centaurea virgata* and *Gundelia tournefortii* are typical Irano-Turanian ruderal steppe species in this zone and are locally dominant in the grazed steppes. *Centaurea virgata* also occurs in zone B. Both species share similar ranges, occurring frequently in western Irano-Turanian montane and submonate regions (Wagenitz 1980a; Rechinger 1989). *Crucianella gilanica* s.l. is a perennial hemicryptophyte to short chamaephyte occurring in mountainous portions of the Irano-Turanian region from northeastern Anatolia to the Pamir and Altai Mountain ranges, while *Crucianella gilanica* subsp. *elbursensis* is endemic on the southern slopes of central Alborz (Schönbeck-Temesy and Ehrendorfer 1989). The only annual species with high frequency and high fidelity in this zone is the ephemeral species *Alyssum szovitsianum* (incl. *A. marginatum*), a species widely distributed throughout southwest Asia.

The *Prangos uloptera*-*Cousinia adenosticta* community subgroup (3,000–3,700 m a.s.l.) is characterized by a much fewer therophytic species (3 *versus* 15), and is represented instead by many xerophytic subshrubs and grasses. Typical Irano-Turanian species *Cousinia adenosticta*, *Thymus kotschyanus*, *Marrubium astracanicum* and *Parlatoria rostrata* show the highest fidelity (>50) (Table **1**, Cb). *Cousinia adenostica* is a local endemic of the central Alborz (Rechinger 1972), *Thymus kotschyanus* s.str. and *Marrubium astracanicum* are both Irano-Turanian species restricted to western Iran and adjacent areas in Anatolia and the Caucasus (Jalas 1982; Seybold 1982). *Parlatoria rostrata* is an endemic species of the central Alborz but its reports from Zagros Mountains are doubtful (Hedge 1968). This zone shows the closest relationship with the proposed class of *Onobrychidetea cornutae* from the central Alborz by Klein (1987). The characteristic species in this class observed in this region include *Onobrychis cornuta*, *Cousinia multiloba*, *Cirsium lappaceum* and *Piptatherum laterale*. It is necessary to re-evaluate this proposed class reducing it to an order within the large *Prangeto-Astragaletea* class.

4. Our TWINSPAN analysis (Table **1**, column D) shows that the alpine and subnival communities are the most distinctive group in this study. This region's plant communities are composed of a limited range of species and none of these are annuals. The most frequent species with high fidelity in this zone include *Bromus tomentosus*, *Catabrosella parviflora*, *Polygonum serpyllaceum*, *Poa araratica*, *Taraxacum brevirostre*, *Helichrysum psychrophilum* and *Draba pulchella*. Detailed data on the phytosociology and phytogeography of this group can be found in Noroozi et al. (2010).

   Few species are shared between all community groups described above (Table **1**). Five species were observed to have very high ecological amplitude with several ecotypes and infraspecific taxa including *Poa bulbosa*, *Ziziphora clinopodioides*, *Senecio glaucus*, *Bromus tectorum* and *B. danthoniae*. However, these are more dominant in three zones and occur sporadically in two others. The only perennial species observed in four zones with notable frequency and fidelity is *Scariola orientalis*. This is an omni-Irano-Turanian ruderal species found from Lebanon to the Himalayas in Tibet at altitudes ranging between 1,000 to 3,400 m a.s.l. (Rechinger 1977). This salt-tolerant species has been observed in xerohalophytic communities of Iran as well (Akhani, pers. observation).

Conservation and Human Impacts

In the study area there are many species with high conservation values that are endemic to the central Alborz and north-central Iran: *Nepeta denudata*, *Cousinia* *adenosticta*, *Eriocycla olivieri*, *Astragalus sciureus*, *A. rubriflorus*, *A. remotijugus*, *Haplophyllum rubro-tinctum*, *Echinops elbursensis*, *Allium tuchalense*, *Euphorbia teheranica* and *Graellsia stylosa* (see also Noroozi et al. 2008). The presence of small patches of phanerophytic scrub in rocky valleys and steep, inaccessible slopes of Alborz, attest to trees and shrubby vegetation having once greater dominance in the past. Today there is a good stand of *Juniperus excelsa* associated with several shrubby species in a steep valley near Ahar village, one of the northern slopes near Mount Tochal (Fig. 6a). An individual *Juniperus excelsa* tree was also located close to our study area in the Darabd valley. In 1859, Kotschy (1861) observed *Juniperus excelsa* trees in northern Tehran, which have apparently disappeared now. Regions in the Zagros Mountains and northeastern Iran with similar climatic conditions (e.g., Mediterranean pluviseasonal bioclimate and Mediterranean xeric continental) are today covered by oak forests, *Pistacia-Amygdalus* scrub and *Juniperus excelsa* woodlands (Bobek 1951; Mobayen and Tregubov 1970; Zohary 1973; Akhani 1998; Djamali et al. 2009).

Tehran and its suburbs is one of the most intensively occupied urban centers in the Middle East with a growing population rapidly approaching 13 million. A 5.7-km-long cable-car route connects the foothills in northern Tehran with the summit of Mount Tochal at an altitude of 3,700 m a.s.l. Consequently, many people can climb to higher altitudes with its colder climate. Coupled with grazing impacts and many construction projects, human activities have largely degraded the natural vegetation (Fig. 6b, see also Fig. 14 in Noroozi et al. 2008). In the lower reaches of our study area, the capital of Tehran is expanding in all directions leading to replacement of the steppic vegetation with plantations of non-native plant species in urban areas. An example of this is the complete transformation of Farahzad valley with many species including the rare orchid *Epipactis veratrifolia*.

Tree plantation is also largely based on exotic species (*Cupressus arizonica*, *Robinia pseudoacacia*, *Pinus eldarica*, among others, Fig. 3c,d). On Mount Tochal introduction of these species on steep slopes has led to degradation of natural vegetation and soil (Fig. 6c). As the results in this paper show, such activities in many cases lead to reduced biodiversity. Species richness in some cultivated zones reflects colonization by many ruderals (Table 1). We have recorded the highest species diversity in communities that have been protected for many years (Table 1, BCa. 1). Another threatening factor of the natural vegetation in Iranian mountains in general and the Alborz range near Tehran in particular, is the exploitation of wild vegetables. Many people harvest valuable species (including *Allium derderianum*, *A. elbursense* and *A. iranicum*) in mountainous regions annually in the spring to sell in the bazaars of Tehran (most notably in Tajrish).

The arid zone biodiversity is comparable to tropical biodiversity in terms of stratification. However, the stratification and diversity in this zone are not vertical and visible at all times. It is distributed temporally and may be retained as seed banks in soils for many years. Conservation of native plant species is a highly complex biological and political issue in an increasingly urbanized world. It is our hope that results of this study will draw attention to the impact of human activities on the diversity of plant species in and around Tehran, and lead authorities and citizens of Iran to adopt policies and daily practices that will minimize these destructive activities.

Acknowledgements Financial support for this research was provided by the Research Council of University of Tehran under grant No. 6104037/1/02 and two studentship grants for Parastoo Mahdavi and Jalil Noroozi. We would like to thank Dr. M. Djamali (Marseille) for his critical reading and improvements of the geological and climatological aspects of this paper, and Prof. G. Prance (Lyme Regis) and Dr. Michael Gregg (McMaster University) for suggestions on English style. The original version of this paper has been extensively revised based on comments of three anonymous reviewers and the associate editor while the first author was on sabbatical leave at the Botanical Garden and Museum in Berlin supported by a grant from Alexander von Humboldt Foundation.

Appendix

Table 1 Synoptic table, diagnostic species, categorical frequency and fidelity index (phi coefficient) of five main community (sub) groups and 58 communities (comm.) recognized along a 3,000 m altitudinal gradient in the Alborz Mountains with their habitat types, average species richness (given in parenthesis), and main impacts and disturbing factors

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
A. Semi-desert steppe: *Artemisia sieberi* community group (1,000–1,400 m a.s.l.)							
Artemisia sieberi	IV$^{78.1}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Astragalus tribuloides	III$^{64.1}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Lallemantia royleana	II$^{48.9}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Diplotaxis harra	II$^{43.1}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Achillea tenuifolia	II$^{35.8}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
A.1. *Artemisia sieberi* comm. (1,150–1,236 m a.s.l.)							
Poa sinaica	III$^{71.8}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Gravelly and scree with large stone particles, alluvium (25.2)	Moderate grazing
Anthemis brachystephana	III$^{68.1}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Crepis kotschyana	III$^{56.5}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Neotorularia torulosa	II$^{58.8}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Lactuca glaucifolia	III$^{60.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Valerianella triplaris	II$^{57.1}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Glaucium elegans	II$^{55.6}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Erodium oxyrrhynchum	II$^{47.6}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Lasiopogon muscoides	I$^{13.2}$	I$^{2.8}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.2. *Amygdalus eburnea-Artemisia sieberi* comm. (1,150–1,200 m a.s.l.)							
Stipa pennata	II$^{45.6}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Andesitic rocky slope (26.2)	Moderate grazing
Astragalus schistosus	II$^{40.7}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Amygdalus eburnea	I$^{38.9}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Lappula spinocarpos	II$^{36.7}$	I$^{8.5}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.3. *Caroxylon orientale-Artemisia sieberi* comm. (1,230–1,390 m a.s.l.)							
Caroxylon orientalis	I$^{31.8}$	.$^{---}$	I^{---}	.$^{---}$	.$^{---}$	Andesitic gravelly and subrocky slope (22.8)	Grazing
Amberboa turanica	I$^{31.2}$	I^{---}	I^{---}	.$^{---}$	.$^{---}$		
Halothamnus glaucus subsp. *glaucus*	I$^{25.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Consolida persica	I$^{12.0}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Eremurus kopetdaghensis	I$^{10.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.4. *Salsola kerneri-Artemisia sieberi* (1,300–1,355 m a.s.l.)							
Caroxylon vermiculata	I$^{37.4}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Andesitic rocky slope (10.9)	Grazing
Salsola kerneri	I$^{35.9}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
Zosima absinthifolia	I$^{21.8}$	.$^{---}$	I^{---}	.$^{---}$	.$^{---}$		
Atraphaxis spinosa	I$^{16.6}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Phagnalon nitidum	I$^{10.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.5. *Acantholimon-Kalakia marginata* comm. (1,090–1,135 m a.s.l.)							
Acantholimon cf. *hohenackeri*	II$^{53.8}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Scree dry soils (27.6)	Moderate grazing
Kalakia marginata	I$^{35.9}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.6. *Ephedra intermedia* comm. (1165m a.s.l.)							
Ephedra intermedia	I$^{22.2}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$	Steep andesitic stony ground (12)	Grazing
A.7. *Atriplex canescens-Gaillonia bruguieri* comm. (1,070 m a.s.l.)							
Atriplex canescens	I$^{21.3}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$	Sandy-gravelly, *Atriplex* cultivation (28.7)	Artificial plantation of exotic species, grazing, irrigation
Gailonia bruguieri	I$^{19.8}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
A.8. *Ptreopyrum aucheri* comm. (1,150–1,235 m a.s.l.)							
Pteropyrum aucheri	I$^{38.6}$	I^{---}	I^{---}	.$^{---}$	.$^{---}$	Sandy-gravelly dry shallow valley bed (25.7)	Heavy grazing
Schismus arabicus	II$^{45.9}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Hordeum glaucum	II$^{33.8}$	I$^{7.6}$	I^{---}	.$^{---}$	.$^{---}$		
Aethionema carneum	I$^{38.3}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Silene arabica	I$^{35.0}$	I^{---}	.$^{---}$	.$^{---}$	.$^{---}$		
Valerianella plagiostephana	I$^{30.4}$	I$^{1.8}$	.$^{---}$	.$^{---}$	.$^{---}$		

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
A.9. *Kaviria tomentosa-Salsola annua* comm. (1,190–1,270 m a.s.l.)							
Salsola annua (=*Anabasis setifera*)	I$^{27.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Andesitic rocky slope (13.3)	Grazing
Kaviria tomentosa (=*Salsola tomentosa*)	I$^{25.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$		
A.10. *Launaea acanthodes-Centaurea bruguierana* comm. (945–975 m a.s.l.)							
Launaea acanthodes	I$^{7.4}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	Roadside, on subsandy disturbed	Roadside, intensive
Centaurea bruguierana	I$^{17.2}$	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	soil near ciment factory (10.5)	disturbance
Linking species between community groups A and B							
Holosteum glutinosum	IV$^{53.0}$	III$^{33.9}$	I^{---}	.$^{---}$	.$^{---}$		
Loliolum subulatum	III$^{35.7}$	III$^{39.9}$	I^{---}	.$^{---}$	.$^{---}$		
Minuartia meyeri	III$^{30.8}$	III$^{35.2}$	I^{---}	.$^{---}$	.$^{---}$		
Noaea mucronata	III$^{52.2}$	II$^{20.1}$	.$^{---}$	.$^{---}$	.$^{---}$		
Roemeria hybrida	IV$^{64.7}$	II$^{4.4}$	I^{---}	.$^{---}$	.$^{---}$		
Eremopyrum bonaepartis	III$^{47.6}$	I$^{9.4}$	.$^{---}$	.$^{---}$	.$^{---}$		
Euphorbia szovitsii	II$^{31.2}$	I$^{14.7}$	.$^{---}$	.$^{---}$	.$^{---}$		
Ziziphora tenuior	III$^{34.8}$	IV$^{47.5}$	I^{---}	.$^{---}$	.$^{---}$		
Erodium cicutarium	II$^{13.3}$	III$^{43.4}$	I^{---}	.$^{---}$	.$^{---}$		
Ceratocephala falcata	II$^{33.2}$	II$^{24.5}$	I^{---}	.$^{---}$	.$^{---}$		
Linaria simplex	III$^{43.2}$	II$^{18.7}$	I^{---}	.$^{---}$	.$^{---}$		
B. *Stipa grassland*: *Stipa hohenackeriana* community group (1,400–1,800 m a.s.l.)							
Aegilops columnaris	.$^{---}$	III$^{70.4}$	.$^{---}$	.$^{---}$	.$^{---}$		
Stipa hohenackeriana	.$^{---}$	III$^{60.3}$	.$^{---}$	I^{---}	.$^{---}$		
Xeranthemum longipapposum	.$^{---}$	III$^{56.3}$	I^{---}	.$^{---}$	.$^{---}$		
Convolvulus gracillimus	.$^{---}$	III$^{58.8}$	I^{---}	.$^{---}$	.$^{---}$		
Alyssum linifolium	I$^{4.1}$	III$^{49.0}$	I^{---}	.$^{---}$	.$^{---}$		
Vulpia ciliata	I$^{1.6}$	II$^{47.0}$	.$^{---}$	.$^{---}$	.$^{---}$		
Rochelia persica	I^{---}	II$^{44.7}$	I^{---}	I^{---}	.$^{---}$		
Stachys inflata	I$^{4.6}$	III$^{44.8}$	I^{---}	.$^{---}$	.$^{---}$		
Euphorbia teheranica	.$^{---}$	II$^{49.8}$	I^{---}	I^{---}	.$^{---}$		
Astragalus iranicus	.$^{---}$	II$^{48.2}$	I^{---}	.$^{---}$	.$^{---}$		
Teucrium polium	I^{---}	II$^{44.6}$	I^{---}	.$^{---}$	.$^{---}$		
Rhizocephalus orientalis	I^{---}	II$^{45.0}$	.$^{---}$	.$^{---}$	.$^{---}$		
Filago desertorum	I$^{5.9}$	II$^{42.7}$	.$^{---}$	.$^{---}$	.$^{---}$		
Echinops cephalotes	I^{---}	II$^{38.2}$	I^{---}	I^{---}	.$^{---}$		
Nonnea caspica	I^{---}	II$^{37.2}$	I^{---}	.$^{---}$	.$^{---}$		
Minuartia hamata	I^{---}	II$^{33.6}$	I^{---}	.$^{---}$	.$^{---}$		
Clypeola jonthlaspi	.$^{---}$	II$^{37.3}$	I$^{4.3}$	.$^{---}$	.$^{---}$		
Clypeola aspera	I$^{7.0}$	I$^{29.3}$	I^{---}	.$^{---}$	.$^{---}$		
Alyssum desertorum	I$^{16.2}$	II$^{26.9}$	I^{---}	I^{---}	.$^{---}$		
Astragalus candolleanus	I^{---}	I$^{32.6}$	.$^{---}$	.$^{---}$	.$^{---}$		
B.1. *Polygonum paronychioides-Stipa hohenackeriana* comm. (1,400–1,470 m a.s.l.)							
Polygonum paronychioides	.$^{---}$	I$^{20.3}$	I$^{21.0}$	.$^{---}$	.$^{---}$	Alluvial undulating slopes, soil	Natural places in some parts
Siebera nana	.$^{---}$	I$^{33.1}$	.$^{---}$	.$^{---}$	.$^{---}$	with scree (35.8)	with low disturbance,
Polygala hohenackeriana	.$^{---}$	I$^{29.9}$	.$^{---}$	.$^{---}$	.$^{---}$		increasing disturbance lead
Cousinia belangeri	.$^{---}$	I$^{23.6}$	.$^{---}$	.$^{---}$	.$^{---}$		to formation of comm. 12 and 14
Scabiosa olivieri	I$^{15.3}$	I$^{19.1}$	.$^{---}$	.$^{---}$	.$^{---}$		
Matthiola ovatifolia	.$^{---}$	I$^{23.6}$	.$^{---}$	.$^{---}$	.$^{---}$		
Astragalus glaucacanthos	.$^{---}$	I$^{20.4}$	.$^{---}$	.$^{---}$	.$^{---}$		
B.2. *Cnicus benedictus-Stipa hohenackeriana* comm. (1,415–1,457 m a.s.l.)							
Cnicus benedictus	.$^{---}$	I$^{26.9}$	.$^{---}$	.$^{---}$	.$^{---}$	Alluvial undulating slopes,	Soil disturbance caused by
Vulpia persica	.$^{---}$	I$^{17.9}$	I^{---}	.$^{---}$	.$^{---}$	soil with scree (41.6)	road and building construction,
Neslia apiculata	.$^{---}$	I$^{15.8}$	.$^{---}$	.$^{---}$	.$^{---}$		in some parts nearby
Hedysarum micropterum	.$^{---}$	I$^{10.5}$	.$^{---}$	.$^{---}$	.$^{---}$		cultivated area by *Cupressus*
Tragopogon pterocarpus	.$^{---}$	I$^{15.0}$	I$^{7.2}$	.$^{---}$	.$^{---}$		*arizonica* and *Robinia* and
Heliotropium aucheri subsp. *aucheri*	I$^{6.9}$	I$^{9.2}$	.$^{---}$	.$^{---}$	.$^{---}$		irrigation facilities
Carex stenophylla	.$^{---}$	I$^{9.1}$	.$^{---}$	.$^{---}$	.$^{---}$		
B.3. *Medicago monspeliaca-Aegilops columnaris* comm. (1,400–1,435 ma.s.l.)							
Medicago monspeliaca	I$^{6.3}$	I$^{20.2}$	.$^{---}$	.$^{---}$	.$^{---}$	Valley bed, soil rich in scree	Trampling, flooding
Heteranthelium piliferum	I^{---}	I$^{22.6}$	I^{---}	.$^{---}$	.$^{---}$	(29.8)	

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
B.4. *Carduus pycnocephalus-Robinia pseudoacacia* comm. (1,420–1,480 m a.s.l.)							
Carduus pycnocephalus	$.^{---}$	$I^{39.2}$	I^{---}	$.^{---}$	$.^{---}$	Dense *Cupressus-Robinia* stands (29.7)	Irrigation, weeding, fertilizing
Chardinia orientalis	$.^{---}$	$I^{34.9}$	I^{---}	$.^{---}$	$.^{---}$		
Cynodon dactylon	$.^{---}$	$I^{23.6}$	$.^{---}$	$.^{---}$	$.^{---}$		
Lactuca serriola	$.^{---}$	$I^{31.4}$	I^{---}	$.^{---}$	$.^{---}$		
Avena fatua	$.^{---}$	$I^{28.0}$	I^{---}	$.^{---}$	$.^{---}$		
Sonchus asper subsp. *glaucescens*	$.^{---}$	$I^{23.6}$	$.^{---}$	$.^{---}$	$.^{---}$		
Robinia pseudoacacia	I^{---}	$I^{23.7}$	$.^{---}$	$.^{---}$	$.^{---}$		
Turgenia latifolia	$.^{---}$	$I^{22.4}$	I^{---}	$.^{---}$	$.^{---}$		
Onopordon leptolepis	$.^{---}$	$I^{22.3}$	$.^{---}$	$.^{---}$	$.^{---}$		
Hordeum spontaneum	$.^{---}$	$I^{21.1}$	$.^{---}$	$.^{---}$	$.^{---}$		
Descurainia sophia	$.^{---}$	$I^{25.3}$	$.^{---}$	$.^{---}$	$.^{---}$		
Lolium rigidum	$.^{---}$	$I^{19.0}$	$.^{---}$	$.^{---}$	$.^{---}$		
Cupressus arizonica	$.^{---}$	$I^{4.7}$	I^{---}	I^{---}	$I^{10.1}$		
Fumaria asepala	$.^{---}$	$I^{7.3}$	$I^{14.4}$	$.^{---}$	$.^{---}$		
B.5. *Heteropappus altaicus-Pinus eldarica* comm. (1,430–1,455 m a.s.l.)							
Heteropappus altaicus	$.^{---}$	$I^{18.2}$	$.^{---}$	$.^{---}$	$.^{---}$	Semi-closed *Pinus eldarica* with small *Robinia pseudoacacia* trees (32)	Irrigation, weeding, fertilizing
Pinus eldarica	$.^{---}$	$I^{16.1}$	I^{---}	$.^{---}$	$.^{---}$		
Goldbachia laevigata	$I^{6.4}$	$I^{10.2}$	$.^{---}$	$.^{---}$	$.^{---}$		
B.6. *Rosa persica* comm. (1,420–1,440 m a.s.l.)							
Rosa persica	$.^{---}$	$I^{28.5}$	$.^{---}$	$.^{---}$	$.^{---}$	Ruderal place (24.1)	Intervals of *Robinia* and *Fraxinus* trees, irrigation, trampling
B.7. *Ducrosia anethifolia-Bromus sterilis* comm. (1,430–1,480 m a.s.l.)							
Ducrosia anethifolia	$.^{---}$	$I^{26.4}$	$.^{---}$	$.^{---}$	$.^{---}$	W-facing steep slopes of the *Cupressus* and *Robinia* cultivated zone (28)	Irrigation, weeding of herbaceous plants
Bromus sterilis	$.^{---}$	$I^{23.0}$	$.^{---}$	$.^{---}$	$.^{---}$		
B.8. *Halimodendron halodendron* comm. (1,380 m a.s.l.)							
Halimodendron halodendron	$.^{---}$	$I^{9.1}$	$.^{---}$	$.^{---}$	$.^{---}$	Steep west slope of the valley (20.3)	Littering, land slide (completely destroyed recently)
Alhagi maurorum	$.^{---}$	$I^{15.8}$	$.^{---}$	$.^{---}$	$.^{---}$		
Picnomon acarna	$.^{---}$	$I^{13.9}$	$.^{---}$	$.^{---}$	$.^{---}$		
Astragalus remotijugus	$.^{---}$	$I^{3.9}$	$I^{6.6}$	$.^{---}$	$.^{---}$		
[ABCa] Linking species between community groups A, B and Ca							
Senecio glaucus	$V^{42.5}$	$IV^{27.9}$	$IV^{22.4}$	I^{---}	$.^{---}$		
Crepis sancta	$II^{2.2}$	$IV^{53.0}$	I^{---}	I^{---}	$.^{---}$		
Callipeltis cucullaris	$II^{26.2}$	$I^{3.6}$	$I^{9.4}$	$.^{---}$	$.^{---}$		
Boissiera squarrosa	$I^{5.0}$	$II^{25.4}$	$I^{9.1}$	$.^{---}$	$.^{---}$		
[BCa] Linking species between community groups B and Ca							
Taeniatherum caput-medusae	I^{---}	$III^{41.2}$	$III^{31.6}$	I^{---}	$.^{---}$		
Centaurea virgata subsp. *squarosa*	$.^{---}$	$II^{16.6}$	$III^{46.1}$	I^{---}	$.^{---}$		
Lamium amplexicaule	$.^{---}$	$II^{33.2}$	$II^{21.2}$	I^{---}	$.^{---}$		
Astragalus macropelmatus	$.^{---}$	$I^{28.7}$	$I^{5.2}$	$.^{---}$	$.^{---}$		
Crupina crupinastrum	$.^{---}$	$I^{18.3}$	$I^{14.7}$	$.^{---}$	$.^{---}$		
BCa.1. *Astragalus compactus-Stipa arabica* comm. (1,800–1,840 m a.s.l.)							
Aegilops triuncialis	$.^{---}$	$I^{26.5}$	I^{---}	$.^{---}$	$.^{---}$	Alluvial undulating slopes (40.5)	No impact, strictly protected
Pimpinella aurea	$.^{---}$	$I^{9.1}$	---	$.^{---}$	$.^{---}$		
Garhadiolus angulosus	$.^{---}$	$I^{12.5}$	$I^{3.5}$	$.^{---}$	$.^{---}$		
Scutellaria pinnatifida	$.^{---}$	$I^{4.6}$	I^{---}	$I^{23.5}$	$.^{---}$		
BCa.2. *Oreophysa microphylla-Astragalus microcephalus* (1,945–2,035 m a.s.l.)							
Sanguisorba minor	$.^{---}$	$I^{10.3}$	$I^{12.0}$	$.^{---}$	$.^{---}$	Alluvial slopes with gravel particles (18.4)	Human activities
Oreophysa microphylla	$.^{---}$	$I^{4.2}$	$I^{12.1}$	$.^{---}$	$.^{---}$		
Hypericum vermiculare	$.^{---}$	$I^{3.1}$	$I^{14.5}$	$.^{---}$	$.^{---}$		
Nepeta cephalotes	$.^{---}$	$I^{12.8}$	---	$.^{---}$	$.^{---}$		
Cerastium dichotomum	$.^{---}$	I^{---}	$I^{27.1}$	$I^{5.1}$	$.^{---}$		
Salvia sclarea	$I^{1.8}$	$I^{12.8}$	$.^{---}$	$.^{---}$	$.^{---}$		
Bca.3. *Sophora alopecuroides* comm. (2,000–2,050 m a.s.l.)							
Sophora alopecuroides	$.^{---}$	$I^{8.1}$	$I^{2.8}$	$.^{---}$	$.^{---}$	Road side close to sloping ground (29.1)	Irrigation and disturbance
Acanthophyllum pachycephalum	$I^{6.5}$	$I^{5.6}$	I^{---}	$.^{---}$	$.^{---}$		
Bca.4. *Cupressus arizonica* cultivation of *Astragalus macropelmatus-Onosma microcarpum* comm. (Ca.5) (2,030–2,040 m a.s.l.)							
Paracaryum undulatum	$.^{---}$	$I^{4.3}$	$I^{19.5}$	$.^{---}$	$.^{---}$	Relatively steep slope in E side with sandy soil (33)	Artificial plantation of *Cupressus arizonica*, trampling, road construction
Cruciata taurica	$.^{---}$	I^{---}	$I^{12.7}$	$I^{19.9}$	I^{---}		
Scrophularia striata	$.^{---}$	$I^{9.1}$	$.^{---}$	$.^{---}$	$.^{---}$		
Chondrilla juncea	$.^{---}$	$I^{22.6}$	I^{---}	$I^{2.6}$	$.^{---}$		

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
[BC] Linking species between community groups B and C							
Astragalus microcephalus	I^{---}	$III^{28.9}$	$II^{11.1}$	$III^{18.5}$	I^{---}		
Eryngium billardieri	$.^{---}$	$II^{2.6}$	$II^{18.6}$	$III^{28.0}$	$.^{---}$		
C. Submontane, montane and subalpine zone of Tuchal Mountains: *Prangos uloptera-Astragalus* community group (2,000–3,750 m a.s.l.)							
Prangos uloptera	$.^{---}$	I^{---}	$III^{30.3}$	$V^{56.5}$	I^{---}		
Hypericum scabrum	$.^{---}$	I^{---}	$IV^{44.1}$	$IV^{43.3}$	I^{---}		
Stipa arabica	$.^{---}$	I^{---}	$III^{44.8}$	I^{---}	I^{---}		
Helichrysum oligocephalum	$.^{---}$	I^{---}	$III^{43.8}$	$II^{18.1}$	I^{---}		
Astragalus compactus	$.^{---}$	I^{---}	$I^{8.9}$	$II^{29.3}$	I^{---}		
Lappula microcarpa	I^{---}	I^{---}	$III^{43.9}$	$II^{7.5}$	I^{---}		
Dactylis glomerata	$.^{---}$	$.^{---}$	$II^{27.8}$	$II^{27.5}$	$.^{---}$		
Melica persica	I^{---}	I^{---}	$II^{29.7}$	$II^{17.0}$	I^{---}		
Bupleurum exaltatum	$.^{---}$	I^{---}	$II^{31.2}$	$II^{18.9}$	$.^{---}$		
Asperula setosa	$.^{---}$	I^{---}	$II^{23.1}$	$II^{22.3}$	I^{---}		
Arenaria gypsophiloides	$.^{---}$	$.^{---}$	$I^{6.2}$	$I^{21.8}$	$.^{---}$		
C_a: submontane and montane zone: *Prangos uloptera-Psathyrostachys fragilis* community subgroup (1,800–2,900 m a.s.l.)							
Psathyrostachys fragilis	$.^{---}$	I^{---}	$IV^{71.8}$	I^{---}	$.^{---}$		
Asperula glomerata subsp. *eriantha*	$.^{---}$	$I^{7.2}$	$III^{48.7}$	I^{---}	$.^{---}$		
Crucianella gilanica subsp. *elbursensis*	$.^{---}$	I^{---}	$II^{42.1}$	I^{---}	$.^{---}$		
Arrhenatherum kotschyi	$.^{---}$	I^{---}	$II^{53.7}$	$.^{---}$	$.^{---}$		
Acinos graveolens	$.^{---}$	$I^{2.3}$	$II^{38.1}$	$.^{---}$	$.^{---}$		
Eremopoa persica var. persica	$.^{---}$	$.^{---}$	$II^{48.9}$	I^{---}	$.^{---}$		
Astrodaucus orientalis	$.^{---}$	I^{---}	$II^{38.4}$	$.^{---}$	$.^{---}$		
Polygonum polycnemoides	$.^{---}$	I^{---}	$II^{41.0}$	I^{---}	$.^{---}$		
Chaerophyllum macropodum	$.^{---}$	$.^{---}$	$II^{45.7}$	I^{---}	$.^{---}$		
Festuca sclerophylla	$.^{---}$	I^{---}	$II^{45.0}$	I^{---}	I^{---}		
Cerastium inflatum	$.^{---}$	I^{---}	$II^{42.8}$	I^{---}	$.^{---}$		
Alyssum minus	$.^{---}$	I^{---}	$II^{35.2}$	I^{---}	$.^{---}$		
Papaver dubium	$I^{1.8}$	I^{---}	$II^{30.8}$	$.^{---}$	$.^{---}$		
Viola occulta	$.^{---}$	$I^{18.4}$	$II^{27.5}$	$.^{---}$	$.^{---}$		
Phlomis olivieri	$.^{---}$	$I^{16.7}$	$II^{28.3}$	I^{---}	$.^{---}$		
Euphorbia cheiradenia	$.^{---}$	I^{---}	$I^{30.7}$	I^{---}	$.^{---}$		
Marrubium cuneatum	$.^{---}$	$I^{3.6}$	$I^{28.4}$	$.^{---}$	$.^{---}$		
Verbascum cheiranthifolium	$.^{---}$	I^{---}	$I^{34.1}$	$.^{---}$	$.^{---}$		
Acanthophyllum mucronatum	$.^{---}$	I^{---}	$I^{23.2}$	$.^{---}$	$.^{---}$		
Ca.1. *Astragalus mesoleios-Psathyrostachys fragilis* comm. (1,972–1,990 m a.s.l.)							
Astragalus mesoleious	$.^{---}$	$I^{1.7}$	$I^{4.7}$	$.^{---}$	$I^{6.5}$	Gentle slope with fine soil in some places with gravelly stone, grassland (40)	Trampling, soil deformation by digging for planting exotic trees
Arenaria serpyllifolia	$.^{---}$	I^{---}	$I^{20.8}$	$.^{---}$	$.^{---}$		
Arabidopsis pumila	$.^{---}$	I^{---}	$I^{22.7}$	$.^{---}$	$.^{---}$		
Lappula sinaica	$I^{1.7}$	I^{---}	$I^{17.2}$	$.^{---}$	$.^{---}$		
Amygdalus lycioides	$.^{---}$	I^{---}	$I^{13.1}$	$.^{---}$	$.^{---}$		
Anthemis odontostephana	$.^{---}$	$I^{2.9}$	$I^{8.5}$	$.^{---}$	$.^{---}$		
Ca.2. *Aethionema grandiflora-Stipa arabica* comm. (1,978–2,027 m a.s.l.)							
Aethionema grandiflorum	$.^{---}$	I^{---}	$I^{19.3}$	$.^{---}$	$.^{---}$	NE steep slope, sub rocky places covered by soil (39)	Natural erosion, mostly well conserved
Galium hyrcanicum	$.^{---}$	$.^{---}$	$II^{26.7}$	$I^{15.3}$	$.^{---}$		
Scorzonera phaeopappa	$.^{---}$	$.^{---}$	$I^{16.3}$	$.^{---}$	$.^{---}$		
Ca.3. *Nepeta denudata-Pseudocamelina glaucophylla* comm. (1,950–1,993 m a.s.l.)							
Nepeta denudata	$.^{---}$	$I^{2.3}$	$I^{18.0}$	$.^{---}$	$.^{---}$	NE steep slope with mobile sandy soil (30)	Soil erosion caused by anthropogenic activities like road construction
Aethionema arabicum	$.^{---}$	I^{---}	$I^{25.9}$	I^{---}	$.^{---}$		
Pseudocamelina glaucophylla	$.^{---}$	I^{---}	$I^{31.2}$	I^{---}	$.^{---}$		
Iris psedocaucasica	$.^{---}$	I^{---}	$I^{22.4}$	$.^{---}$	$.^{---}$		
Fibigia suffruticosa	$.^{---}$	I^{---}	$I^{20.3}$	I^{---}	I^{---}		
Echinops orientalis	$.^{---}$	$I^{3.7}$	$I^{16.4}$	$.^{---}$	$.^{---}$		
Allium derderianum	$.^{---}$	I^{---}	$I^{11.3}$	$I^{17.7}$	I^{---}		
Salvia reuterana	$.^{---}$	I^{---}	$I^{15.1}$	$.^{---}$	$.^{---}$		
Hesperis persica	$.^{---}$	I^{---}	$I^{15.1}$	$.^{---}$	$.^{---}$		
Salvia xanthocheila	$.^{---}$	$.^{---}$	$I^{12.9}$	$I^{4.6}$	I^{---}		

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
Ca.4. *Leutea petiolaris-Ferula persica* comm. (2,000–2,020 m a.s.l.)							
Ferula persica	.$^{---}$	.$^{---}$	I$^{19.5}$	.$^{---}$	.$^{---}$	Scree and gravelly steep slope (20.8)	Moving gravel, close to a calcareous mine
Silene chlorifolia	.$^{---}$	I$^{6.7}$	I$^{1.6}$	.$^{---}$	.$^{---}$		
Leutea petiolaris	.$^{---}$	I$^{6.3}$	I^{---}	.$^{---}$	I^{---}		
Zeravschania pastinacifolia	.$^{---}$	.$^{---}$	I$^{6.1}$	.$^{---}$	.$^{---}$		
Ca.5. *Astragalus macropelmatus-Onosma microcarpum* comm. (2,065–2,130 m a.s.l.)							
Onosma microcarpum	.$^{---}$	I^{---}	I$^{22.1}$	I^{---}	.$^{---}$	Gravelly and scree soil with large stones in some parts (36.6)	Soil erosion, trampling
Eremostachys laciniata	.$^{---}$	I$^{5.5}$	I$^{5.7}$	.$^{---}$	.$^{---}$		
Tulipa montana var. *chrysantha*	.$^{---}$	I$^{2.7}$	I$^{24.5}$	.$^{---}$	.$^{---}$		
Ca.6. *Salvia limbata- Psathyrostachys fragilis* comm. (2,030–2,248 m a.s.l.)							
Delphinium aquilegifolium	.$^{---}$	I^{---}	I$^{35.9}$	I^{---}	.$^{---}$	SW steep slope, gravelly and scree soil (34)	Trampling
Salvia limbata	.$^{---}$	I$^{5.7}$	I$^{12.1}$	.$^{---}$	.$^{---}$		
Lathyrus inconspicuus	.$^{---}$	.$^{---}$	I$^{16.3}$	.$^{---}$	.$^{---}$		
Cicer chorassanicum	.$^{---}$	.$^{---}$	I$^{12.3}$	.$^{---}$	.$^{---}$		
Ca.7. *Nepeta fissa-Asperula glomerata* comm. (2,125–2,225 m a.s.l.)							
Nepeta fissa	.$^{---}$	I^{---}	I$^{30.4}$	I^{---}	.$^{---}$	SE steep slope, sandy mobile soil (30)	Artificial plantation, road construction, soil erosion, trampling
Torilis heterophylla	.$^{---}$	I$^{3.6}$	I$^{15.0}$	.$^{---}$	.$^{---}$		
Anchusaltalica	.$^{---}$	I$^{11.5}$	I$^{4.0}$	.$^{---}$	.$^{---}$		
Alcea sulphurea	.$^{---}$	I$^{7.0}$	I$^{9.5}$	.$^{---}$	.$^{---}$		
Ca.8. *Gundelia tournefortii-Bupleurum exaltatum* comm. (2,236 m a.s.l.)							
Gundelia tournefortii	.$^{---}$	I$^{14.0}$	II$^{33.3}$	.$^{---}$	.$^{---}$	Disturbed area (27)	Road construction, soil deformation by digging for plantation
Tragopogon longirostris	.$^{---}$	I^{---}	I$^{9.0}$	.$^{---}$	.$^{---}$		
Ca.9. *Astragalus compactus-Hordeum bulbosum* comm. (2,520–2,565 m a.s.l.)							
Crucianella exasperata	.$^{---}$	.$^{---}$	I$^{21.4}$	.$^{---}$	.$^{---}$	Gravelly and scree soil (34.6)	Grazing, soil disturbance
Hordeum bulbosum	.$^{---}$	.$^{---}$	I$^{18.5}$	.$^{---}$	.$^{---}$		
Elymus libanoticus	.$^{---}$	.$^{---}$	I$^{11.2}$	I$^{7.4}$	.$^{---}$		
Ca.10. *Dianthus orientalis-Ferula ovina* comm. (2,558–2,626 m a.s.l.)							
Ferula ovina	.$^{---}$	I^{---}	I$^{25.3}$	I^{---}	.$^{---}$	Dry steep slope with rocky bed (26)	Natural places with low or no human impact
Dianthus orientalis	.$^{---}$	I^{---}	I$^{29.1}$	I$^{3.1}$	.$^{---}$		
Piptatherum holciforme	.$^{---}$	.$^{---}$	I$^{10.6}$	.$^{---}$	.$^{---}$		
Ca.11-13. Cliff communities (*Rosularia persica* comm. 2,530–2,626 m a.s.l.; *Graellsia stylosa* comm. 2,230–2,900 m a.s.l.; *Parietaria judaica* comm. 2,520–2,630 m a.s.l.)							
Rosularia persica	.$^{---}$	I^{---}	I$^{32.3}$	I^{---}	.$^{---}$	Rock cliff (20.3)	Natural erosion
Arabis nova	.$^{---}$	.$^{---}$	I$^{23.1}$	.$^{---}$	.$^{---}$		
Poa sterilis	.$^{---}$	.$^{---}$	I$^{27.0}$	.$^{---}$	.$^{---}$		
Graellsia stylosa	.$^{---}$	.$^{---}$	I$^{19.4}$	I^{---}	I^{---}		
Eriocycla olivieri	.$^{---}$	.$^{---}$	I$^{4.3}$	.$^{---}$	I$^{8.3}$		
Galium spurium	.$^{---}$	I^{---}	I$^{29.1}$	.$^{---}$	.$^{---}$		
Arenaria leptoclados	.$^{---}$	.$^{---}$	I$^{22.3}$	I^{---}	.$^{---}$		
Parietaria judaica	.$^{---}$	I^{---}	I$^{18.0}$	.$^{---}$	I^{---}		
Cerasus species	.$^{---}$	.$^{---}$	I$^{12.3}$	.$^{---}$	.$^{---}$		
Dracocephalum kotschyi	.$^{---}$	.$^{---}$	I^{---}	I$^{10.7}$	I^{---}		
CaCb.1. *Aethionema virgatum-Festuca sclerophylla* comm. (2,725 m a.s.l.)							
Aethionema virgatum	.$^{---}$	.$^{---}$	I^{---}	I$^{20.2}$	I^{---}	E steep slope (29)	Evidence of former disturbance
Astragalus submitis	.$^{---}$	.$^{---}$	I$^{8.0}$	I$^{6.0}$	.$^{---}$		
CaCb.2. *Pterocephalus canus-Thymus kotschyanus* comm. (2,831 m a.s.l.)							
Pterocephalus canus	.$^{---}$	I^{---}	II$^{40.6}$	I^{---}	.$^{---}$	E gentle slope with dense plant cover (24)	Trampling
Odontites aucheri	.$^{---}$	.$^{---}$	.$^{---}$	I$^{24.3}$	.$^{---}$		
Stipa caucasica	.$^{---}$	.$^{---}$	I^{---}	I$^{14.7}$	.$^{---}$		
CaCb.3. *Nepeta racemosa-Eryngium billardieri* comm. (2,725–3,015 m a.s.l.)							
Nepeta racemosa	.$^{---}$	.$^{---}$	I^{---}	II$^{44.1}$	I^{---}	S gentle slope, soil with rocky bed in some places (25.7)	Moderate grazing?
Veronica biloba	.$^{---}$	.$^{---}$	I^{---}	II$^{45.9}$	I^{---}		
Secale montanum	.$^{---}$	.$^{---}$	.$^{---}$	I$^{22.0}$	.$^{---}$		
CaCb.3. *Achillea* cf. *aucheri-Cousinia calocephala* comm. (2,900 m a.s.l.)							
Achillea cf. aucheri	.$^{---}$	.$^{---}$	I$^{6.8}$	I$^{8.3}$	.$^{---}$	Valley bed with gentle slope and scree moist soil (15)	Disturbed area by human activities, ski pass
Cousinia calocephala	.$^{---}$	.$^{---}$	I$^{7.9}$	I$^{25.2}$	.$^{---}$		
Echinops elbursensis	.$^{---}$	I^{---}	I$^{3.5}$	I$^{26.7}$	I^{---}		
Alkanna bracteosa	.$^{---}$	.$^{---}$	I$^{5.3}$	I$^{17.3}$	.$^{---}$		

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
Cb. Subalpine zone: *Prangos uloptera-Cousinia adenosticta* community subgroup (3,000–3,700 m a.s.l.)							
Cousinia adenosticta	.---	.---	I---	$IV^{66.3}$	I---		
Marrubium astracanicum	.---	I---	I---	$III^{61.0}$	I---		
Polygonum molliaeforme	.---	I---	I---	$II^{47.7}$	I---		
Tanacetum polycephalum	.---	.---	$I^{2.1}$	$III^{42.0}$	$I^{2.2}$		
Thymus kotschyanus	.---	I---	I---	$III^{51.6}$	I---		
Parlatoria rostrata	.---	.---	I---	$II^{46.9}$	I---		
Geranium kotschyi	.---	.---	.---	$II^{47.7}$	I---		
Lamium album subsp. *crinitum*	.---	I---	I---	$II^{45.3}$	I---		
Festuca arundinacea	.---	I---	$I^{1.7}$	$II^{40.9}$	I---		
Bromus tomentellus	.---	I---	I---	$II^{35.9}$	I---		
Silene aucheriana	.---	I---	$I^{5.8}$	$II^{31.7}$	I---		
Mesostemma kotschyana	.---	I---	I---	$I^{29.3}$	I---		
Cephalaria microcephala	.---	.---	$I^{5.2}$	$I^{30.0}$	.---		
Cousinia hypoleuca	.---	.---	$I^{12.6}$	$II^{28.9}$	I---		
Cb.1. *Tanacetum polycephalum-Silene commelinifolia* comm. (2,980–3,300 m a.s.l.)							
Allium ampeloprasum subsp.*Iranicum*	.---	.---	.---	$II^{41.4}$	I---	Gravelly and scree soil (15.9)	Grazing
Silene commelinifolia	.---	.---	.---	$I^{16.9}$	I---		
Cirsium lappaceum	.---	.---	.---	$I^{15.9}$	$I^{10.8}$		
Allium elburzense	.---	.---	$I^{12.4}$	$I^{2.1}$	.---		
Cb.2. *Onobrychis cornuta* comm. (3,550–3,750 m a.s.l.)							
Onobrychis cornuta	.---	.---	.---	$I^{21.7}$	$I^{21.4}$	Wind swept area with thorny cushions (13.5)	Grazing, wind erosion
Linaria lineolata	I---	I---	$I^{8.4}$	$II^{25.2}$	I---		
Fibigia multicaulis	.---	.---	I---	$I^{25.6}$	.---		
Alyssum murale	.---	.---	.---	$I^{19.3}$	.---		
Iris barnumae subsp. *demawendica*	.---	.---	.---	$I^{17.6}$	$I^{10.8}$		
Tanacetum parthenium	.---	.---	I---	$I^{18.0}$	.---		
Chalcanthus renifolius	.---	.---	.---	$I^{18.5}$	I---		
Astragalus sciureus	.---	.---	I---	$I^{18.0}$	.---		
Linking species between Cb and D							
Piptatherum laterale	.---	.---	.---	$III^{37.6}$	$III^{33.7}$		
Elymus longearistatus	.---	.---	I---	$IV^{51.1}$	$III^{25.9}$		
Cousinia multiloba	.---	.---	I---	$III^{42.3}$	$I^{10.5}$		
Erysimum caespitosum	.---	.---	.---	$I^{11.3}$	I---		
Veronica kurdica	.---	.---	.---	$I^{3.3}$	$I^{24.9}$		
CbD.1. *Arabis caucasica-Silene odontopetala* comm. (3,014–3,365 m a.s.l.)							
Arabis caucasica	.---	.---	.---	$I^{1.2}$	$I^{9.3}$	Rock cliff (5.2)	No particular impact
Silene odontopetala	.---	.---	I---	I---	$I^{14.6}$		
CbD.2. *Bufonia kotschyana-Cousinia multiloba comm.* (3260-3350m a.s.l.)							
Bufonia kotschyana	.---	.---	I---	$I^{27.4}$	I---	Gentle slope, mild to moderate wind, thick layer of soil (4.5)	Grazing
D. The alpine and subnival zone: *Oxytropis persica-Catabrosella parviflora* community group (3,200–(3,500–4,000 m a.s.l.)							
Bromus tomentosus	.---	.---	.---	.---	$III^{63.5}$		
Catabrosella parviflorum	.---	.---	.---	.---	$II^{55.0}$		
Poa araratica	.---	I---	I---	I---	$II^{50.9}$		
Taraxacum brevirostre	.---	.---	.---	.---	$II^{48.1}$		
Helichrysum psychrophilum	.---	.---	.---	.---	$II^{50.3}$		
Draba pulchella	.---	.---	.---	.---	$II^{49.5}$		
Arenaria insignis	.---	.---	.---	.---	$II^{44.7}$		
Acantholimon brachystachyum	.---	.---	.---	I---	$II^{45.9}$		
Campanula stevenii	.---	.---	.---	I---	$II^{42.9}$		
Caroxylon canescens	.---	.---	I---	$I^{4.0}$	$II^{35.0}$		
Allium tuchalense	.---	.---	.---	.---	$I^{39.5}$		
Scorzonera meyeri	.---	.---	.---	.---	$I^{38.5}$		
Gagea alexeenkoana	.---	.---	.---	$I^{1.3}$	$I^{24.4}$		
Erigeron uniflorus subsp. *elbursensis*	.---	.---	.---	.---	$I^{24.6}$		
Festuca alaica	.---	.---	.---	.---	$I^{4.9}$		
Dracocephalum aucheri	.---	.---	.---	.---	$I^{20.8}$		
D.1. *Hordeum violaceum-Cousinia multiloba* comm. (3,450–3,550 m a.s.l.)							
Hordeum violaceum	.---	.---	.---	.---	$I^{12.9}$	Seasonal streambeds at the bottom of valleys (9.5)	Grazing
D.2. *Astragalus chrysanthus-Cousinia multiloba* comm. (3,500–3,850 m a.s.l.)							
Astragalus chrysanthus	.---	.---	.---	.---	$I^{17.7}$	Gentle slope, mild to moderate wind, thick layer of soil (12)	Grazing
Pedicularis pycnantha	.---	.---	.---	.---	$I^{17.0}$		
D.3. *Oxytopis persica-Cousinia multiloba* comm. (3,680–3,800 m a.s.l.)							
Oxytropis persica	.---	.---	.---	.---	$I^{22.5}$	Gentle slopes covered by snow for long time (16.5)	Grazing

Group No. of releve	A 77	B 292	Ca 213	Cb 151	D 336	Habitat type and species richness	Main impacts and disturbing factors
D.4. *Semenovia frigida* comm. (3,560 m a.s.l.)							
Semenovia tragioides	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{2.4}$	Gravelly and rocky bed (14.9)	Grazing
D.5. *Rumex elbursensis-Cirsium lappaceum* comm. (3,650 m a.s.l.)							
Rumex elbursensis	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	I$^{15.6}$	E facinf steep slope, soil with scree and high moisture (12)	Water erosion
D.6. *Galium decumbens-Thymus pubescens* comm. (3,500–3,850 m a.s.l.)							
Achillea millefolium subsp. *elbursensis*	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{7.6}$	N steep slope, moderate to high wind, graminoid-thorn cushion forms (16)	Grazing
Galium decumbens	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{22.0}$		
Thymus pubescens	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{20.8}$		
D.7. *Astragaluslodotropis-Tragopogon kotschyi* comm. (3,680–3,760 m a.s.l.)							
Astragaluslodotropis	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	II$^{43.5}$	W gentle slope, high moisture, late snow melting (11)	Grazing
Tragopogon kotschyi	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{30.8}$		
Cousinia crispa	.$^{---}$	.$^{---}$	.$^{---}$	I$^{15.4}$	II$^{31.9}$		
D.8. *Trifolium radicosum* comm. (3,700 m a.s.l.)							
Trifolium radicosum	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{24.6}$	Snow patch habitat, damp, flat and fine soil rich (4)	Intensive grazing
D.9. *Ranunculus crymophilus* comm. (3,700 m a.s.l.)							
Ranunculus crymophilus	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{30.8}$	Wetland community, gentle slope, soil with small scree particles (5)	Grazing, flooding
Cerastium persicum	.$^{---}$	.$^{---}$	.$^{---}$	I$^{5.4}$	I$^{1.2}$		
Potentilla species	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{15.5}$		
D.10. *Polygonum serpyllaceum* comm. (3,700–3,710 m a.s.l.)							
Polygonum serpyllaceum	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	II$^{50.0}$	Moist gravelly bed (3)	Grazing
D.11. *Vicia ciceroides-Cirsium lappaceum* comm. (3,700 m a.s.l.)							
Vicia ciceroidea	.$^{---}$	.$^{---}$	.$^{---}$	I$^{4.3}$	I$^{17.7}$	N, NE steep slope with scree soil (15)	Grazing, moving ground
Leonurus cardica subsp. *persicus*	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{19.0}$		
D.12. *Euphorbia aucheri-Scutellaria glechomoides* comm. (3,720 m a.s.l.)							
Euphorbia aucheri	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{21.4}$	Mobile scree (1.8)	Habitat unstability
Scutellaria glechomoides	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{17.0}$		
D.13. *Acantholimon demavandicum-Physoptychys gnaphaloides* comm. (3,500–3,750 m a.s.l.)							
Acantholimon demawendicum	.$^{---}$	.$^{---}$	.$^{---}$	I$^{26.6}$	I^{---}	Stabilized scree (15)	Wind erosion
Trachydium depressum	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{30.4}$		
Physoptychis gnaphalodes	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	II$^{36.5}$		
Crepis heterotricha subsp. *lobata*	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	I$^{12.3}$		
D.14. *Cicer tragacanthoides* comm. (3,600–3,730 m a.s.l.)							
Cicer tragacanthoides	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{17.7}$	Stabilized scree (6)	Grazing, erosion
D.15. *Jurinella frigida-Astragalus capito* comm. (3,700–3,735 m a.s.l.)							
Jurinella frigida	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{17.0}$	Scree habitat, poor soil, sever wind, low moisture (10.5)	Grazing, trampling
Astragalus capito	.$^{---}$	.$^{---}$	.$^{---}$	.$^{---}$	I$^{14.7}$		
D.16. *Astragalus macrosemius-Asperula glomerata* comm. (3,900–3,966 m a.s.l.)							
Astragalus macrosemius	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	II$^{42.9}$	Xerophytic alpine habitat (5.8)	Wind erosion
Asperula glomerata subsp. *bracteata*	.$^{---}$	.$^{---}$	.$^{---}$	I^{---}	II$^{39.2}$		
Widspread species occuring in different zones							
Scariola orientalis	II^{---}	III$^{24.1}$	IV$^{27.8}$	II^{---}	.$^{---}$		
Poa bulbosa	I^{---}	I^{---}	III$^{34.2}$	III$^{28.2}$	I^{---}		
Ziziphora clinopodioides	I^{---}	I^{---}	I$^{1.5}$	I^{---}	II$^{25.4}$		
Bromus tectorum	III$^{7.3}$	IV$^{29.0}$	V$^{31.1}$	II^{---}	I^{---}		
Bromus danthoniae	II^{---}	IV$^{26.9}$	V$^{40.8}$	III^{---}	.$^{---}$		
Alyssum szowitsianum	IV$^{28.3}$	III^{---}	IV$^{30.5}$	II^{---}	.$^{---}$		

Rare species with low frequency in community group A

Acantholepis orientalis, *Allium bungei*, *Alyssum marginatum*, *Anthochlamys polygaloides*, *Arnebia linearaifolia*, *Atriplex leucoclada*, *Capparis spinosa*, *Caroxlon incanescens*, *Dianthus crossopetalus*, *Eremostachys macrophylla*, *Erodium lacinatum*, *Halimocnemis mollissima*, *Halimocnemis rariflora*, *Hymenocrater elegans*, *Hyoscyamus pusillus*, *Kochia scoparia*, *Linaria michauxii*, *Microparacaryum species*, *Pteropyrum olivieri*, *Reaumuria alternifolia*, *Silene chaetodonta*, *Stipagrostis plumosa*

Rare species with low frequencyin community group B

Acantholimon scorpius, *Aegilops umbellulata*, *Allium scabriscapum*, *Alyssum meniocoides*, *Argyrolobium trigonelloides*, *Astragalus campylorrhynchus*, *Astragalus kerkukiensis*, *Astragalus michauxianus*, *Calamagrostis pseudophragmites*, *Chenopodium album*, *Chenopodium strictum*, *Cirsium vulgare*, *Convolvulus cantabrica*, *Conyza canadensis*, *Dianthus szowitsianus*, *Echinophora platyloba*, *Epilobium minutiflorum*, *Erophila verna*, *Euphorbia helioscopia*, *Falcaria vulgaris*, *Galium ceratopodum*, *Gladiolus segetum*, *Haplophyllum rubro-tinctum*, *Helianthemum salicifolium*, *Lagochillus macracanthus*, *Linum album*, *Malcolmia strigosa*, *Malcomia africana*, *Medicago polymorpha*, *Outreya carduiformis*, *Peganum harmala*, *Phragmites australis*, *Plantago lanceolata*, *Plantago major*, *Polypogon fugax*, *Pulicaria gnaphalodes*, *Rapistrum rugosum*, *Saccharum ravennae*, *Salsola kali*, *Setaria verticillata*, *Sonchus maritimus*, *Thalictrum sultanabadense*, *Thesium kotschyanum*, *Tragopogon graminifolius*, *Trifolium montanum*, *Vaccaria oxyodonta*, *Valerianella dufresina*, *Velezia rigida*, *Xanthium stumarium*

Rare linking species with low frequencyin community groups A and B

Andrachne telephioides, *Astragalus oxyglottis*, *Carthamus oxyacanthus*, *Ceratocarpus arenarius*, *Cleome coluteoides*, *Gagea tenuifolia*, *Gypsophila pilosa*, *Hernardia persica*, *Koelpinia tenuissima*, *Onobrychis aucheri*, *Papaver argemone*, *Pycnocycla spinos*, *Stachys annua*, *Thevenotia persica*

Linking rare species between community groups B and Ca

Acanthophyllum microcephalum, *Ajuga chamaecistus*, *Alyssum tortuosum*, *Capsella bursa-pastoris*, *CleomeIberica*, *Cousinia species*, *Ephedra species*, *Hypericum hirtellum*, *Leontice armeniaca*, *Malva neglecta*, *Mindium laevigatum*, *Onobrychis michauxii*, *Pilostyles haussknechtii*, *Trigonella uncinata*

Linking species between community groups A,B and Ca
Androsace maxima, *Centaurea balsamita* subsp. *balsamita*, *Clypeola microcarpa*, *Conringia perfoliata*, *Gagea reticulata*, *Hypecoum pendulum* var. *pendulum*, *Papaver tenuifolium*, *Prosopis farcta*, *Reseda lutea*, *Trigonella monantha*, *Valerianella oxyrrhyncha*
Rare species with low frequencyIn community group Ca
Achillea oxyodonta, *Agropyron cristatum* subsp. *pectinatum*, *Allium xiphopetalum*, *Aubrieta parviflora*, *Barbarea plantaginea*, *Bongardia chrysogonum*, *Cicer oxyodon*, *Corydalis verticillaris*, *Cousinia amplissima*, *Dianthus agrostolepis*, *Elymus repens*, *Geranium rotundifolium*, *Geranium species*, *Hypericum helianthemoides*, *Mentha longifolia*, *Morus species*, *Nepeta bracteata*, *Nepeta pungens*, *Ononis spinosa* subsp.*antiqurum*, *Onosma dichroantha*, *Paronychia caespitosa*, *Poa pratensis*, *Ranunculus bulbilliferus*, *Ranunculus oxyspermus*, *Ranunculus species*, *Rochelia cardiosepala*, *Sameraria stylophora*, *Saponaria orientalis*, *Scrophularia syriaca*, *Silene dichotoma*, *Steptorrhamphus tuberosus*, *Stipa pulcherrima*, *ThalictrumIsopyroides*, *Thlaspi perfoliatum*, *Verbascum aucheri*, *Verbascum gossypinum*, *Vitis vinifera*
Rare species with low frequencyin community group Cb
Allium schoenoparsum, *Asperugo procumbens*, *Astragalus rubriflorus*, *Bromus gracillimus*, *Bromus species*, *Bupleurum gerardii*, *Gagea gageoides*, *Ornithogalum brachystachys*, *Salvia atropatana*, *Taraxacum montanum*, *Tulipa humilis*, *Veronica polita*
Linking rare species between community groups Cb and D
Achillea vermicularis, *Allium stamineum*, *Chenopodium foliosum* subsp. *montanum*, *Colchicum robustum*, *Erysimum elbrusense*, *Gagea confusa*, *Herniariaincana*, *Hyoscyamus senecionis*, *Minuartia lineata*, *Scrophularia amplexicaulis*, *Scrophularia frigida*, *Urtica dioica*
Rare species with low frequencyin community group D
Alopecurus textilis, *Clastopus vestitus*, *Epilobium confusum*, *Minuartia mesogitana* subsp. *turcomanicum*, *Papaver armeniacum*, *Silene marschallii* subsp. *sahendic*, *Solenanthus circinnatus*
Other rare species occuringin three zones of B, C and D
Geranium tuberosum, *Astragalus aegobromus*, *Biebersteinia multifida*, *Filago arvensis*, *Geum kokanicum*, *Ixiolirion tataricum*, *Poa angustifolia*, *Ranunculus elbursensis*, *Rumex scutatus*, *Sherardia arvensis*, *Stachys lavandulifolia*

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Received: 10 August 2010 / Revised: 1 June 2012 / Accepted: 11 June 2012