Plant communities of the Karkas Hunting-Prohibited Region, Isfahan-Iran

S.J. Khajeddin, H. Yeganeh

Department of Natural Resources, Isfahan University of Technology, Isfahan, Iran

ABSTRACT

The Karkas mountainous region is a very interesting area for its big game wildlife and rare species in the Irano-Touranian biogeographic region. It is essential to study the plant communities and the impact of environmental factors, to protect and rehabilitate these ecosystems. The studied region is located in the Isfahan province, central Iran, with the area of about 92 100 ha. The aim of the study was to identify the plant communities of the Karkas Hunting--Prohibited Region. Vegetation cover was sampled using a stratified random sampling method and the entities were preliminarily segmented with the physiognomic-floristic-ecologic method. 10 × 10 m quadrates (100 m^2) were used to estimate the species cover, litter, stone, gravel and bare soil percentages. Plant communities were classified using cluster analyses and denderogram construction. The results confirmed the importance of the climatic and topographic factors that affect the establishment of the plant communities. Plant habitats in the region are mosaics and cause ecoton formations, so diversities in species combinations increase. The species diversity of the communities was measured using the Shannon coefficient; it varied from 2.26 to 0.39. According to cluster analyses, there are 15 different plant communities, but when the second dominant species were considered, some communities were further divided into sub-communities.

Keywords: plant community; cluster analyses; similarity index; Karkas; Iran

The Karkas Hunting-Prohibited Region has been one of the protected areas in Iran since 1980 and the Iranian Environmental Protection Organization (IEPO) is responsible for the management of such regions. The Karkas area is of international interest and its big game wildlife attracts numerous visitors (Darvishsefat 2006, IPDEP 2007); the fauna includes wild sheep, Persian ibex, hare and wolf (Ziaii 1996, Hemami and Kaboli 2007) and about 62 bird species are identified in the region (Hemami and Kaboli 2007). This region is managed as pasture for domestic animal grazing for goat and sheep as well as a habitat for wildlife (IPDEP 2007). Plants establishment in the nature are under close species relations and their dependent to the environmental factors. Vegetation cover studies are important for better habitat management because pastures in these protected areas are habitats for the wildlife, which graze the hay produced there and whose survival in these regions depends on the protection of their habitat. Studying plant communities can facilitate a better understanding of species relations, which is valuable to evaluate the habitat potential (Müller-Dombois and Ellenberg 1974, Moghaddam 2001).

Cluster analysis is a mathematical method used to classify the vegetation segments in abstracted communities. In this way the releves can be grouped into similar species compositions. Research often uses cluster analysis to study plant communities (e.g. Ohtsuka et al. 2006); of particular interest are Ariavand (1994), who studies the Isfahan-Iran pastures using cluster analysis, and Khajeddin (1995), who studies the Jazmorian-Iran plant communities through this method. The latter article compares the ordination and classification methods, and concludes that clustering has a better ability to describe arid land plant communities. It gives the impression that these communities are discrete units or the ecotons are so extensively established that they can be considered as an entity or a separate community. Ariavand

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(1994) compares the releves produced by the classification and ordination methods and concludes that the two methods create five similar groups. Khajeddin (2004) studies plant communities of the Mooteh Wildlife Refuge using cluster analysis; it is of interest because the habitat is similar to the Karkas region and some plant communities have very similar species composition.

Ohtsuka et al. (2006) classify the northern coasts of the Brogger Peninsula, Svalbard vegetation cover with 26 releves using cluster analysis. They use a 50% similarity threshold to define 3 main vegetation communities dominated by *Salix* sp., *Cardamine* sp. and *Oxyria-Luzula*. They also study the species relations with chemical and physical properties of the soil using Canonical Correspondence Analysis (CCA). They conclude that the soil properties are not the only environmental factors affecting vegetation pattern formation and distribution.

Vegetation maps are important tools to site description and management as they can present the geographical distributions of the plant communities (Roy and Millington 2000). By evaluating and assessing the digital vegetation layer with digital topographic and other environmental factor layers in the Geographical Information System (GIS), plant habitats can be described (Küchler and Zonneveld 1988, Tor 2001). For these purposes, Boolean images and/or fuzzy functions can define and characterize the habitat of a community (Tor 2001). Domestic animal grazing on the studied area is under the supervision of IEPO and is maintained with a pastoralist and/or transhumance approach. These types of vegetation management can influence species composition and eliminate the palatable species (Moghaddam 2001).

The aims of this study are to classify the plant communities of the Karkas Hunting-Prohibited Region and to map their distributions.

MATERIAL AND METHODS

The Karkas Mountains are located in the Isfahan province, central Iran with an area of about 92 100 ha, and hunting has been prohibited in this area since 1980. More precisely, the area is located between the latitude of 33°20' and 33°37'E and longitude 51°26' and 52°58'N, and the town Natanz is located at the eastern edge of the region (Figure 1). The elevation of this region is between 1389 m and 3880 m above sea level. It is very steeply

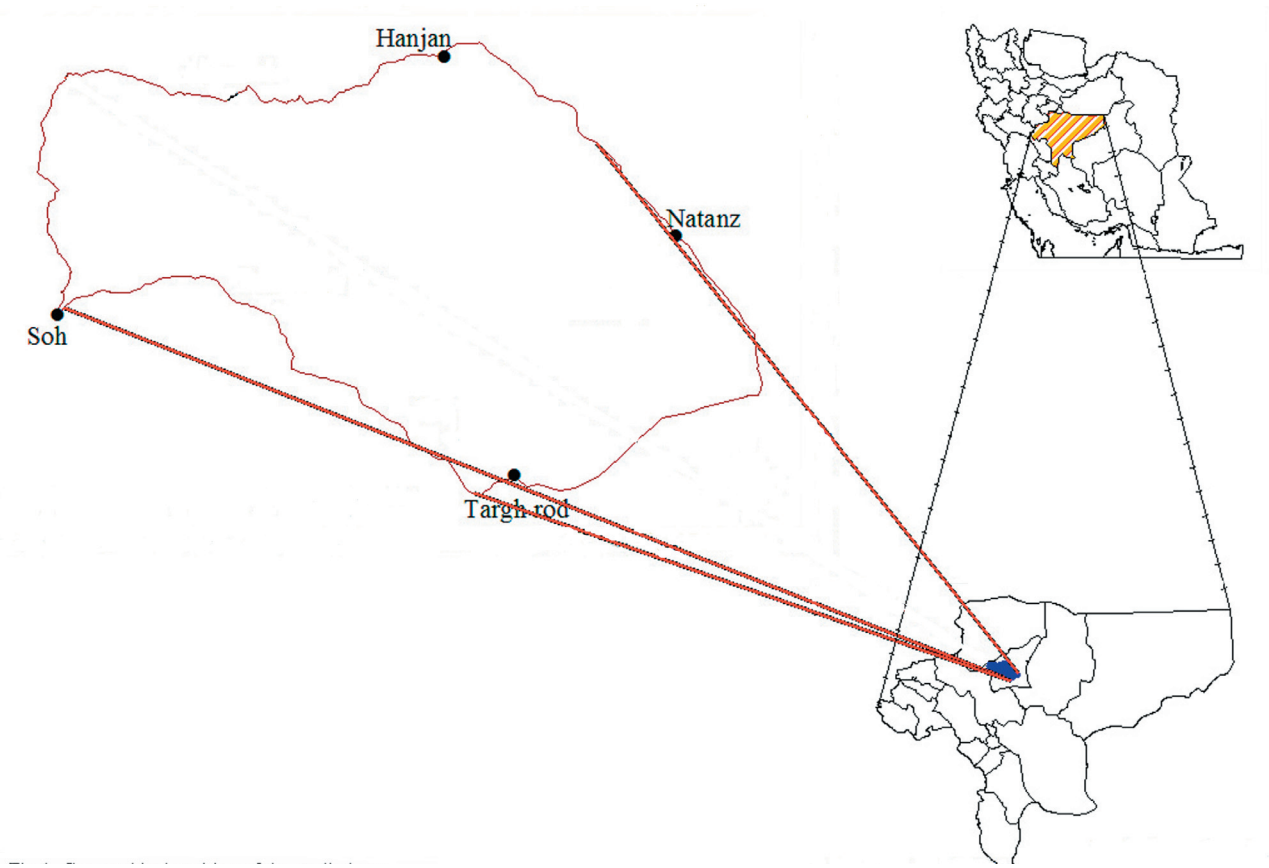

Figure 1. Geographical position of the studied area

sloped region, with the most common slope class being 30–65% while the slope class of 0–2% has the least occurrence in the study region. The average annual precipitation is 240 mm with minimum and maximums of 153 mm and 328 mm per annum, respectively. The average annual temperature is 2.1°C with the minimum temperature of –11.6°C in January and the maximum temperature of 15.8°C in August.

Site studies and data collection were carried out from the spring to autumn 2006. Vegetation segments, pasture boundaries, agricultural lands, gardens, urban settlements, bare soils, out-cropped rocks and stony areas were mapped with field studies using a 1:50 000 scale map and aerial photographs (Küchler and Zonneveld 1988, Roy and Millington 2000). Preliminary plant communities and vegetation types were distinguished with the physiognomic-floristic-ecologic method. Meanwhile, with determination of a pasture type, boundaries were checked on the map according to the vegetation entity's features and dominant species (Küchler and Zonneveld 1988, Guinochet 1997, Moghaddam 2001), and the stratified random sampling method was employed to sample the vegetation cover. A 10 m × 10 m (100 m^2) quadrat was used to estimate the species cover, litter, stone, gravel and bare soil percentages (Müller-Dombois and Ellenberg 1974, Khajeddin 1995), while plant communities were classified using cluster analyzes and denderogram construction (Jongman et al. 1995). Ten quadrats were established for each vegetation entity as replicates for any sampling point; these quadrats groups are named "quadrat series" (Khajeddin 1995). In total, 63 quadrat series were established in the studied region. The sampled species were determined according to the flora (Rechinger 1963–2003, RIFR 1988–2006), and species cover was estimated in m^2 with an accuracy of up to two decimal digits.

The field data of vegetation cover from 10 quadrats (each quadrat series) were added together to make a summation for a 1000 m^2 releve. The Motyka similarity coefficient (given in equation 1) (Müller-Dombois and Ellenberg 1974) and the unweighted pair-group average method were used to construct the denderogram (Müller-Dombois and Ellenberg 1974, Kent and Coker 1992) to classify the releves:

$$IS_{MO} = \frac{200 \sum MW}{MA + MB} \quad (1)$$

where: IS_{MO} is the similarity coefficient between 2 stands; MW is the smaller amount of cover between 2 stands; MA and MB are the total coverages of all species in stand A and stand B accordingly

The species diversity of the communities has been calculated according to the Shannon index (given in equation 2) (Magurran 1988):

$$H' = -\Sigma P_i \ln P_i \quad (2)$$

where: H´ is the species diversity index; P_i is the relative abundance of each species [the proportion of species *i* relative to the total number of species (p_i)]; $\ln P_i$ is the natural logarithm of the relative abundance

The field-prepared vegetation map of the region was finalized with aerial photograph interpretation and digitized to make a vegetation cover layer for a GIS environment. Finally, the digital map was crossed with slope, aspect, altitude above sea level, precipitation, and annual mean temperature layers to provide the habitat characteristics of each plant community.

RESULTS AND DISCUSSION

The cluster analysis of vegetation cover data has classified the releves into 15 clusters of interest on two different levels, as shown in Figure 2. Ten clusters are formed on a similarity coefficient (SiC) of 30%, marked by a horizontal line and the letters from A through J. At the 50% similarity coefficient, there are 5 communities consisting of at least 5 releves, highlighted by letters from K through O.

Scariola orientalis is the dominant species of cluster A and it is formed by quadrat series numbers 1, 43, 5, 48, 60, 9, 54, 55, 14 and 58. Cluster B with *Astragalus parrowianus* domination is formed by quadrat series numbers 8, 18, 11, 42, 39, 46 and 31. In cluster C *Artemisia aucheri* is the dominant species and quadrat series numbers 3, 4, 51, 50, 10, 25, 28, 12, 34, 16, 35, 38, 63, 52, 53, 62, 37, 59, 15, 24, 17 and 23 are in its cluster. This community is the most extended community in the region. *Eryngium billardieri* is a species present in other communities but it is dominant in cluster D with quadrat series number 7, 41 and 45. *Perovskia abrotanoides* is the dominant species in cluster E with quadrat series number 56 and 40. *Stipa barbata* is dominant in cluster F with quadrat series number 2. *Artemisia sieberi* is dominant in cluster G with quadrat series numbers 6, 27, 36, 32, 49, 33, 13, 57, 19, 26, 61, 20, 30 and 29. This community can be found on the

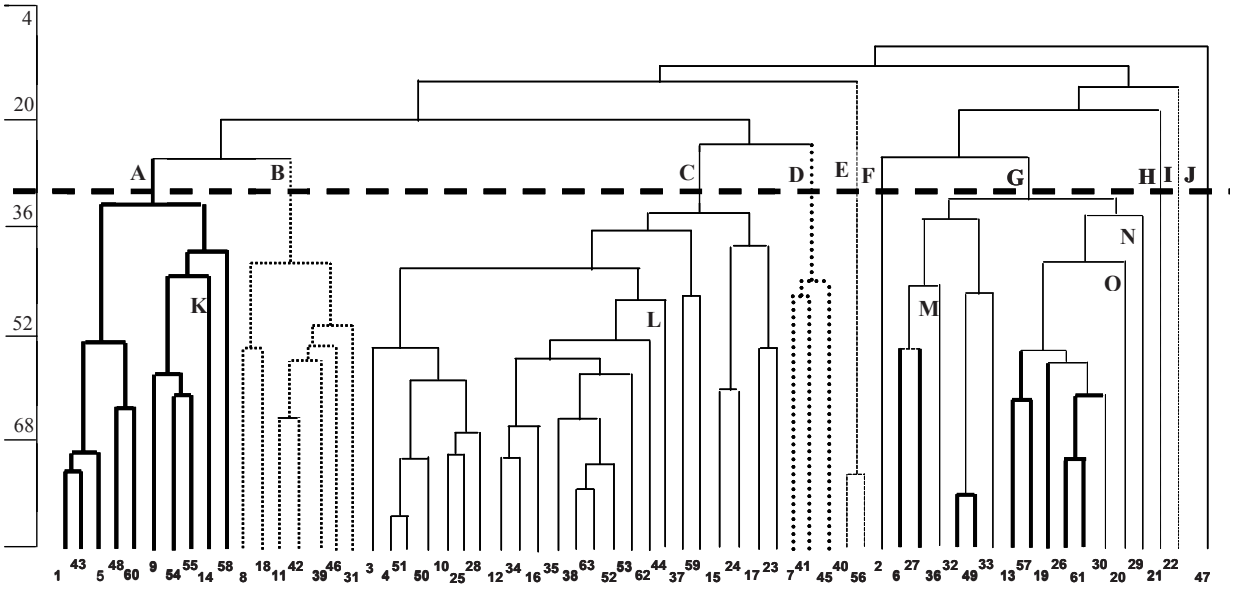

Figure 2. Denderogram of the cluster analysis and the vegetation types in the Karkas Hunting-Prohibited Region

plateau. *Stachys inflate* (cluster H), *Amygdalus scoparia* (cluster I) and *Centaurea gaubae* (cluster J) are dominant in quadrat series numbers 47, 22 and 21 accordingly.

There are other 5 plant communities that can be distinguished in 50% SiC and they are dominated by the following species: *Acanthophyllum bracteatum*, *Bromus tomentellus*, *Hertia angustifolia*, *Pteropyrum aucheri* and *Ebenus stellata*. Their species composition is quite different from the above-mentioned clusters.

The outcome of the mapping and classification proves that the plant communities vary according to the region: *Artemisia aucheri* can be found on the high lands, mountain foot and high plateaus; *Artemisia sieberi* are widespread on the low lands plateau; *Pteropyrum aucheri* are common on the flood plains and floodways; *Amygdalus scoparia* are common on the rocks and outcropped rocks; *Scariola orientalis* and *Eryngium billardieri* are common on overgrazed sites; and other plant communities are found only in limited areas with a few rare communities in the region such as *Centaurea gaubae*. *Eryngium billardieri* is established on the upper sections of the mountainous habitat while the *Stachys* can be found on the lower sections of this habitat. *Ebenus stellata* always establishes on warm sun-facing rocks. Table 1 provides the habitat information for and the diversity coefficients of the communities.

The vegetation map demonstrates the plant community distributions and land uses as follow: pasture lands 64 487 ha (70.01%); irrigated farmlands 431 ha (0.47%); orchards 2 598 ha (2.82%); outcropped rocks 23 401 ha (25.41%); without vegetation cover (bare soil) 348 ha (0.38%); residential areas 598 ha (0.65%); wetlands 82 ha (0.09%), and mines 155 ha (0.17%) (Figure 3). Other land uses, such as wetlands, have limited areas in the region.

The study area has steppe vegetation of the Irano-Touranian Bioclimatic Region type (Zohary 1973). The main influencing elements of the vegetation on the region are climatic, topographic, edaphic and biological factors of which the first two elements have the most effect. From 1400–3400 m above sea level *Artemisia Sieberi* and *Pteropyrum aucheri* are common but above 3400 m *A. aucheri* and other cushion-form species such as *Astragalus* spp. and *Acantholimon* spp. grow. According to De Martonne, below 3400 m the climate is dry, but it is semi-dry with Mediterranean regime precipitation above it (Soltani 2007). The established plant communities are formed according to pasture management and herbivores. Some species such as *Bromus tectorum*, *Bromus danthoniae*, *Taeniatherum crinitum*, *Minuartia meyeri* and *Boissiera squarrosa* have very wide habitats and are present on various communities in the region. They have not been considered in the community analyses.

The 15 plant communities can be divided to sub-communities according to their second dominant species. In this regards *Eryngietum* has four clear sub-communities that have been discussed and their information is given in Table 1.

The results confirm the importance of the climatic and topographic factors on plant-commu-

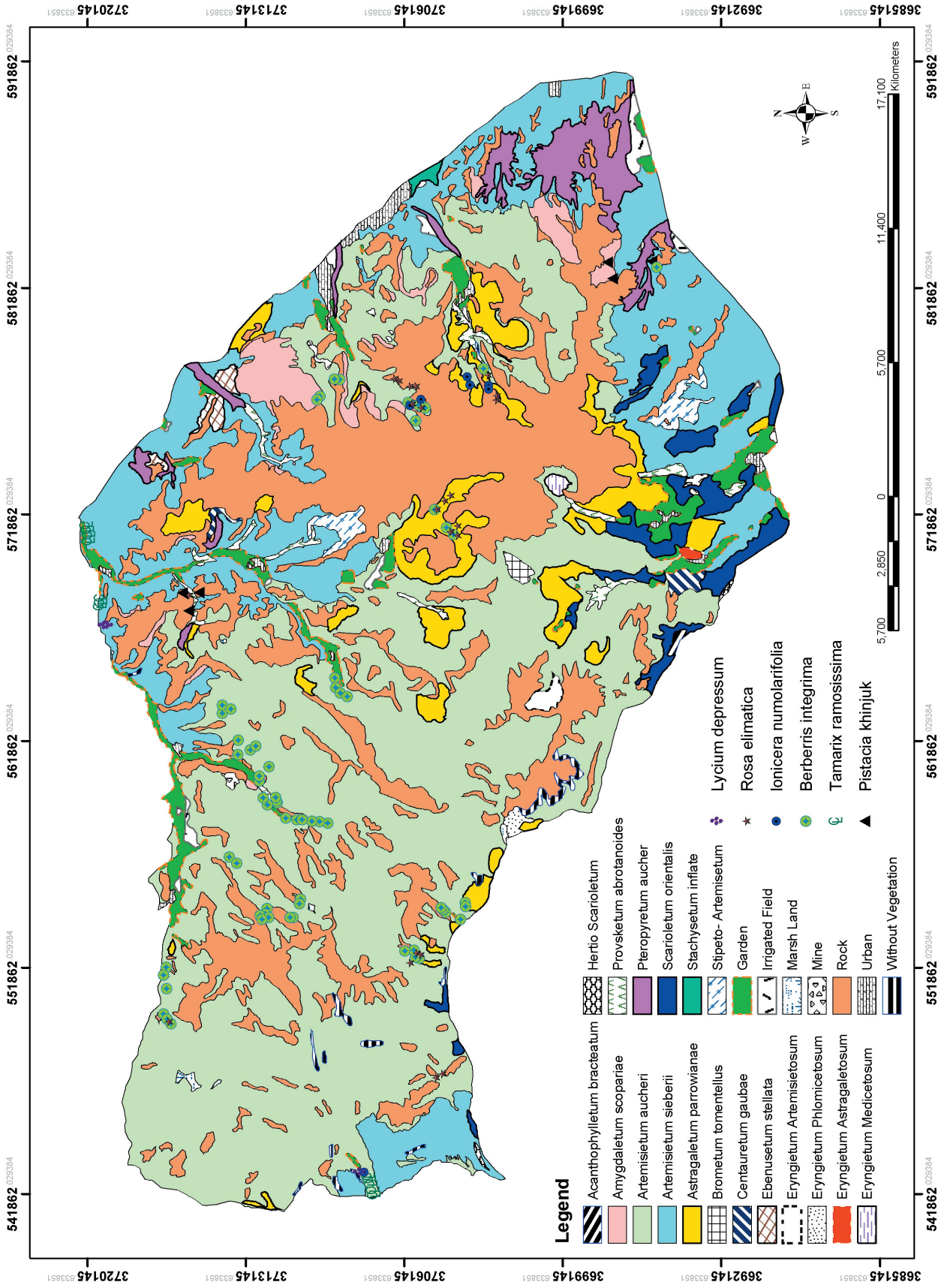

Figure 3. Vegetation map of the Karkas Hunting-Prohibited Region

nity establishment in the studied region. Plant habitats in the region are mosaics and cause ecoton formations so the species combination diversities increase. The species diversity of the communities was measured with the Shannon coefficient (Magurran 1988). The highest species diversity coefficient was 2.26 in the *Eryngium billardieri-Medicago sativa* community, while two plant communities dominated by *Pteropyrum aucheri* and *Centaurea gaubea* had the least species diversity in the region. These are nearly sustainable for species changes and the dominant species have large sizes. In contrast, the communities of *Scariola orientalis* and *Eryngium billardieri* have the highest species diversity on the disturbed sites (Magurran 1988). These last communities will be changed toward low species diversity in the close future because palatable species will disappear because of overgrazing. The plant communities of the studied region are described below and further information is given in Table 1.

1 – *Acanthophylletum bracteati*. This community establishes at the foot of the mountain as well as on the high mountains in large patches on the south facing slopes. Its dominant species is *Acanthophyllum,* which is a perennial, cushion form, alpine and unpalatable species. The dominant species has 3.7% cover with the density of 17 plants per 100 m^2. Its second dominant species is *Scariola orientalis*, an invader species that establishes in open places. Cluster K with quadrat series number 14 has the sampled point information. Its species diversity is high and the associated species are *Astragalus strictifolius*, *Gundelia tourenfortii* and *Tanacetum polycephalum*.

2 – *Amygdaletum scopariae* is scrub dominated by *Amygdalus scoparia*, an association that is established on the eastern and the north-eastern parts of the region. The dominant species is a shrub with 2–4 m height, 5 m crown diameter and is a very distinct plant species in the region. Under its canopy no species have been recorded, which could be due to its allelopathic effects. Cluster I with

Table 1. Plant habitats properties of Karkas Hunting-Prohibited Region

Area (%)	Area (ha)	Diversity index	Temperature (°C)	Precipitation (mm)	SG[4] (%)	VC[3] (%)	Aspect[2]	Slope (%)	Altitude[1] (m)	Plant community
0.03	26	2.02	5	222	26	7	SE	25–45	2100–2600	*Acanthophylletum bracteati*
0.97	890	1.2	8.3	201	> 90	9	SE, NE	65 >	1800–2300	*Amygdaletum scopariae*
41.47	38190	1.35	2.1	241	60	25	all aspects	65–30	1800–3100	*Artemisietum aucheri*
16.18	14902	1.27	9.5	193	30	18	NE, P	< 40	1200–2700	*Artemisietum sieberi*
4.63	4260	1.4	3.7	231	78	17	all aspects	65–30	2200–3000	*Astragaletum parrowiani*
0.11	102	1.6	0.3	253	45	18	S	45 >	2500–3000	*Brometum tomentelli*
0.16	144	0.39	6.5	213	75	10	S, P	70–25	2000–2700	*Centaureetum gaubae*
0.26	237	1.63	13	172	80	12	NE	> 65	1400–1800	*Ebenetum stellatae*
0.15	141	1.2	–0.9	260	70	11	SE, SW	65–30	2500–3000	*Eryngietum Artemisietosum*
0.04	38	1.9	6.1	216	67	10	P	65–30	2200–2600	*Eryngietum Astragaletosum*
0.08	73	2.26	–1.4	263	31	16	S, W	40–15	2600–3000	*Eryngietum Medicetosum*
0.09	83	1.35	–0.7	259	42	14	P	65–20	2600–3000	*Eryngietum Phlomicetosum*
0.03	31	1.7	5.5	219	50 <	15	p	15–35	2000–2600	*Hertio Scarioletum*
0.7	647	1.2	7.2	208	80	30	P	30 <	1400–2800	*Perovskietum abrotanoides*
2.5	2298	0.83	7.8	181	80	24	P	30 <	1400–2100	*Pteropyretum aucheri*
1.96	1803	1.6	6.2	215	47	10	P	40–5	1800–3000	*Scarioletum orientalis*
0.09	87	1.3	10.2	176	80	7	P	30–5	1400–1800	*Stachysetum inflate*
0.58	535	1.4	6.2	215	77	9	SE, NW	65–30	1800–2700	*Stipeto-Artemisietum*

[1]altitude above sea level; [2]aspect: SE – South East, NE – North East, SW – South West, NW – North West, P – Plain; [3]VC – total vegetation cover; [4]SG – stone and gravel cover

quadrat series number 22 has the sampled point information. Its habitat is outcropped rocks or the rocky steep slopes and the Entisols with sandy loam textures. On this habitat, *Artemisia aucheri* establishments occur where the soil depth increases as mosaics. Its associated species are: *Melica persica* and *Acanthophyllum bracteatum*.

3 – *Artemisietum aucheri* is dominated by *Artemisia aucheri* and it is the most widespread plant association in the studied region. Together with its sub-associations they cover more than 41.4% of the studied area. The dominant species is a dwarf bushy plant that establishes on the steep and semi-steep of the Irano-Touranian bioclimatic regions (Zohary 1973, Khodagholi et al. 2006). It is an aromatic species, so herbivores do not graze it before autumn precipitation when the rain washes out its aromas. Most of the east, north and central parts of the Karkas are covered with this association. The cover of main species varies from 1.7% to 30% and its density in good conditions is 101 bushes per 100 m^2. *Artemisia* bushes on waterways have larger sizes and are fresher. Cluster C with quadrat series number 3, 4, 10, 12, 15, 16, 17, 23, 24, 25, 28, 34, 35, 37, 38, 50, 51, 52, 53, 59, 62 and 63 have the sampled point's information from this community. Species diversity varies on the sites from 0.2 on site 4 to 2.2 on sites 37 and 59. Most of the associated species are held in common between the two *Artemisietum* communities but the *Artemisietum aucheri* community has a higher species diversity than the *Artemisietum sieberi* community (Khodagholi et al. 2006). The reason for the high species diversity at site 37 is the overgrazing that allows both differential species and invaders to be present together. This association can establish in various habitats and forms sub-associations accordingly. Its prime habitat is highland and high hills and gravelly colluvial fans (Zohary 1973, Khajeddin 2004). Also, Azarnivand et al. (2003) finds that this species can establish on the highlands above 1800 m above sea level, while *A. sieberi* can dominate below 1800 m in the Garmsar and Semnan regions. Jafari et al. (2004) declare that *A. aucheri* domination has a direct relation with elevation and slope and an inverse relationship with lime and soil pH in the Yazd-Iran region. In addition, this species prefers light texture and low soluble contents in the soil. The main species can establish up to rocky habitats on the highlands. This association is common on shallow chalk or calcareous gravelly soils on the high hills, shale peaks soils and old terraces. The habitat soil type is Aridisols and Entisols with sandy loam to loamy sand texture.

This dominant association is divided into sub-associations based on the second dominant species. The sub-associations are formed on the basis of the habitat changes: the two *Artemisia* species form topographic sub-associations, as on the highlands *A. aucheri* and *A. sieberi* on the lowlands are common. Their sub-associations can be found in between: on stony and gravelly habitats *Astragalus parrowianus* is the second dominant species; where the soil depth increases *Bromus tomentellus* appears; and on the shiest soils *Stipa barbata* forms the sub-association. The characteristic species are: *Agropyrom taure*, *Buffonia macrocarpa*, *Acantholimon erinaceum* and *Phlomis olivieri*. Both *Artemisia* species are palatable for Persian gazelle during the autumn (Nowzari et al. 2007) because of their aromatic oils (Ghasemi et al. 2005).

4 – *Artemisietum sieberi* is dominated by *Artemisia sieberi* and is one of the Irano-Touranian plant communities that are extensively dominant in Central Iran (Zohary 1973, Khodagholi et al. 2006) as well as in the studied area and its suburbs, covering 16.3% of the studied area. This species forms sub-associations with *A. aucheri* as are described above. Similar to *A. aucheri*, it has aromatics oils that increase its palatability after autumn precipitation (Gharehbash et al. 2001, Ghasemi et al. 2005). Its habitat is plateaus and old terraces with deep and very deep chalky or calcareous soils formed on the gravelly alluvial fans. The soil type is Aridisols and its texture is silt loam to sandy clay loam. Azarnivand et al. (2003) report that this species can establish on various soil types in various climatic conditions. The present research proves a similar distribution of *A. sieberi* in the studied area as in Zohary (1973).

Comparing the two species, *Artemisia sieberi* establishes on heavy textures with higher concentration of soluble salts on lowlands (Zohary 1973, Jafari et al. 2004). Both species have negative correlation with salinity increasing and *A. sieberi* establishes on soils except where the limiting factor is the salinity of the habitat (Jafari et al. 2004) and it occupies sites with other associations in mosaic form. The dominant species cover is 8.5% with the density of 62 bushes on 100 m^2. Cluster G with quadrat series number 6, 13, 19, 26, 27, 30, 32, 33, 49, 57 and 61 have the sampled point's information from this association. Species diversity is variable between the stands of this association; it is 0.27 at site 61 and 1.9 at site 32.

Sub-associations have been formed according to the habitat suitability for other species: on

deep soils *Stachys inflate*; on schisty soils *Stipa barbata*; on overgrazed sites *Scariola orientalis* and *Noaea mucronata* are common (confirmed by Khodagholi et al. 2006); and on deep soils *Reseda lutea* have established. *Stipa barbata* associate with *Artemisietum* nearly everywhere (Khodagholi et al. 2006).

The characteristic species are: *Stipa barbata*, *Astragalus parrowianus* and *Andrachne telephioides*.

5 – *Astragaletum parrowiani* is dominated by *Astragalus parrowianus* and its habitat is the high mountains of the Karkas region. It has formed some ecotons with *Artemisia aucheri* and *A. sieberi*. The cover of the main species is about 4.5–10.5% and its density reaches 32 bushes per 100 m^2. Cluster B with quadrat series number 8, 11, 18, 31, 39, 42 and 46 has the sampled point's information for this association. Its habitat is relatively high mountains with rounded tops where the soil depths vary from shallow to nearly deep condition and the soil texture is sandy clay loam (Jafari et al. 2004, Khajeddin 2004).

Sub-associations have formed with the following species according to the habitat: on the mountains with rather shallow soils and gentle slops *Artemisia aucheri* is established; on high rocky mountains with high precipitation and low temperatures the alpine species *Acanthophyllum bracteatum*; on overgrazed areas *Scariola orientalis*; on schists and steep slopes *Stipa barbata* is common; on rocky and stony sites *Agropyron tauri*; on overgrazed or disturbed sites with deep and fertile soils *Phlomis olivieri* is dominated as second species.

The characteristic species are: *Echinophora platyloba*, *Gundelia tourenfortii*, *Arrhenatherum kotschyi* and *Noaea mucronata*. This plant composition is not ideal for Persian gazelle because the dominant species palatability is low with their thorns and spines (Nowzari et al. 2007).

6 – *Brometum tomentelli* is one of the alpine plant associations and is dominated by *Bromus tomentellus*. Its cover reaches 6% with 101 individuals per 100 m^2 in regions where total plant cover is 17.6%, with gravel and stone cover of 45% or more in some places. Its sub-association is with *Astragalus parrowianus* and is found mainly on the south parts of the Karkas Range from 2600 to 3000 m above sea level, for example in quadrat series number 44 (cluster L). The presence of *A. aucheri* caused this association to be classified under cluster C while it is a various association from *Artemisietum*. Species diversity is 1.5 on this site and the characteristic species are: *Cousinia bachtiarica*, *Acantholimon leucacanthum* and *Marrubium vulgare*. This community is preferred for wildlife all over the year because of its dominant and associated species, especially for the presence of *Stipa* spp. and the palatable *Astragalus* spp. (Nowzari et al. 2007).

7 – *Centaureetum gaubae* has a limited distribution in the south of the Karkas region from 2200 to 2600 m above sea level and is dominated with *Centaurea gaubae*. It is classified independently in cluster J and is very different from other associations. It is established on a habitat where the slope is mainly 30–50%. The dominant species is perennial, spiny and unpalatable so it is protected from grazing. The total plant cover is 9.7% while the main species covers about 3.3% with a density of 13 bushes per 100 m^2. This association is established on the rocky, sandy and shiest highlands piedmont. The species diversity is very low and about 0.38. This association is mostly mono-species community and the characteristic species are: *Astragalus parrowianus*, *Andrachne telephioides* and *Lepidium persicum*. This plant composition is not ideal for big game wildlife throughout the year (Nowzari et al. 2007).

8 – *Ebenetum stellatae* is a community common in the east part of the studied region and the dominant species is *Ebenus stellata*. This is the Soudano-Decanian bioclimatic region (Zohary 1973) type. It has entered into the Irano-Touranian bioclimatic region and establishes on the warm sun-facing slopes. Its habitat is hilly or outcropped rocks and is known as climatic community. It is sampled with quadrat series number 29 (cluster N). *Ebenus stellata* has beautiful yellow flowers and spiny leaves which protect the species from grazing. Its canopy cover is 6.3% with about 20 shrubs density per 100 m^2. Species diversity is moderate and varies on its ecotons with *Artemisia sieberi*. Its characteristic species are: *Pennisetum orientalis*, *Astragalus podolobus* and *Teucrium polium*. This community is preferred for wildlife during the year not for its dominant species but for its associated species especially for the presence of *Stipa* spp. (Nowzari et al. 2007).

9 – *Eryngietum* is a common association in central Iran and in the Zagross Ranges. In the studied region it has two species, *Eryngium bungei* and *E. billardieri*, as dominant species. They have spiny leaves that protect them from direct grazing, so the perennial plant can stay safe and its density increases. Also their seed production rate is very high and the seeds can establish very well every year. The seedlings can be grazed during

the spring before the appearance of leaf spines in early summer. The ranchers collect the whole plant parts on the above ground during the late summer or early autumn to feed the livestock during winter after drying and chopping them. These two *Eryngium* species can establish and become a dominant species on overgrazed areas so it is a secondary association in these regions. On these new associations the species composition varies according to the main plant association and the influencing biological factors. Because of the overgrazing effects, it can be predicted that the species composition will change and the thorny and spiny species will be dominated in the region. The recorded species compositions are:

A – *Eryngietum Artemisietosum* is dominated with the invader species of *Eryngium billardieri*. Its crown cover is 4.3% with a density of 48 bushes per 100 m^2. The second dominant species is *Artemisia aucheri* and is sampled with quadrat series number 45. It is clustered under the D branch and the total crown cover is 11%. The differentiating species are: *Acanthophyllum bracteatum*, *Astragalus strictifolius*, *Festuca ovina* and *Dianthus orientalis*;

B – *Eryngietum Astragaletosum* is dominated with the second invader species *Eryngium bungei*. The two species of *Eryngium* spp. are present in sub-association but *E. bungei* is common and dominant everywhere. The crown cover of the dominant species is 4.27% with the density of 32 bushes per 100 m^2. It is sampled with quadrat series number 58. Because of the species composition similarities it is clustered under the A branch but the dominant species and its trend confirms this grouping. The second dominant species is *Astragalus parrowianus* and is established on stony habitat. The differentiating species are: *Lagochillus aucheri*, *Centaurea gaubae* and *Acanthophyllum bracteatum*;

C – *Eryngietum Medicetosum* with domination of *Eryngium billardieri* and *Medicago sativa* can be found on the southern slopes of Karkas as a small patch of 73 ha. The second species is a perennial palatable species that has been cultivated during the past decades by the native men. It is sampled with quadrat series number 41 and is clustered under the D branch. The crown cover of the dominant species is 7.1% with a density of 46 bushes per 100 m^2. Its differentiating species are: *Phlomis olivieri*, *Carex stenophylla* and *Poa bullbosa*;

D – *Eryngietum Phlomicetosum* has *Eryngium billardieri* as dominant species and the second dominant species is *Phlomis olivieri*. Both of these species are invaders and can establish on eroded sites. The crown cover of the dominant species is 8.2% and its density is 105 bushes per 100 m^2 while the second species has 3.9% cover and 49 bushes per 100 m^2. It is sampled with quadrat series number of 7 and is clustered under D branch. Its differentiating species are: *Stachys pilifera*, *Euphorbia* spp. and *Acanthopyllum squarrosum*.

10 – *Hertio Scarioletum* has the *Hertia angustifolia* as dominant species and *Scariola orientalis* is its second dominant species. These species are shrubby invaders and can be found in narrow margins of the roads in the south part of the studied region. The original association was *Artemisietum sieberi* and these species have invaded after soil disturbances for road construction. It is sampled with quadrat series number 36 and is classified under the G branch (cluster M). Its species composition is very similar to the *Artemisietum sieberi* association. Both dominant species are unpalatable species and herbivores do not graze them. The new branches and the leaves of the second dominant species are grazed by goats during the spring. The crown cover of the dominant species is 9.6% with the density of 18 shrubs per 100 m^2 and the second species has 4.7% crown cover with a density of 21 per 100 m^2. Its habitat is old plateaus and terraces with calcareous deep soil on alluvial fans. The soil texture is sandy clay loam and the characteristic species are: *Andrachne telephioides* and *Iris songarica*.

11 – *Perovskietum abrotanoides* is established on the eroded floodways and the river alluvial, where the soil salinity has decreased through its washing out, however this association cannot be found on the lowlands where *Pteropyretum aucheri* can occur. The dominant species is *Perovskia abrotanoides*, a tall shrub whose height can reach up to 2 m with a cover of up to 5 m^2. It is an aromatic and unpalatable species whose crown cover can reach 24.1% and a density of 12 shrubs per 100 m^2. It is sampled with quadrat series number 40 and 56 and is clustered under the E branch. This branch is a very dissimilar group and has very little species crown cover in common with the other associations. This is a hydrophyte association which can be found on the canyon bottoms or waterway beds where fresh water is available, especially during the dry season. On broad waterways it establishes rather widely in large patches. Its species diversity is very low where the water availability is high but the species diversity increases on its margins, where the water availability decreases. The characteristic

species are: *Moriera spinosa*, *Launaea acanthodes* and *Halimodendron halodendron.*

12 – *Pteropyretum aucheri* is dominated by the shrubby species *Pteropyrum aucheri*, a hydrophyte species that can be found on eroded stony or gravelly waterways. Mostly its habitat has sandy soils on physiographic units such as plateaus and gravelly alluvial fans. *Pteropyrum olivieri* is the other species that is present there but never becomes dominant. The main species has 2 m height and each individual shrub has up to 4 m^2 cover. The crown cover of the dominant species is 22% with the density of 18 shrubs per 100 m^2. It is sampled with quadrat series number 20 and is clustered under the G branch (cluster O). Similar to *Perovskietum* and with the same explanation its species diversity is low. The characteristic species are: *Astragalus parrowianus*, *Scariola orientalis* and *Noaea mucronata*.

13 – *Scarioletum orientalis* is dominated by *Scariola orientalis* and can be found on small or very large patches in the south of the studied region where the pasture is degraded by overgrazing. Most of the year (about 10–11 months) the dominant species is leafless, because it drops its leaves very early during the spring to survive dry periods of the year. Then it conducts photosynthesis in green narrow stripes on its branches, which are active all year round. Domestic animals and wildlife like to graze the young and fresh branches. Its crown cover is 6.7% with the density of 75 shrubs per 100 m^2. It is sampled with quadrat series number 1, 5, 9, 43, 48, 54, 55 and 60 and is clustered under the A branch. This is a degraded plant association so its species diversity is very high. The highest diversity coefficient is 2.3 on site 55. This association establishes on old plateaus and terraces with deep gypsiferous soils and gravelly alluvial fans. Its habitat has Aridisols. The following species become the second dominant species on some sites: *Artemisia sieberi*, common on less degraded sites; *Noaea mucronata* on overgrazed sits; *Stipa barbata* on stony and rocky habitats; and *Astragalus parrowianus*, common on the high rocks. The characteristic species are: *Launea acanthodes*, *Dendrostellera lessertii* and *Acanthophyllum bracteatum*. This community is not preferred by big game wildlife during the year (Nowzari et al. 2007).

14 – *Stachysetum inflate* is common in the eastern part of the studied area. The bushy *Stachys inflate* is the dominant species and is not palatable. It has attractive violet color flowers. *Noaea mucronata* is the second dominant species that appears on degraded sites, and both species are invaders. The second species can be grazed in early spring when the new shoots are rather soft. Its stems and branches become thorny when they mature in late spring or early summer and develop into woody stems, at which point it cannot be used by herbivores. Crown cover of the dominant species is about 4.6% with the density of 13 bushes per 100 m^2, while the second dominant species has 1% cover with the density of 16 bushes per 100 m^2. It is sampled with quadrat series number 21 and is clustered under the H branch with a species diversity coefficient of 1.3. The characteristic species are: *Heliotropium aucheri*, *Teucrium polium* and *Astragalus parrowianus*.

15 – *Stipeto-Artemisietum* is an association that establishes on the highlands waterways with shallow soil in the Karkas region, making very low cover on the rocks. It is sampled with quadrat series number 2 and is clustered under the F branch. Its first dominant species are *Stipa parvifolia* or *Stipa barbata*. This association establishes on the floodways or waterways and makes mosaic patches with *Pteropyretum aucheri*. The crown cover of the dominant species is 5.7% and its density is 64 bushes per 100 m^2. Both of the dominant species are perennial *Gramineae* and herbivorous animals use this species before appearance of the spikelet aristates. Both *Stipa* spp. establishes on steep slopes of schisty highlands. On various habitats their ecotons appear with *Astragalus parrowianus* on rocky sites; *Artemisia aucheri* on deep soils and *Artemisia sieberi* on lowlands. The characteristic species are: *Pteropyrum aucheri*, *Scabiosa olivieri* and *Launaea acanthodes*. This community is preferred for Persian gazelle during spring and summer times because of its dominant species, as well for its associated species and palatable *Astragalus* spp. and annual *Gramineae* species (Nowzari et al. 2007).

In addition to the common associations above, the following species associations can be found in the studied region in limited areas: *Lycium depressum*, *Pistacia khinjuk*, *Tamarix ramosissima*, *Rosa elymaitica*, *Berberis integerrima* and *Lonicera nummulariifolia*. They are scattered in the region and they have single stands on their habitat. The remaining stumps of these species in the region confirm that their population was higher during the past times and their densities have decreased because of firewood collections by the natives and only some stands have been left. *Pistacia khinjuk* can be found on rocks of the highlands, *Lonicera nummulariifolia* on stony sites of the highlands,

and the others on moist sites where the water availability is high, such as floodway bottoms or waterway beds as well as around the springs. One can add to them the hydrophyte associations dominated by *Carex stenophylla*, *Populus* spp., *Juncus* spp. and *Salix* spp. too. These associations have not been sampled because their area was very limited.

In general the vegetation maps can result in a better habitat and wildlife management of the region. Overlaying the vegetation map with information layers of the sheepfolds distribution proves severe over-grazing of pastures and palatable species in our study area. Due to overgrazing, the vegetation cover is very poor and most of the palatable species have decreased or disappeared in some areas and plants are scattered with low density in the studied region. Thus we strongly believe that controlling the increasing trend of domestic herbivores which are competing for forage with wildlife is essential for conservation of the existing threatened wildlife and also for maintaining the international interests of Karkas region.

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Corresponding author:

Assoc. Prof. Sayed Jamaleddin Khajeddin, Ph.D., Isfahan University of Technology, Department of Natural Resources, Isfahan 84156–83111, Iran
phone: + 983 113 912 841, fax: + 983 113 912 840, e-mail: khajedin@gmail.com