RANGE SIZE RARITY ANALYSIS OF THE FABACEAE, (EXCEPT ASTRAGALUS L.) IN IRAN

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The geographic distribution of the *Fabaceae* (except the genus *Astragalus* L.) has been analyzed to have insights about the distribution pattern of this family as an approach for a better conservation policymaking. In doing so, we used a dataset of 10498 geo-referenced observations from Iran. Species richness, endemic species, weighted endemism and corrected weighted endemism were mapped in 1° x 1° latitude/longitude grids using ArcView and DIVA-GIS software. Iran was divided into 196 grid cells and of these, 173 grid cells had at least one record each. The highest endemic species values were observed in a grid cell located in Tehran province, which also possessed high species richness and even the highest weighted endemism values. But high values for corrected weighted endemism were obtained from grid cells located in the North East of Iran (mostly from Razavi Khorasan province). Species with very small documented distribution area (one grid cell only) were distributed in North and North West (West and East Azerbaijan provinces) of Iran and along the Zagros mountain range. In this study, seven regions with conservation importance were identified which can be compared with the present protected areas.

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Key words. Weighted endemism, species richness, diversity mapping, priority setting, *Fabaceae*, Iran.

آنالیز محدوده کمیابی تیره باقلائیان به جزء جنس گون در ایران

طلیعه السادات موسوی، فارغ التحصیل کارشناسی ارشد بخش زیست شناسی دانشگاه شیراز.

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پراکنش جغرافیایی تیره باقلائیان (به جزء جنس گون) تجزیه و تحلیل گردیده تا با داشتن چشم‌اندازی از الگوی پراکنش این خانواده بتوانیم تصمیمات حفاظتی بهتری داشته باشیم. به این منظور از ۱۰۴۹۸ گزارش ثبت شده ی ژئورفرنس شده از ایران استفاده گردید. با استفاده از نرم افزار DIVA-GIS و ArcView و خانه های 1° x 1° عرض/طول جغرافیایی، غنای گونه‌ای، گونه‌های انحصاری، weighted endemism، corrected weighted endemism بر روی نقشه آورده شد. ایران به ۱۹٦ خانه تقسیم گردید که از این تعداد ۱۷۳ خانه حداقل یک گزارش ثبت شده دارند. بالاترین تعداد گونه‌های انحصاری در خانه‌ای در استان تهران مشاهده شده است که همچنین بالاترین میزان غنای گونه‌ای و weighted endemism را دارد. بالاترین میزان corrected weighted endemism در خانه‌ای در شمال شرق ایران مشاهده شده است. گونه‌هایی که پراکندگی آنها محدود به یک خانه می باشد در شمال، شمال غرب و در امتداد رشته کوه زاگرس پراکنده هستند. در این مطالعه هفت ناحیه با اهمیت حفاظتی شناسایی شدند که می توان آنها را با مناطق حفاظتی کنونی مقایسه کرد.

Introduction

With an area of 1,623,779 km^2, Iran occupies a large part of the Iranian Plateau (Zehzad *et al.* 2002). Most of this area belongs to Holarctic phytogeographical kingdom. The coastal areas on the Persian Gulf along with the foothills belong to Paleotropic phytogeographical kingdom. The border between these two kingdoms runs toward south of Iran.

Iran has a unique flora among the Middle East and southwest Asian countries. It acts as a bridge among the major phytogeographical regions: The Irano-Turanian, the Euro-Siberian and the Saharo-Sindian (Zohary 1963, White & Leonard 1991). Additionally, it is one of the largest speciation centers of the Holarctic

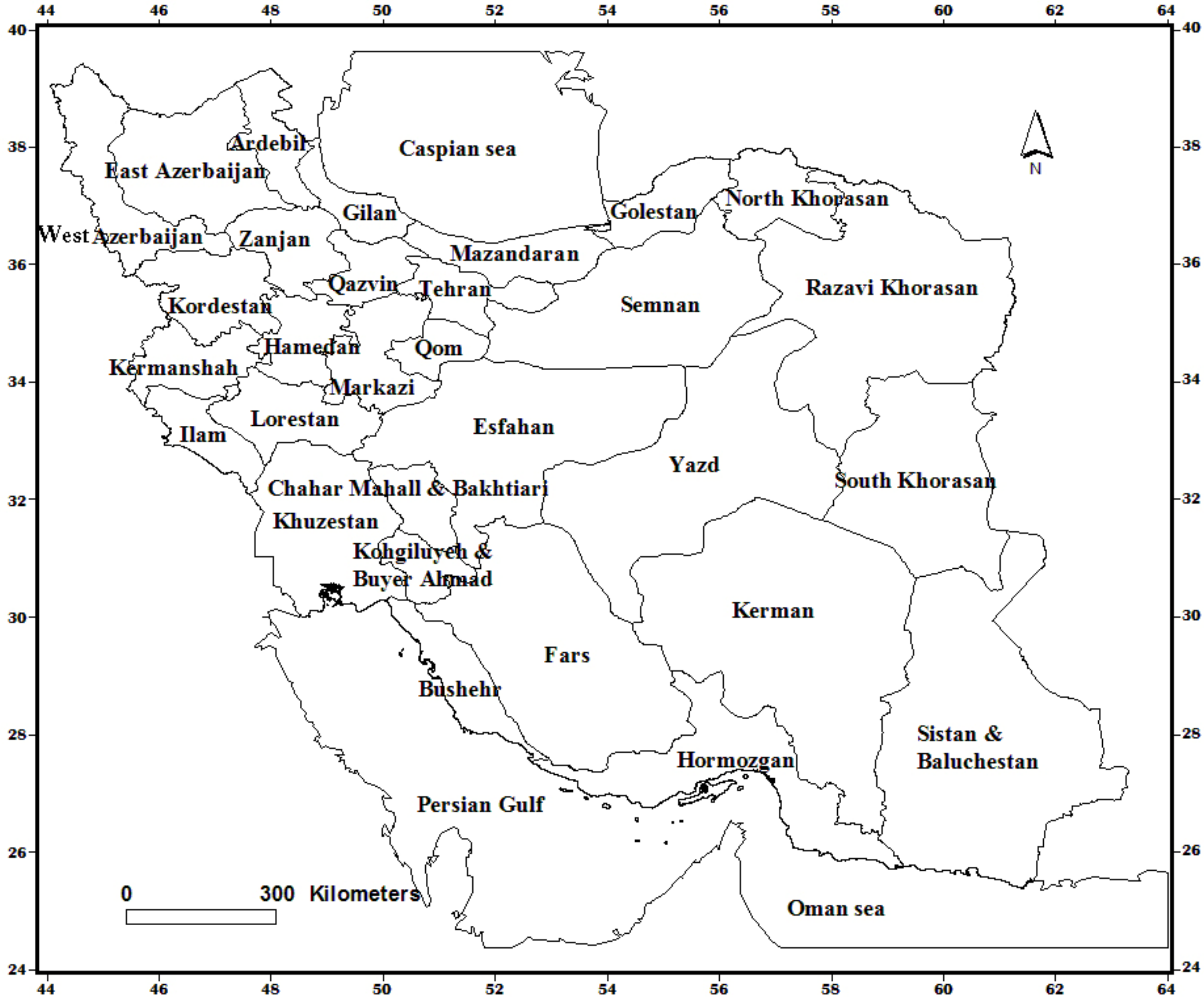

Fig. 1, Iran and its thirty provinces.

desert flora. Iran is not only a center of speciation for many taxa, but also is a highway of floral migrations and distribution from east to west and from south to north (Zohary 1963). Evidence supporting this unique position is the existence of 180 vascular plant families, around 1,200 genera and about 8,000 species in Iran (Yousefi 2006).

Biodiversity plays an important role in the functioning of all natural ecosystems, as well as providing essential resources for human consumption. However, there are evidences showing that during the last millennium, human exploitation of natural resources has led to an exponential loss in plant biodiversity and in the variations existing within communities, species and genes (Hawkes *et al*. 2000). For example, 8457 plant species are currently facing extinction on a global scale (Vě *et al*. 2009). Although numerous species have been described so far, there are still species expected to be discovered. It is the task of biologists to study the biodiversity as a means to conserve it. Since financial supports for conservation studies are limited, it is imperative to maximize the efficiency and do the accurate spatial mapping of the species diversity, which is an essential prerequisite for effectively prioritizing conservation interventions (Maxted *et al.* 2004).

The family *Fabaceae* including 429 species (without counting the genus *Astragalus*) is the second largest family of angiosperm in Iran (Yousefi 2006). The agricultural and economic importance of *Fabaceae* is second only to *Poaceae*. This family includes horticultural varieties and many of its species are cultivated as crops and are used in producing oils, fiber, fuel, medicines, and chemicals.

Geographic information systems (GIS) were used to analyze a large geo-referenced *Fabaceae* database. To suggest some areas for conservation of *Fabaceae* species, areas with greater species richness and endemism using grid cells were determined. Since countries like Iran generally make conservation decisions within political, rather than natural boundaries, in each part of the analysis, grid level results were compared with the existing provinces (Fig. 1).

Species richness was used because it is simple, widely used, well-understood, and is a useful measure of taxonomic diversity (Gaston 1996). It is also less sensitive to the problems associated with the unsystematic sampling intensities and procedures than diversity indices (Hijmans *et al*. 2000). This type of study provides baseline data for further GIS analysis, exploration, conservation, and also for the use of germplasm of the selected species (Guarino *et al*. 2002), as well as for studies of the factors that affect the geographic distribution of these species.

Material and Methods

Flora Iranica (Chrtková-Zertová *et al*. 1979, Rechinger 1984, 1986a, 1986b) as the major taxonomic and nomenclatural reference was used to compile the distribution database for this study. Additional distribution data were also obtained from local Herbaria such TARI, IRAN, CHSFT, FUMH, HCAT and the herbarium of the Shiraz University (Pakravan *et al.* 2000, Zaify 1996, Ghahremaninejad 2004). For some taxa, information given in some recent articles have been adopted (Assadi 1988, Attar *et al*. 2004, Amirabadizadeh *et al*. 2007, Naqinejad *et al*. 2007, Ghahremaninejad & Ghahremani 2008, Amirabadizadeh *et al*. 2009, Badrzadeh & Ghafarzadeh-Namazi 2009).

Specimens from the original database which lacked geographic coordinates were excluded and geographic coordinates were then subjected to an error checking exercise using Map info GIS Software. The final data set used in this analysis contained 10498 accurately geo-referenced entries.

In order to perform the biogeographic analysis, 1° x 1° latitude/longitude squares were used as units of study. This scale size was used because it had already been tested in previous studies on diversity of different groups at country level (Contreras-Medina *et al*. 2007, Del Juarez *et al*. 2009).

Species richness was measured simply as the total count of species within each grid-cell which is also known as unweighted species richness (Linder 2001). Each species was scored as present in a grid cell regardless of the number of times recorded in it (Linder 2001). In addition, to compare the results with the number of observations, the numbers of documented occurrences were also mapped. We also mapped the richness of species endemic to Iran and the number of species restricted only to one grid cell.

Two spatially based quantitative measures of endemism were considered: (1) Weighted Endemism, and (2) Corrected Weighted Endemism (CWE) (Crisp *et al.* 2001, Linder 2001). The first index ‘weighted endemism’, was related to species richness (Crisp *et al.* 2001). The first step was consisted of dividing each grid-occurrence by the total number of grids in which one species occurs. Thus, a species restricted to a single grid was scored as ‘1’ for that grid, and ‘0’ for all other grids, and a species found in four grids, was scored as ‘0.25’ for each of the four grids, and ‘0’ for all remaining grids. From this, the sum of all score species values for each grid was obtained. A second index named ‘corrected weighted endemism’ (Crisp *et al.* 2001), was consisted of dividing the weighted endemism index by the total count of species in each grid cell. So, the second index is seldom correlated with species (Crisp *et al*. 2001). This index emphasizes such areas that are not necessarily high in species richness, but have a high proportion of geographically-restricted species (Del Juarez *et al*. 2009). Weighted endemism is even known as range size rarity (Williams 1996) and can be described as a calculation of the sum of the inverse of range sizes of all species occurring in each grid cell (Williams 1996). It is also referred to as ‘endemism richness’ (Kier 2009).

Those grid-cells with the highest scores in the first index were considered as centers of richness and for the second index as centers of endemic (here restricted) species (Crisp *et al*. 2001, Linder 2001). Grid-cells values obtained for both weighted endemism and corrected weighted endemism indices ranged from 1 to 10. Finally, to reach a more precise conclusion, we mapped the endemic species richness. Geographic distribution maps were obtained using ArcView GIS version 3.2a (ESRI 1999) and DIVA-GIS version 5.2 (URL: http://www.diva-gis.org/) software.

Results

Of a total of 10498 geo-referenced records available at Shiraz University’s Herbarium database, 2776 are based on specimens at Shiraz University’s Herbarium. According to the database, the *Fabaceae* (excluding *Astragalus*) has 66 genera and approximately 429 species in Iran. This family has 117 endemic species, indicating that about one third of its species are restricted to Iran. Some of the largest genera in the database are: *Onobrychis* Miller with 56 species, *Vicia* L. with 52 species, *Trifolium* L. with 45 species,

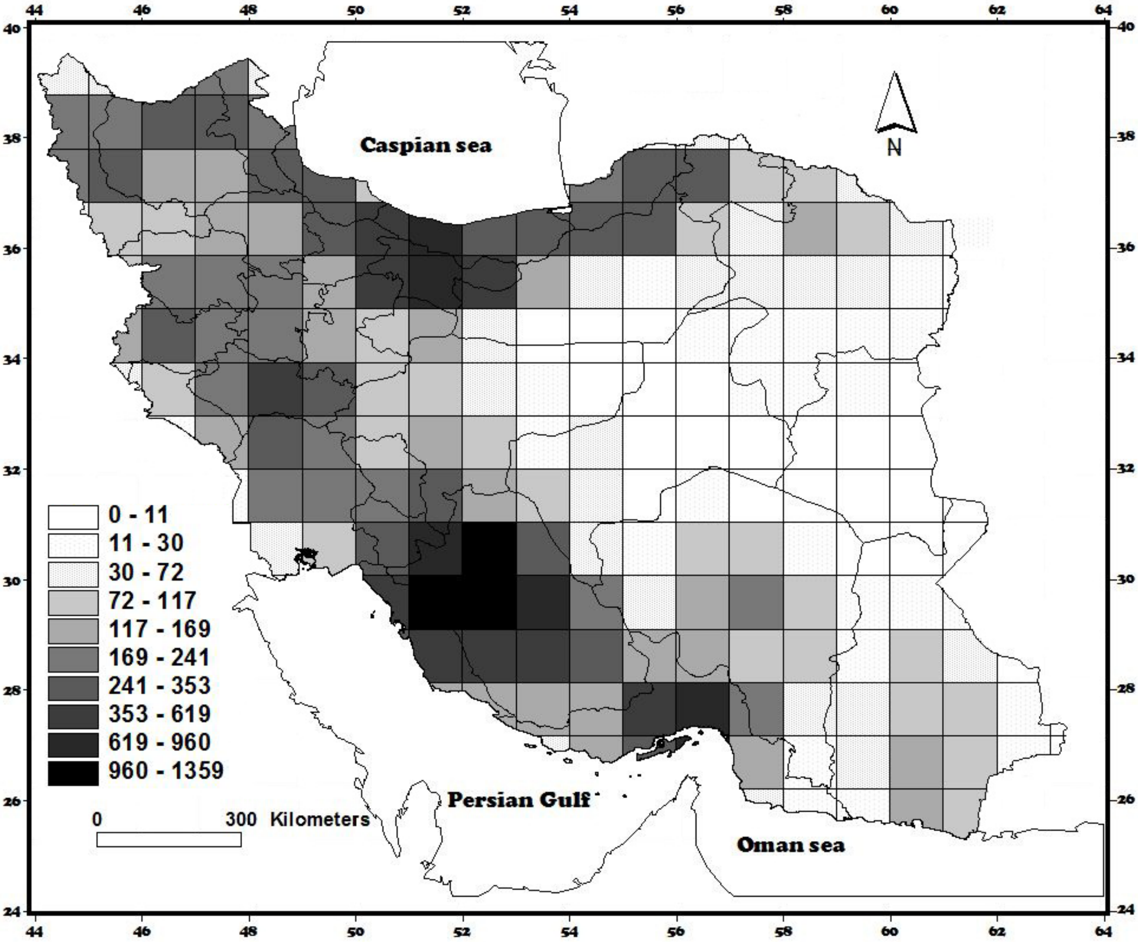

Fig. 2, Number of documented occurences (observations) of Iranian *Fabaceae* per 1°⁑° grid cells.

Oxytropis DC. with 34 species and *Trigonella* L. with 31 species. Genera with one species are: *Aeschynomene* L., *Ammodendron* Fisch., *Ammothamnus* Bunge, *Anagyris* L., *Anthyllis* L., *Caragana* Lam, *Crotalaria* L., *Dalbergia* L. fil., *Dorycnium* Miller, *Ebenus* L., *Eversmania* Bunge, *Faba* Miller, *Genista* L., *Hymenocarpus* Savi, *Lotononis* L. (DC.) Eckl. & Zeyh., *Meristotropis* Fisch. & C. A. May., *Oreophysa* (Bunge ex Boiss.) Bornm., *Podolotus* Benth., *Pseudolotus* Rech. f., *Psoralea* L., *Robinia* L., *Scorpiurus* L., *Securigera* DC., *Sesbania* Adans., *Smirnovia* Bunge, *Spartium* L. and *Sphaerophysa* DC.

Iran was divided into 196 grid cells, 173 of which had at least one record in each. *Trigonella monantha* C.A. Mey., had the greatest number of grid occurrence (64 grid cells). Other well represented taxa were *Onobrychis aucheri* Boiss., *Vicia sativa* L. and *Medicago sativa* L. recorded in 60, 49 and 48 grid cells, respectively. On the other hand, species like *Oxytropis assadliensis* Vassilcz. and *Trigonella caerulea* Ser. were found in just one grid cell.

One complication in using species richness is the presence of conflicting taxonomic classifications (Gaston 1996). However, since in this study a group of plants with a high classification taxa rank (family rank) was used, further changes in species circumscription will not have much effect on the results presented here. This family has a wide distribution in Iran. The *Fabaceae* species are mainly distributed in mountainous regions (Fig. 3). The most species rich grid cells were located in West and Central of Fars province and Central Tehran province with 94, 92 and 92 species, respectively. The grid cells located in Central and West of Fras province have the highest

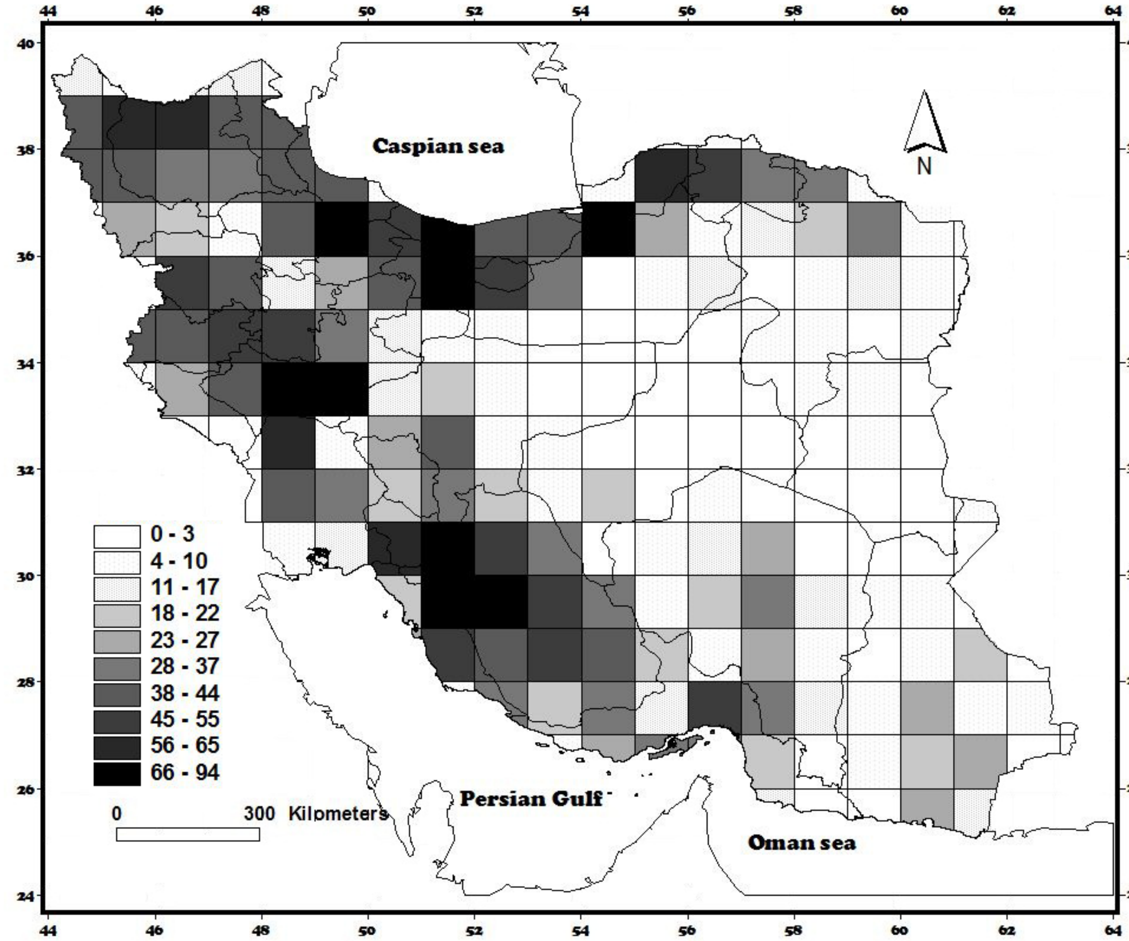

Fig. 3, Species richness of Iranian *Fabaceae* mapped in 1°x1° grid cells.

observation too (Fig. 2). The Tehran province grid cell has been investigated very well over the years and has a high observation level (compare Fig. 2 with Fig. 3). This grid cell along with its northern territory (a grid cell with 82 species) comprises most of the central Albourz region in which the occurrence of high species richness has been reported in a previous study (Noroozi *et al.* 2008).

Other grid cells with high species richness are located in Lorestan, Golestan-Semnan and Qazvin-Zanjan-Gilan provinces (Fig. 3).

Species occurring in a single grid cell are distributed in North and North West of Iran (In West and East Azerbaijan provinces) and along the Zagros mountain ranges. The highest number of these species (6 restricted species) is present in a grid cell located in East Azerbaijan (Fig. 4)

Because of the high correlation between weighted endemism and species richness (Crisp *et al*. 2001), the map of weighted endemism resembles the species richness map (compare Fig. 3 and Fig. 5). Only those grid cells located in North East Iran do not conform to the species richness map and despite their moderate species richness they have high values of weighted endemism (compare Fig. 3 and Fig. 5).

The previous mentioned region has a high level of corrected weighted endemism (Fig. 6). Other grid cells with very high values of corrected weighted endemism are those from North West of Iran, which have higher species richness than the ones from North East of Iran (compare Fig. 3 and Fig. 6).

Most of the endemic species are distributed in North and North East of Iran and also in Fars province grid cells (Fig. 7). Lorestan province has a grid cell with 14 endemic species. The two grid cells located in Tehran and Mazandaran provinces which form the Central Albourz, have the highest number and include 22 and 20 endemic species respectively. The grid cell East of this region has 17 and the one West of it has 15 endemic species. The grid cell located North of Razavi

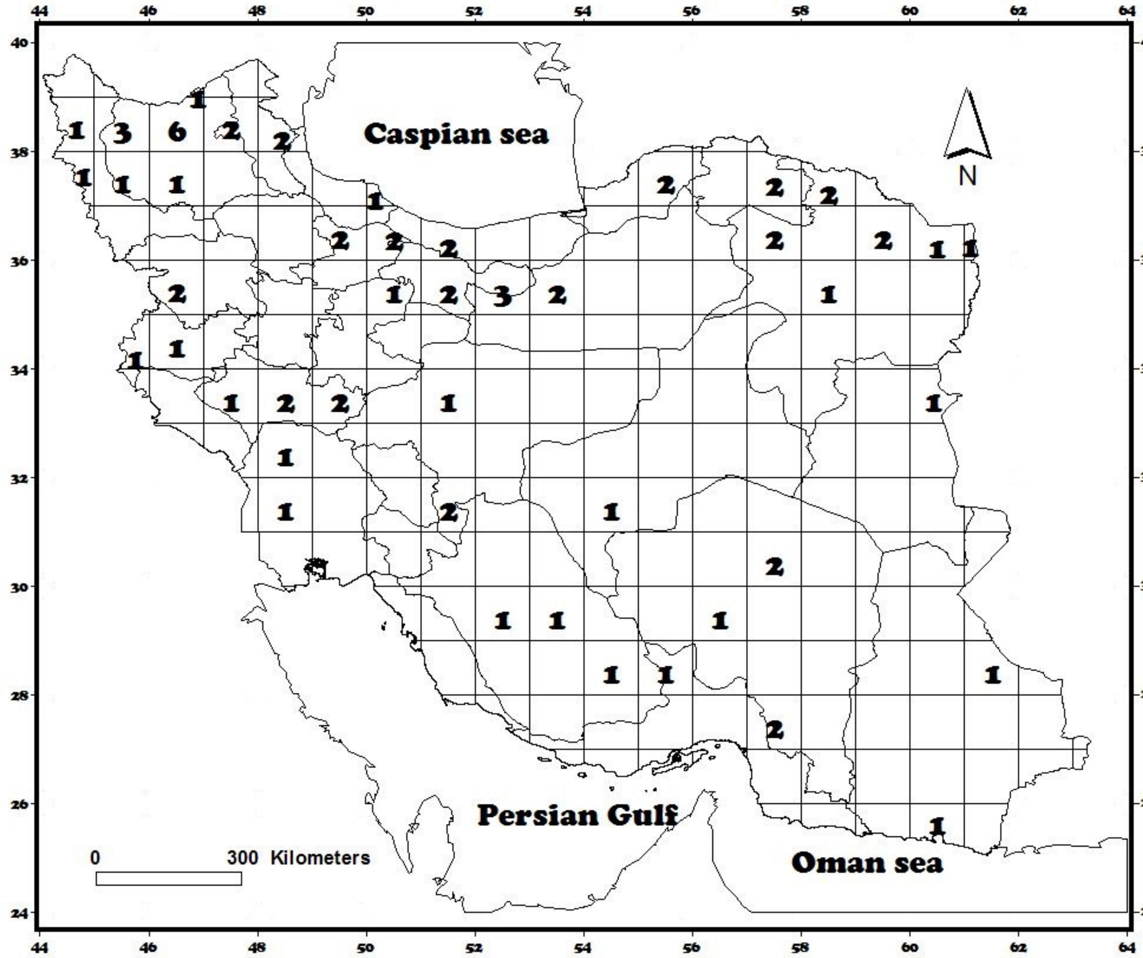

Fig. 4, Species of Iranian *Fabaceae* restricted to one grid cell mapped in 1°x1° grid cells.

Khorasan has 14 endemic species. Here exists a significant congruence between centers of endemism and richness.

Discussion

It can be said that a good representation of overall *Fabaceae* distribution has been represented. Very low observation number (occurrence) was only from the central parts of Iran (Dasht-e Kavir and Dasht-e Lut deserts) which was due to poor road networks, very hot climate and security concerns for the travellers. These deserts are defined as barriers for most of the taxa. These taxa proceed towards the border lines of semi-desert and desert regions and stop there (Wendelbo 1971). On the other hand, the province of Fars has a high number of observations due to the accesses we had of the herbarium of the Shiraz University. This might make a bias in the results, but to be sure, we have to compile more data especially from those areas, which had a low observation.

All high species rich grid cells are located on mountainous region of Alborz and Zagros. This is congruent with Klein (1991) assessments indicating that the Albourz mountains located in the middle of the Irano-Anatolian province acts as a center of speciation and even Zagros mountain ranges and mountainous region of Kurdestan in the west of Iran have a similar function (Klein 1991).

Dividing the weighted endemism by the total number of species in that grid will give the corrected weighted endemism, which is less correlated with species richness (Crisp *et al*. 2001). The corrected weighted endemism index highlights areas with restricted distributions which are not necessarily high in species richness, but unfortunately it is sensitive to poor sampling artifacts. This indicates that there are cells with artificially high values because the sample size is very small but randomly it includes one or more restricted species. This is the case with the grid cell located in the northern region of South Khorasan province which has the highest corrected weighted

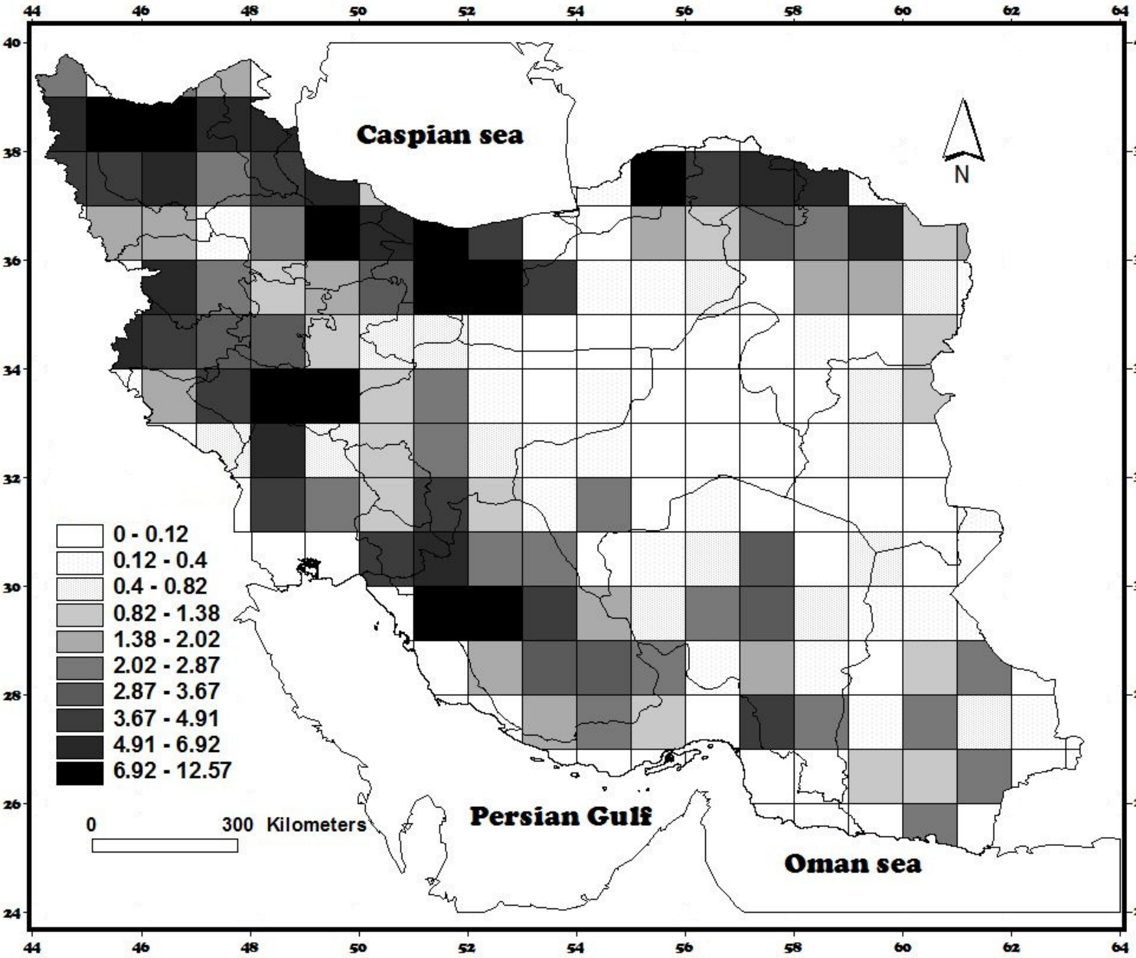

Fig. 5, Weighted endemism of Iranian *Fabaceae.*

endemism and also in Kerman, Sistan & Baluchestan and Ilam provinces (compare Fig. 6 with Fig. 2 and Fig. 4).

For optimal conservation one has to determine optimal locations having maximum species richness, species endemism, and high number of rare species. We used the corrected weighted endemism (for rarity) and the number of endemic species to determine the most important sites.

Results obtained from these maps (Fig. 6 and Fig. 7) highlights the importance of seven locations. These locations contain grid cells with high conservation values. The first location is the Central Albourz (North Iran) which has high species richness, weighted endemism, corrected weighted endemism and the highest number of endemic species. Thus, protected areas located in these grid cells for species richness and endemic species will also tend to encompass a high protection for geographically restricted species.

The other six locations with simultaneous high rarity, endemism and species values are the grid cells located in north and northwest of East Azerbaijan province, east of Lorestan province and a grid cell located among Qazvin, Zanjan and Gilan provinces and the region North of Razavi Khorasan (2 grid cells). These to grid cells have moderate species richness and a high weighted and corrected weighted endemism, which indicates a high rarity value for this region (see Fig. 3, Fig. 5 and Fig. 6). Also they have a high amount of endemic species (Fig. 7). The grid cell located among Fars and Bushehr province has high species richness but is not very important from the aspect of rarity and endemism. The grid cell among Golestan and Semnan province is also important, because it has high endemism species value.

Comparing these locations with the current protected areas reveals that all co-occur. The first two grids comprise the Central Albourz, Varjin and Jajrud Protected Areas, Lar, Khojir and Sorkh-e Hesar National Parks. The second location in East Azerbaijan

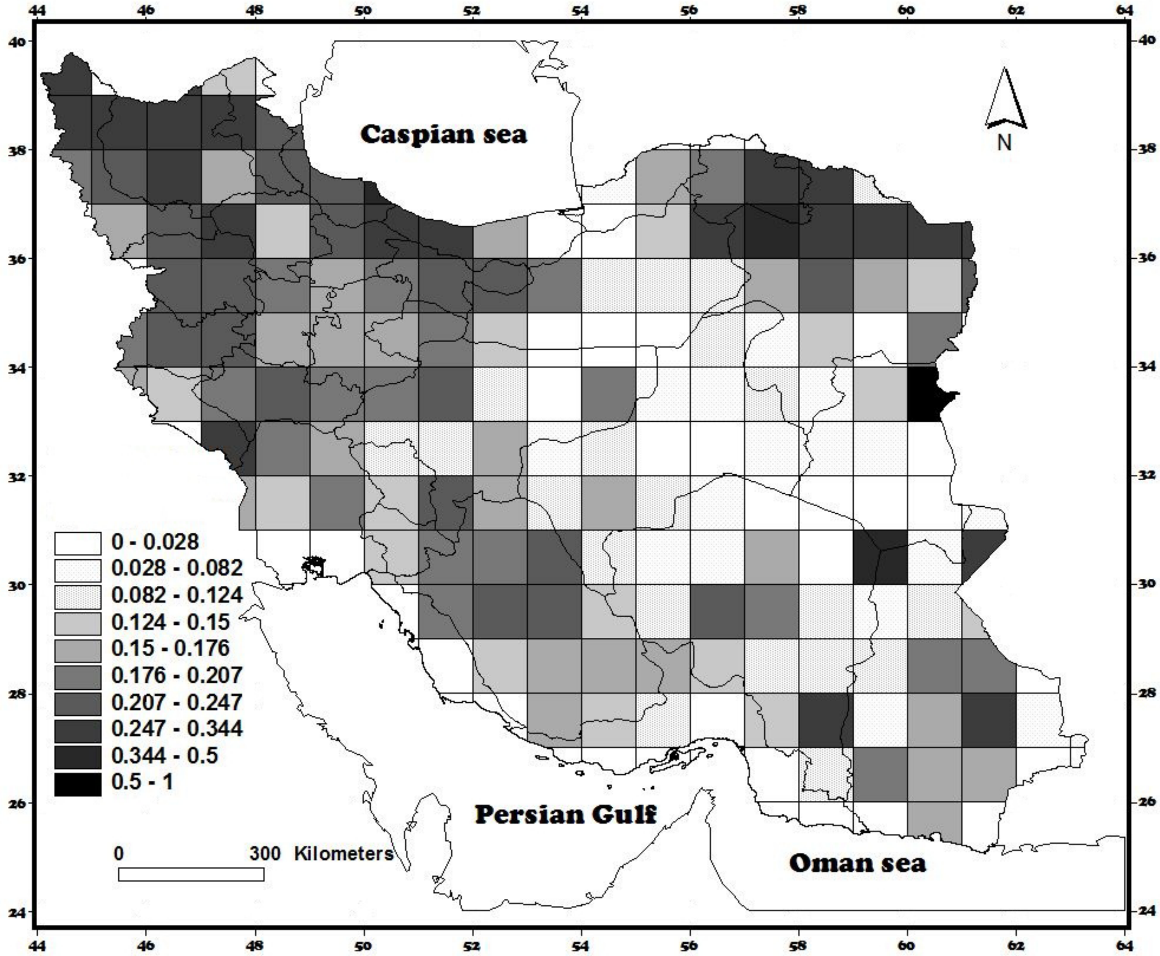

Fig. 6, Corrected weighted endemism of Iranian *Fabaceae*.

includes Kiamaky Wildlife Refuge and Arasbaran and Marakan Protected Areas, the grid cell in Lorestan province contains Oshtoran Kuh and Alvand Protected Areas and Rasband Wild Refugee. The grid cell located among Qazvin, Zanjan and Gilan provinces covers Siah Rud-e Rudbar and Bashgol Protected areas. The grid cells located North of Razavi Khorasan include a great amount of Protected Areas like Sarany, Gharchagheh, Dorbadam, Tandoureh, Ors-e Sistan, Binalood and the Tandooreh National Park. Arjan & Parishan Protected Area occurs in the grid cell located among Fars and Bushehr province. Finally, grid cell located among Golestan and Semnan province makes up the Jahannama Protected Area (Fig. 8).

Studying the efficiency of protected areas needs further information and is beyond the scope of this study. Therefore, for now we are contented that the most important sites related to our study are located in the protected areas.

Considering the high species richness that Iran harbors, a great deal of systematic studies have to be carried out in this country. Even germplasm collection has not received sufficient attention it needs.

As a final point, we suggest further distributional studies for different groups of organisms in Iran. An initial step would be to digitalize herbarium localities and to express them by their coordinates. Thus, if the observations are to be extended to the local herbaria, such as those in Esfahan, FUMH, Kordestan and Tabriz, it would have great impact on the results.

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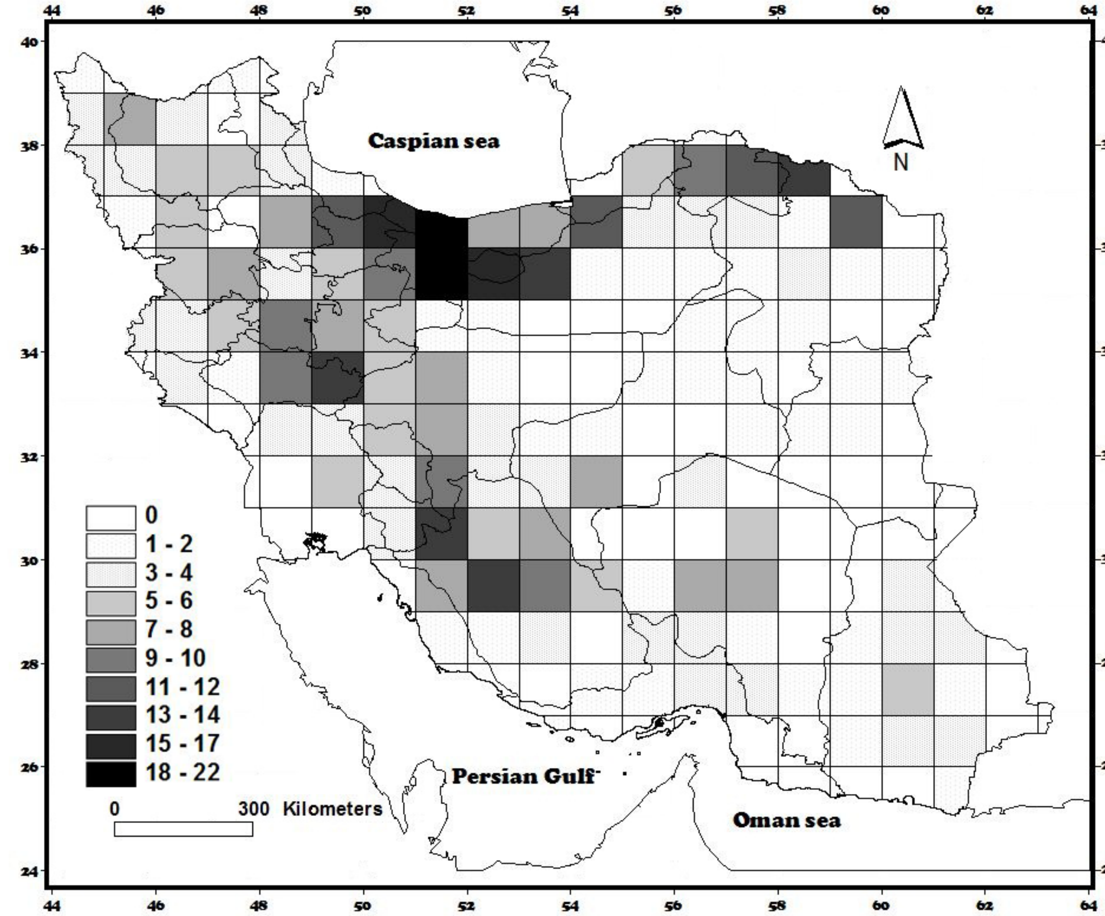

Fig. 7, Number of *Fabaceae* species endemic to Iran mapped in 1°x1° grid cells.

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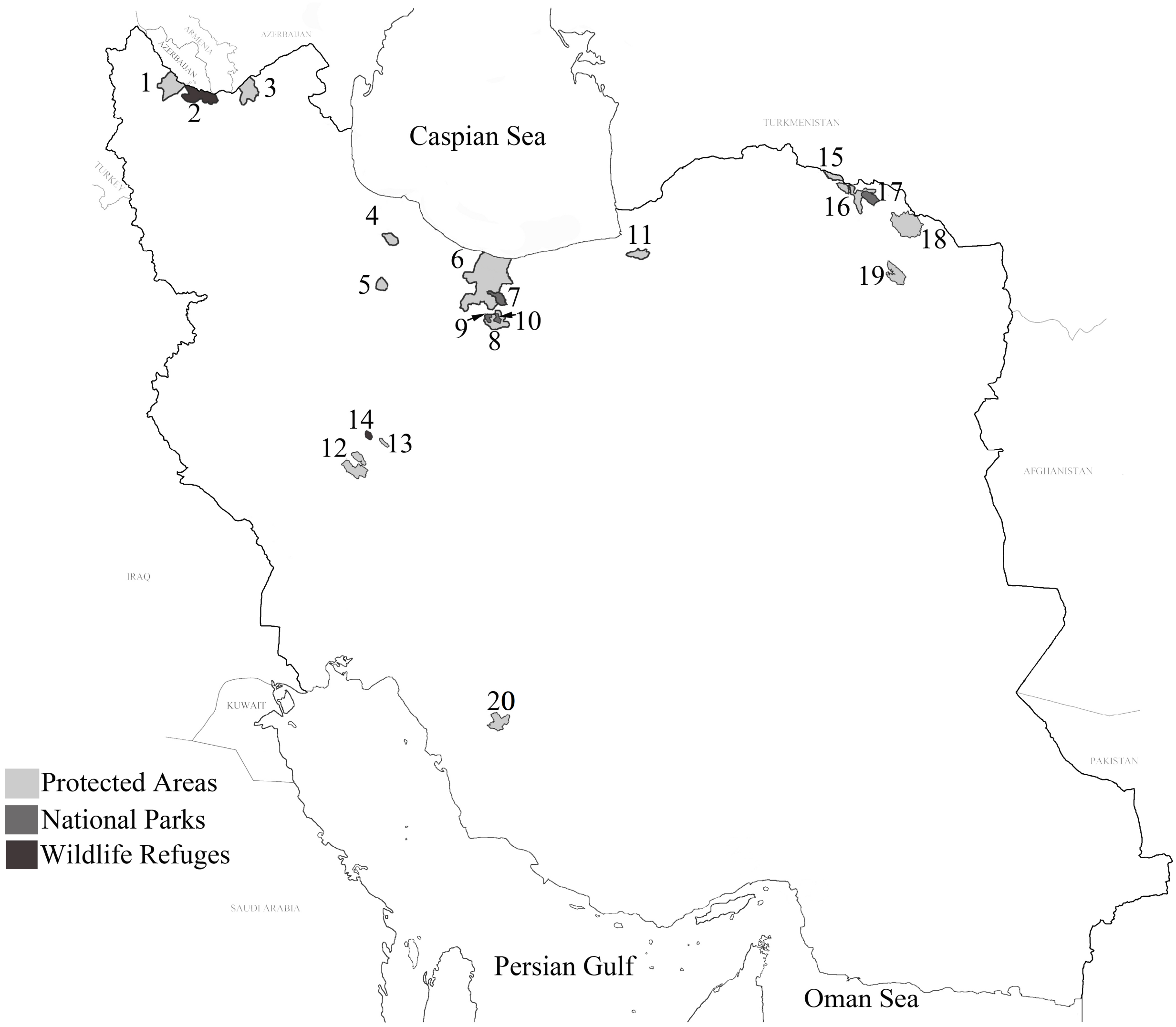

Fig. 8, Location of some Protected Areas in Iran; 1- Marakan, 2- Kiamaky, 3- Arasbaran, 4- Siah Rud-e Rudbar, 5- Bashgol, 6- Central Albourz and Varijin, 7- Lar, 8- Jajrud, 9- Sorkh-e Hesar, 10- Khojir, 11- Jahannama, 12- Oshtorankuh, 13- Alvand, 14- Rasband, 15- Sarany, 16- Gharchagheh, Dorbadam and Tandoureh, 17- Tandooreh, 18- Ors-e Sistan, 19- Binalood, 20- Arjan & Parishan.

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