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# Diversity centers as well as conservation priorities of the genus *Onosma* L. (Boraginaceae) in Iran

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***Keywords***: areas of endemism, Boraginaceae, conservation, important plant areas, species richness.

***Summary***. Conservation of biological diversity is one of the most important issues in conservation biology, so a wide range of quantitative spatial methods have been used to determine the biodiversity hotspots and the conservation priority areas. The main aims of the present study are determining the areas of endemism as well as the centers of diversity of the genus *Onosma* based on the GIE, IPAs, species richness, and AZE-like criteria approaches, to assess the status and priorities of conservation of the mentioned genus in Iran. Based on the findings of this research, centers of species richness, the main areas of endemism, top-ranked IPAs, and AZE-like criteria are situated in the Zagros ecosystems. The comparison of the four approaches used in this study shows that the IPAs and GIE techniques have succeeded in identifying the most important centers of diversity and endemism of *Onosma* in Iran. Considering that this genus with a high percentage of endemic species is one of the most important genera of Iranian flora and only 46 % of the IPAs and areas of endemism specified in the research are located in protected areas, identification and protection of the rest of these areas is one of the prevalent measures needed for conservation of *Onosma* species diversity in Iran.

# Центры разнообразия и приоритеты сохранения рода *Onosma* L. (Boraginaceae) в Иране

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***Ключевые слова***: видовое богатство, ключевые ботанические территории, области эндемизма, сохранение, Boraginaceae.

***Аннотация***. Сохранение биологического разнообразия является одним из наиболее важных вопросов охраны природы. В настоящее время для определения очагов биоразнообразия и ключевых природоохранных зон используется широкий спектр аналитических методов. Основные цели настоящего исследования – выявление очагов эндемизма и центров видового богатства рода *Onosma* в Иране посредством географической интерполяции эндемизма (Geographical Interpolation of Endemism, GIE) и определения ключевых ботанических территорий (Important Plant Areas, IPA), а также оценка состояния и выработка стратегии сохранения рода на территории страны с использованием критериев, разработанных Альянсом за нулевое вымирание (Alliance for Zero Extinction, AZE). Результаты исследования показали, что центры видового разнообразия и основные районы эндемизма рода *Onosma* в Иране расположены в пределах Загроса, что было выявлено главным образом методами географической интерполяции эндемизма и определения ключевых ботанических территорий. Учитывая, что изучаемый род, характеризующийся высоким процентом эндемичных видов, является одним

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из важнейших родов иранской флоры, и только 46 % ключевых участков, в т. ч. очагов эндемизма, выявленных в настоящем исследовании, находятся под государственной охраной, включение максимального числа остальных в сеть ООПТ является наиболее очевидной и действенной мерой для сохранения видового разнообразия *Onosma* в Иране.

## Introduction

Rapidly declining global biodiversity (Myer, 1980) has led to increased rates of permanent damage to natural ecosystems and has reinforced the need for biodiversity data banking (Mutke, Barthlott, 2005). Data banking is the most important step in the planning of conservation priorities (Lovett et al., 2000; Kier et al., 2009). Conserving biodiversity is one of the most important targets of conservation biology (McNeely et al., 1990). Regardless, experts often believe that protection is not possible only through the creation of protected areas or reserves based on classic methods (Wilcove, 1989), so a wide range of quantitative methods has been used to determine the conservation-priority biodiversity hotspots (Myers, 1990).

Species richness (alpha diversity) is one of the most widely used measures to evaluate biodiversity hotspots. In addition to species richness, identifying areas of endemism (AOEs) and endemic diversity are among the most important approaches in evaluating the value of areas for protection. Endemic plants are the natural heritage of nations and represent the phytogeographic position and evolutionary history of the flora of each geographic area. Areas of endemism (AOEs) as one of the main candidates for protection of natural plant diversity have been evaluated by diverse methods such as PAE (Morrone, 1994), AE (Szumik, Goloboff, 2004), and GIE (Oliveira et al., 2015). The Alliance for Zero Extinction (AZE) sites are including the Key Biodiversity Areas (KBAs) that have one or more species listed as Endangered (EN) or Critically Endangered (CR) in the IUCN Red List of Threatened Species. Using AZE-like criteria could be another effective approach in determining protected areas at the regional levels. Recently the identification and conservation of Important Plant Areas (IPAs) have been endorsed according to Target 5 of the Global Strategy for Plant Conservation (GSPC-CBD). IPAs are identified at a national or regional level basis of three consistent criteria: the presence of threatened species, botanical richness, and the presence of threatened habitats (Anderson, 2002).

*Onosma* L. is the third large genus of plants in the borage family, Boraginaceae, with nearly 240 species of the biennial to perennial herbs (Popov, 1950, 1974; Zemskova, Popova, 1991; Jian-Chang et al., 1995; Mehrabian et al., 2013; Cecchi et al., 2016; Mehrabian, Amini Rad, 2018; Mehrabian, Mozaffarian, 2018; Khajoei Nasab et al., 2020a) distributed in mountain steppe of the Irano-Turanian region of Asia along with the Mediterranean region, especially Iran and Turkey (Meusel et al., 1978; Mehrabian, 2015; Cecchi et al., 2016; Khajoei Nasab et al., 2020b; Mehrabian et al., 2022a, b). So far about 69 plant taxa of this genus have been reported in Iran, many of which are endemic to the flora of Iran (Mehrabian, Amini Rad, 2018; Khatamsaz, 2002; Attar et al., 2020). Despite the importance of this genus in the world, there are few geographical and ecological studies on *Onosma* in the world. Mehrabian (2015) assessed distribution patterns and diversity of *Onosma* in Iran. Recently, distribution patterns, diversity, and conservation priorities of *Onosma* in some sections of the northwestern geomorphologic unit and Central Alborz of Iran were investigated (Moradi Zeinab et al., 2019; Khajoei Nasab et al., 2020a, b).

Iran has an exceptional plant species richness in southwest Asia, but so far relatively few comparative studies have been conducted using the IPA, AZE, GIE approaches. Considering the importance of the genus *Onosma*, comprehensive ecological and geographical studies in the species and habitat are necessary to determine the important areas of the diversity of this genus in Iran. The main aims of the present study are to determine the areas of endemism and centres of diversity based on IPAs and AZE-like criteria, to assess the status and priorities of conservation of this genus in Iran.

## Materials and Methods

*Study Area, Distribution and Ecology of the genus Onosma*

Iran as a known country in southwestern Asia located in the dry belt of Asia between 24°–40°N longitude and 44°–64°E latitude, with a total surface area of 1.6 million km$^2$ and a population of about 81/5 million in 2018. The average elevation of Iran is 1305 m a. s. l. and Damavand is the highest peak (5771 m). The country is mostly mountainous (55 %) and is surrounded by several high mountain ranges (Fig. 1). The Zagros mountain range is 1600 km long and is the longest mountain range in Iran. Iran's climate is very diverse due to the vast extension of latitude, the existence of high mountains with extreme climate changes over altitudinal gradients, and the position of Iran between the Arabian desert areas and the eastern Mediterranean regions (Roozitalab et al., 2018). The desert and semi-arid climates are dominant climates due to Iran being located in the Afro-Asian desert belt. The average annual precipitation and average annual temperature in different regions of Iran are highly variable. *Onosma* is distributed in the highland ecosystems of Iran, including the Kopet Dagh in the northeast, the southern slopes of the Alborz, the western and eastern slopes of the Zagros, the Central Iran mountains and part of the Makran Mountains (Mehrabian, 2015) (Fig. 1). The genus is completely absent in desert areas in central Iran, as well as in the coastal areas of Caspian Sea, Persian Gulf and Oman Sea. *Onosma* species are often found in four types of habitats: **1 – Woodland of *Quercus* or *Pistacia-Amygdalus* in the Zagros**. Species are found in this type of habitat at altitudes between 1500–3100 m. Annual rainfall is more than 300 mm. Mediterranean pluviseasonal-continental and Mediterranean xeric-continental bioclimates predominate in these habitats. Species often grow in alkaline and organic matter-rich soils. *O. marivanensis* Mozaff. et Mehrabian, *O. mozaffariani* Mehrabian, *O. sheidaii* Mehrabian, *O. platyphylla* Riedl, *O. bakhteganensis* Mozaff. et Mehrabian, *O. sarvestanica* Mozaff. et Mehrabian and *O. sanandajensis* Mehrabian et Mozaff. are found in these habitats. **2 – Mountain shrub-steppe.** These habitats are often found in the mountain ecosystems of northwestern (West Azarbaijan and Ardabil provinces) and Central Iran (Fars, Kerman and Yazd provinces). The altitude in these habitats is between 2000–3500 m. Mediterranean xeric-continental, Mediterranean pluviseasonal-oceanic and Mediterranean pluviseasonal-continental bioclimates constitute the dominant bioclimatic units in these habitats. *Onosma* species are commonly found in alkaline soils with sandy-loamy or sandy-loamy-clay texture (Moradi et al., 2019). The most prominent species of these habitats are *O. subsericea* Freyn, *O. stenosiphon* Boiss., *O. sabalanica* Ponert. and *O. elwendica* Wettst. **3 – Mountain shrubs-meadow steppe.** These habitats harbor many species of this genus in the uplands of Alborz, Kopt Dagh, Zagros, and parts of Central Iran. Altitude in these habitats varies between 300–3100 m and often has a gentle-steep slope. Mediterranean pluviseasonal-continental, Mediterranean pluviseasonal-oceanic, Mediterranean xeric-continental, and Mediterranean desertic-continental bioclimates are

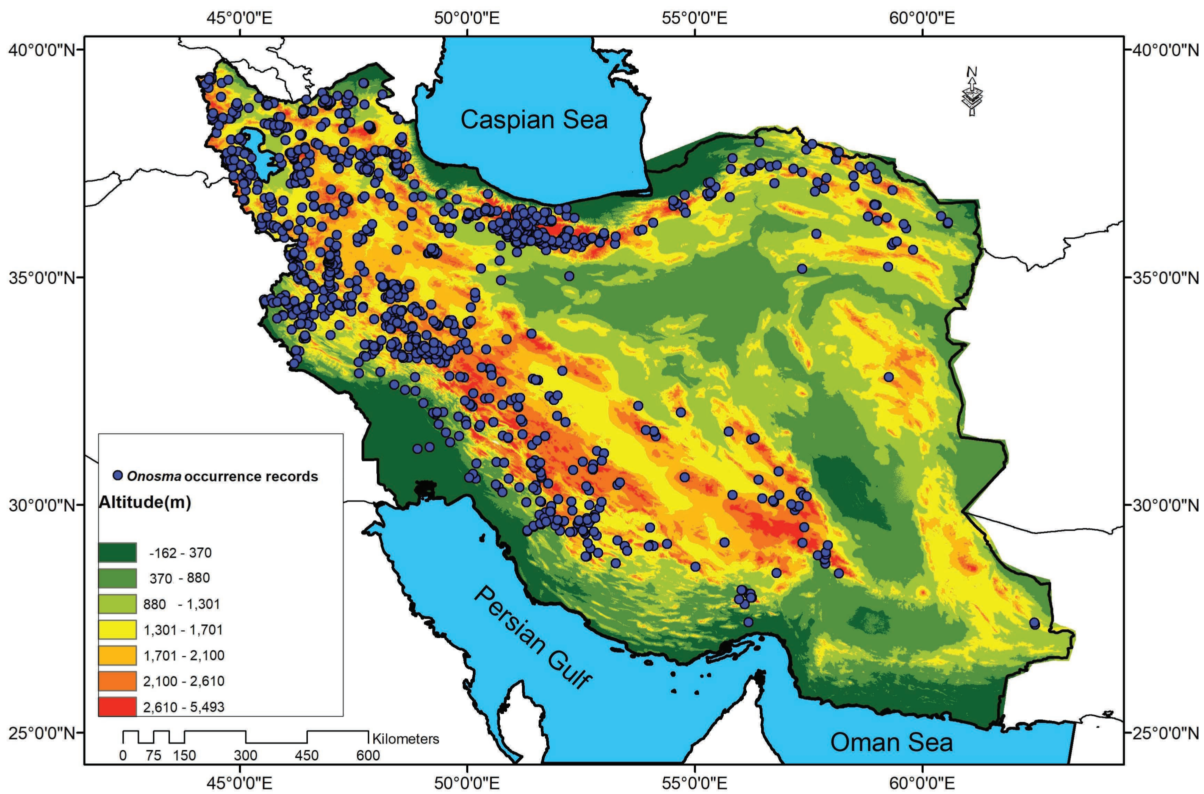


Fig. 1. Map of the study area and Occurrences points of *Onosma* spp. in Iran.

found in these habitats. Species such as *O. gaubae* Bornm., *O. longiloba* Bge., *O. mousavi* Mehrabian et Amini Rad, *O. pachypoda* Boiss., *O. rascheyana* Boiss. and *O. sericea* Willd grow in these habitats. **4 – Wasteland and agricultural habitat.** A small number of species such as *O. straussii* Khatamsaz and *O. bulbotricha* DC. are found in this habitat.

## Methods

*Data banking*

We prepared a geo-referenced database of *Onosma* species from all sites of this genus reported in Iran. The main distribution data sources include historical data available in "Flora Iranica" (Riedl, 1967), "Flora of Iran" (Khatamsaz, 2002), information provided by recently published articles (Ranjbar, Almasi, 2015; Mehrabian et al., 2013, 2018a), and recent data obtained from our fieldworks during 2009–2018 (acronyms according to Thiers, 2019). In this study, more than 400 surveys were conducted in 300 areas across 27 provinces of Iran. The "Flora Iranica" as well some new Iranian literature (e. g. Mehrabian et al., 2013; Mehrabian, Amini Rad, 2018; Mehrabian, Mozaffarian, 2018) and the website of Tropicos (www.Tropicos.org) and IPNI (www.IPNI.org) were used to determine nomenclature and species description information.

### IPAs and AZE sites

In biological conservation studies, the grid-based ranking system has been widely used to determine the patterns of biodiversity (McAllister et al., 1994), hotspots of species richness (Lawton et al., 1994), areas of endemism and recently in the identification of the important plant areas (Al-Abbasi et al., 2010; Dagher-Kharrat et al., 2018). The important plant areas (IPAs), total species richness, and endemic species richness of the genus *Onosma* were mapped in 0.25° × 0.25° resolution Universal Transverse Mercator (UTM) grid cells using Geographic Information System (ArcView vs.10.3). We applied the methodology available in Plantlife International guidelines (Anderson, 2002) and other methodologies used in the recent studies (Marignani et al., 2014; Dagher-Kharrat et al., 2018) to identify IPAs worldwide. Plantlife has established three criteria to qualify IPAs following Criterion A (threatened species), Criterion B (botanical richness), and Criterion C (threatened habitats). We used the scoring method to determine the rank of each grid using the three calculated criteria (A, B, C), combined all scores for each grid cell and ranked them. One of the measured indices used here is botanical richness (criterion B) which refers to the number of plant species present in each grid cell which is useful for measuring taxonomic diversity (Gaston, 1996). The richness index was obtained by calculating the species richness of each grid cell and ranking the cells into five levels from 0 to 5 using the Jenks natural breaks classification method (Supplementary). The presence of threatened species in each cell (specific index (SP_ index)) was also calculated (Supplementary). The list of species that satisfy criterion A or SP_ index was based on three arbitrary scales: I. IUCN red list of species. II. Rarity. III. Endemism. The red list of species was assessed based on IUCN criteria at the regional scale (IUCN, 2011) calculated by Kew GeoCAT (http://geocat.kew.org/; Buchman et al., 2011) and species were assigned to one of the following categories: Least Concern (LC), Data Deficient (DD), Near Threatened (NT), Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) (Supplementary). Then a different score was given to each red-list category according to their importance i.e. 0 = Least Concern (LC), 1 = Vulnerable (VU), 2 = Endangered (EN) and 3 = Critically Endangered (CR). Species rarity was calculated using the index of species rarity (RI) (Supplementary). The RI was computed as the inverse of the cell numbers, including the target area, as RI = 1/Ci, where Ci is the number of grid cells and l is the number of taxa present (Selvi, 1997; Sapir et al., 2003) (Supplementary). The three categories and scoring based on this index were: very rare = 2, rare = 1, not rare= 0. Endemism levels for any species were as follows: endemic of three, two, and one phytogeographical provinces in Iran were scored 3, 2, and 1, respectively, and non-endemic species were scored 0 (Supplementary). The threatened habitats or habitat index (HAB_index) was based on the uniqueness and severity and the importance of each habitat during our fieldwork. Woodland of *Quercus* or *Pistacia – Amygdalus* were scored 4, Mountain shrub-steppe were scored 3, Mountain shrubs-meadow steppe was scored 2, Mountain meadow steppe was scored 1, Wasteland and agricultural habitat were scored 0. Finally, the IPA index was obtained from the sum of the points of these three indices (Supplementary). We identified AZE sites using three criteria Irreplaceability, Discreteness, and Endangerment (Langhammer, 2007). AZE sites were mapped using the number of endangered and critically endangered species in each grid cell 0.25° × 0.25° using Diva-GIS software.

**Areas of Endemism (AOEs)**

Most of the methods used to identify areas of endemism like PAE (Morrone, 1994) and AE (Szumik, Goloboff, 2004) use grid cells as spatial units that the size of these cells which can affect the results. Also, when a species occurs at the edges of the cells, assigning this species to a cell can also change the results. Using neighboring grid cells grouping techniques can solve the problems associated with using grid-based methods. We applied the Geographical Interpolation of Endemism (GIE) method to delimit areas of endemism of *Onosma* in Iran. This method was first proposed by Oliveira et al. in 2015. The GIE includes neighboring grid cells methods and identifies the areas of endemism by estimating the overlap between the distribution of species through a kernel interpolation of centroids of species distributions (Oliveira et al., 2015). Areas of endemism were identified using the GIE method in the ArcGIS software ver.10.3.

## Results

In total, our database of *Onosma* populations contained of 1625 entries recording the presence of this genus in different parts of Iran (Fig. 1). The species richness map shows that mountainous regions of Iran such as Alborz, Zagros, Kopet Dagh, and the mountain range of the central and southern Iran are among the most desirable habitats of this genus (Fig. 2). According to our analysis the probability of the presence of this genus in the lowland and desert areas such as the central parts of Iran and the northern and southern coastal strip is zero, and so far no species has been reported in these areas. We categorized the species richness map cells into five groups of 1 to 12 species. The highest species richness (12 species) of this genus occurred in one grid cell in the parts of the Central Zagros, namely, Dalahu County in Kermanshah province (Fig. 2). Also, two grid cells have 8 to 10 species: a cell located in Doruod of Lorestan

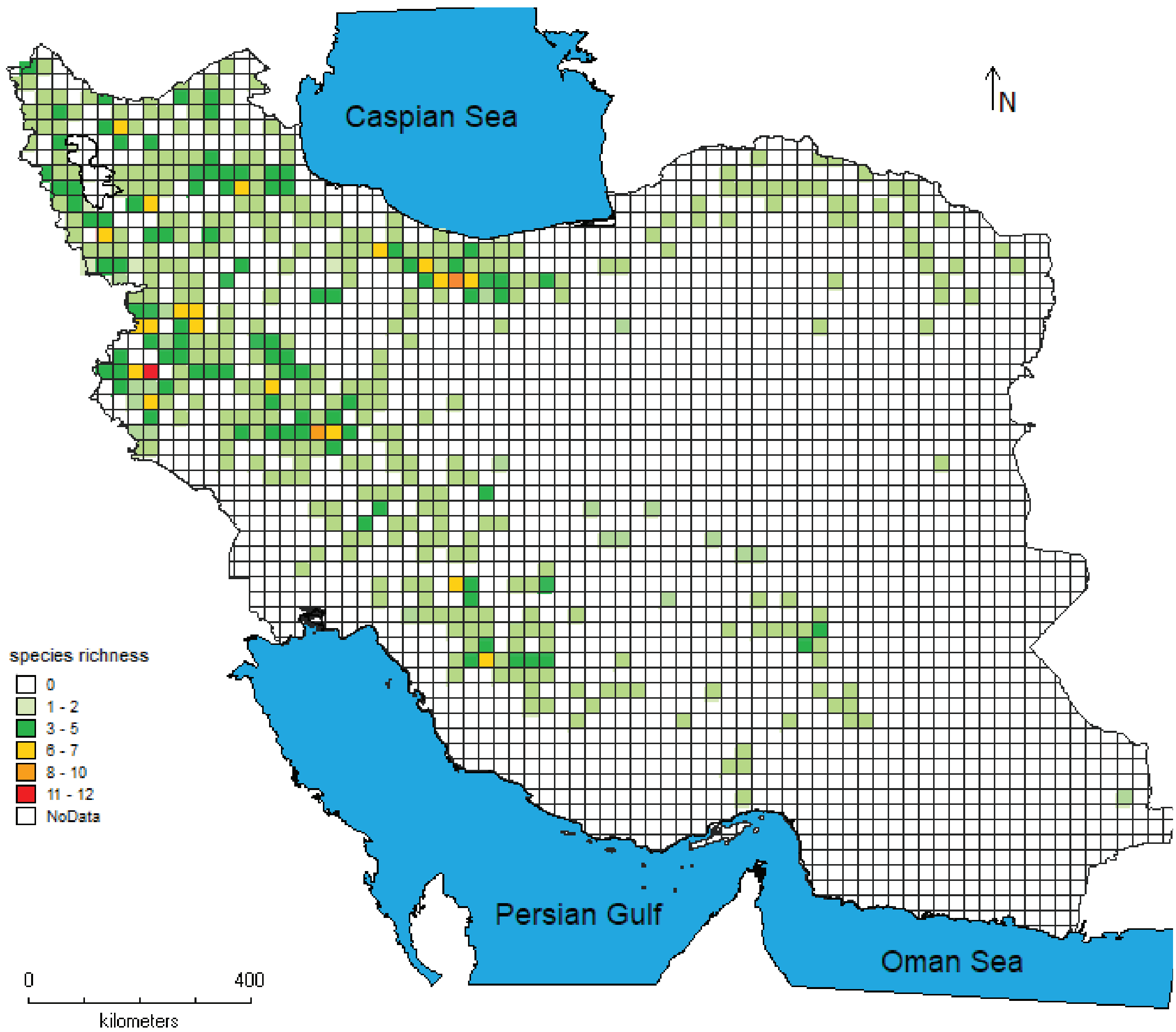


Fig. 2. Species Richness map of the genus *Onosma* in Iran.

province and the other located at the border between Tehran and Karaj. In addition, 19 grid cells have 6–7 species, often concentrated in the northern, western, northwest, and south-western parts of Iran. The Alborz and Zagros mountains in the north, northwest, and parts of southern Iran contain 91 grid cells with 3–5 *Onosma* species. The map of endemic species richness was categorized into four groups of 1 to 4 species (Fig. 3). The highest endemic species richness occurs in two cells (4 species) in Lorestan province and followed by 4 grids in Lorestan province, two cells in Kermanshah province, two cells in Central Alborz, and two cells in Fars province each with three endemic species. There are also 22 cells in Zagros ecosystems, 3 cells in central Alborz, one cell in Azerbaijan, and 2 cells in southeastern Iran, each of which has two *Onosma* endemic species.

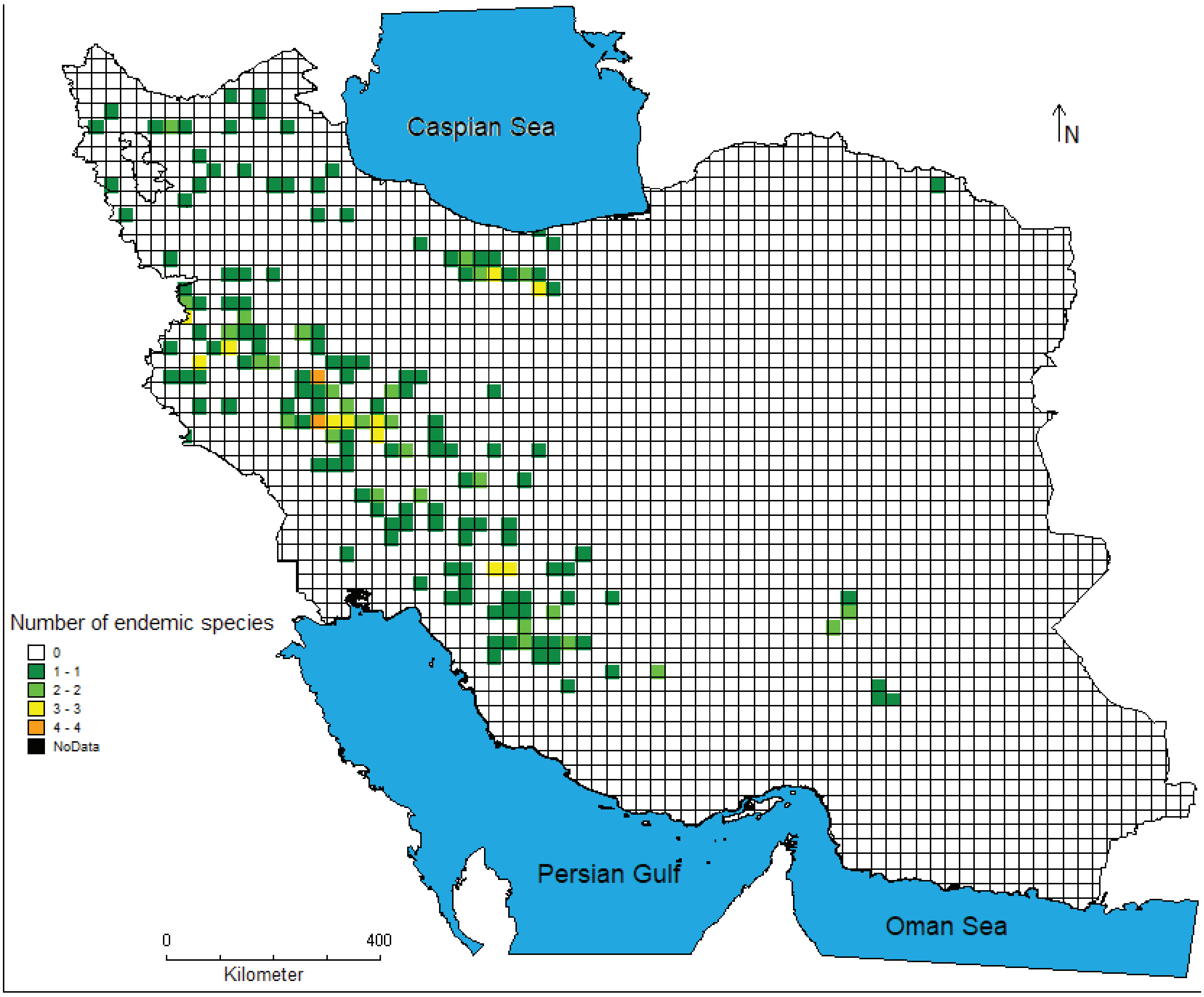


Fig. 3. Endemic Species Richness map of the genus *Onosma* in Iran.

**IPAs and AZE sites**

Based on the findings of this research, the IPA index values ranged between 2 to 28, which was classified into five groups ranging from very high to low values using the Jenks natural breaks classification method (Fig. 4). According to this method, 12 grid cells are in class 5 (very high value), 23 cells into the class 4 (high value), 32 grids into the class 3 (important value), 89 cells in class 2 (medium value), and the remaining cells into the class 1 (low value). Information about the top-ranking cells are listed in Table, and this table shows that 67 % of the grid cells (8 cells) with very high IPA value are located in the Zagros Mountains and Kermanshah province has the largest number of grid cells of class 5. Parts of the Central Alborz, i. e. Tehran and Alborz provinces, include 0.25 % (3 grid cells) of the very high value of the IPA index as well as a small part of northwest Iran located between the Alborz and the Caucasus Mountains in Ardebil province. We identified AZE sites using the number of endangered and critically endangered species in each grid cell. The highest value of AZE sites exists in a cell at the border of Lorestan and Hamedan provinces (5 species) followed by a cell in Fars province (4 species) and 7 cells in the Zagros Mountains with 3 species (Fig. 5). Comparison of the map of protected areas of Iran, IPAs, and AZE sites shows that only 6 top-ranked IPAs and AZE sites (46 % of all) are located in the officially protected areas of Iran (Fig. 6). There are 5 cells in protected areas and one cell in the wildlife refuge.

Table

List of the 12 top ranked IPAs. Each IPA is characterized by its IPA-INDEX, species index (SP_INDEX); species richness (SP_RICHNESS); RICHNESS_INDEX; habitat index (HAB_INDEX)

| Grid Number | IPA INDEX | SP_RICHNESS | Richness INDEX | Sp-INDEX | Hab INDEX | Province |
|---|---|---|---|---|---|---|
| 1 | 28 | 11 | 5 | 16 | 7 | Kermanshah |
| 2 | 26 | 3 | 2 | 17 | 7 | Kermanshah |
| 3 | 26 | 4 | 2 | 17 | 7 | Kurdistan |
| 4 | 23 | 7 | 3 | 15 | 5 | Kermanshah |
| 5 | 20 | 6 | 3 | 11 | 6 | Kurdistan |
| 6 | 19 | 4 | 2 | 14 | 3 | Tehran |
| 7 | 18 | 9 | 4 | 11 | 3 | Alborz-Tehran |
| 8 | 18 | 7 | 3 | 8 | 7 | Kurdistan |
| 9 | 16 | 6 | 3 | 10 | 3 | Alborz |
| 10 | 16 | 9 | 4 | 8 | 4 | Lorestan |
| 11 | 15 | 3 | 2 | 8 | 5 | East Azarbaijan |
| 12 | 15 | 5 | 2 | 9 | 4 | Lorestan |

**Areas of Endemism (AOEs)**

The GIE method was identified four main areas of endemism for this genus in Iran (Fig. 7). The two major areas of endemism of the genus *Onosma* are situated in the Zagros Mountain, i.e. AOE1 and AOE2. These regions have the highest Kernel index, and then the two areas in the Central Alborz (AOE3) and Ardabil-West Azarbaijan provinces (AOE4) have the highest rates of this index. AOE1 is located in the middle parts of the Central Zagros. The area covers the major parts of Lorestan, Hamedan and Markazi provinces. **AOE1** is influenced by seven endemic species. *O. asperrima*, *O. kotschyi*, *O. platyphylla*, *O. bilabiata* Boiss., *O. straussii*, *O. chrysochaeta* Bornm. and O. *kilouyense* Boiss. et Hausskn. are found in this area. Moving northwest, the next AOE identify in Kermanshah and Kurdistan provinces. **AOE2** is the richest area of endemism, which harbors 10 species of all Iranian *Onosma* endemics. All species in AOE1 present in this area except *O. asperrima* and *O. chrysochaeta*. In addition, there are five local endemic species named *O. iranshahrii* Ghahreman et Attar, *O. bisotunensis* Attar et Hamzeh'ee, *O. sheidaii*, *O. sanandajensis* and *O. marivanensis* in this area. **AOE3** occupies most of the Central Alborz region. This area is located in the provinces of Alborz, Tehran and Mazandaran. AOE3 is influenced by four endemic species, i. e. *O. pachypoda*, *O. gaubae*, *O. chrysochaeta* and *O. kilouyense*. In this area, there are two endemic species of Alborz, namely *O. pachypoda* and *O. gaubae.* The northernmost area, named **AOE4**, is located in the provinces of Ardabil and West Azarbaijan. This area is defined by influence from four endemic species: *O. chrysochaeta*, *O. ilabiate*, *O. sabalanica*, and *O. assadi*.

**Discussion**

The results of the present study show that high species richness, the main areas of endemism, top-ranked IPAs, and AZE sites of this taxon are situated in the Zagros ecosystems. The Zagros mountains have been identified as important centres of species richness and areas of endemism for many important plant species in Iran (Hedge, Wendlbo, 1978), including some alpine plant species and subgroups of true subnival and nival plants in Iran (Noroozi et al., 2008, 2011), endemic trees and shrubs (Mehrabian et al., 2020) and the genus *Acantholimon* (Khajoei Nasab, Khosravi, 2020). Special topographic heterogeneity, high annual rainfall, dominant Mediterranean

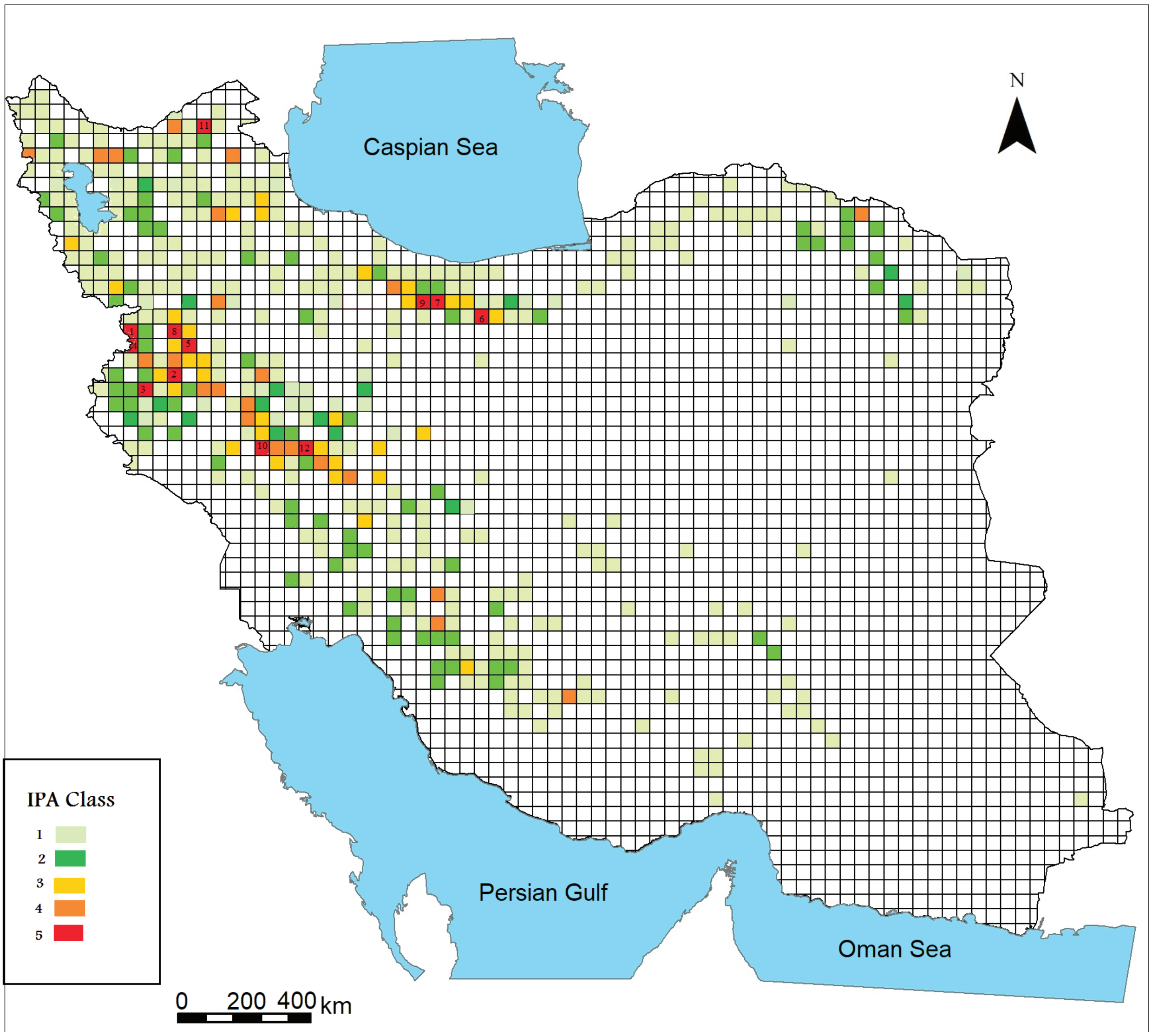


Fig. 4. IPA map of the genus *Onosma* in Iran.

pluviseasonal-continental (Djmali et al., 2011) in Zagros have led to high plant diversity and the creation of various habitats including oak forests, shrubs and grasslands and other types of habitats. The existence of these diverse habitats across the high mountain range has led to an increase in species richness and the number of local endemic species of this genus such as *O. mozaffariani* Mehrabian and *O. sheidaii* Mehrabian. In addition, three top-ranked IPAs and one area of endemism are located in the central Alborz region. The Central Alborz ecosystems, including important centers of speciation and endemism in Iran (Hedge, Wendlbo, 1978). This pattern corresponds well with the Alborz distribution pattern of endemism of montane/Alpine area of Irano-Touranian region (Hedge, Wendlbo, 1978; Noroozi et al., 2008, 2011, 2018; Khajoei Nasab, Khosravi, 2020). As well as one IPA and area of endemism have been identified in Ardebil province. Northwest Iran is an important center of speciation of plants in the country which is considered as the Atropatanean province of Irano-Turanian region. This area is located in the intersection of the Alborz, the Zagros and the Caucasus mountain ranges. In addition, mentioned area covers two different bioclimatic zones following Mediterranean xeric-continental (Mxc) and Mediterranean pluviseasonal-oceanic (Mpo) (Dajmali et al., 2011), so mentioned conditions created special habitats for various of the endemic species of *Onosma* such as *O. sabalanica* Ponet. as well as the Asteraceae family (Noroozi et al., 2018). The comparison of the four approaches used in this study (IPAs, AZE sites, GIE, and Species Richness) shows that the IPAs and GIE techniques have succeeded in identifying the most important centres of diversity and endemism of *Onosma* in Iran. The highest species rich-

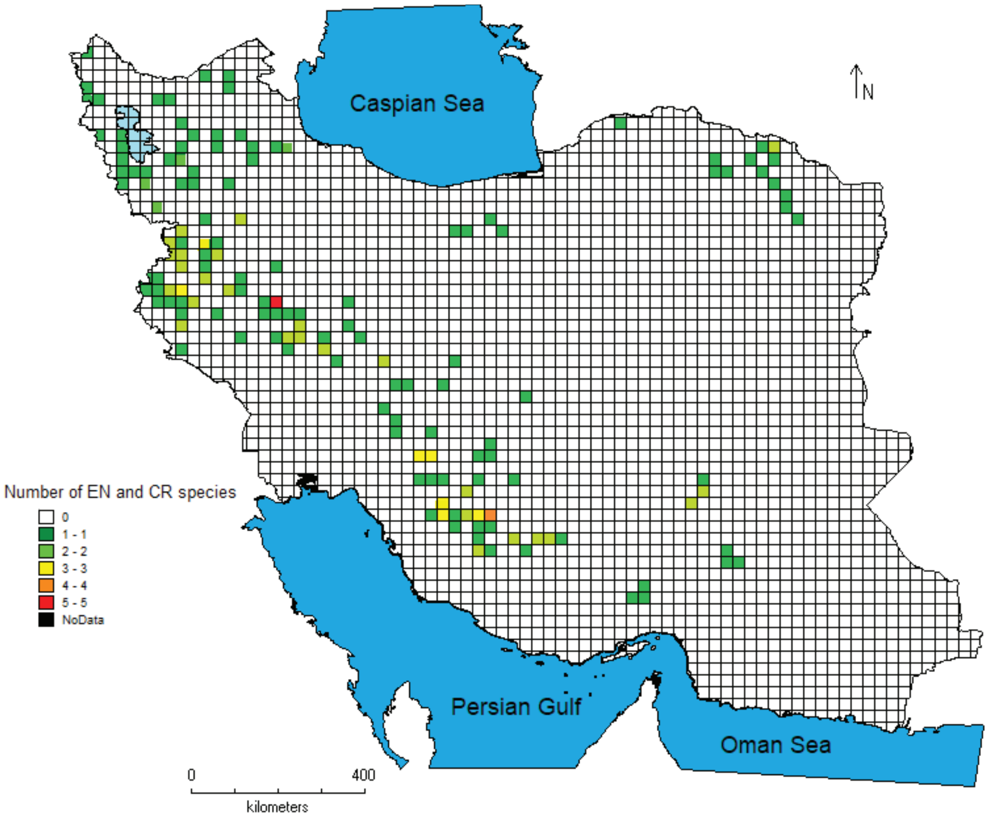


Fig. 5. AZE map of the genus *Onosma* in Iran.

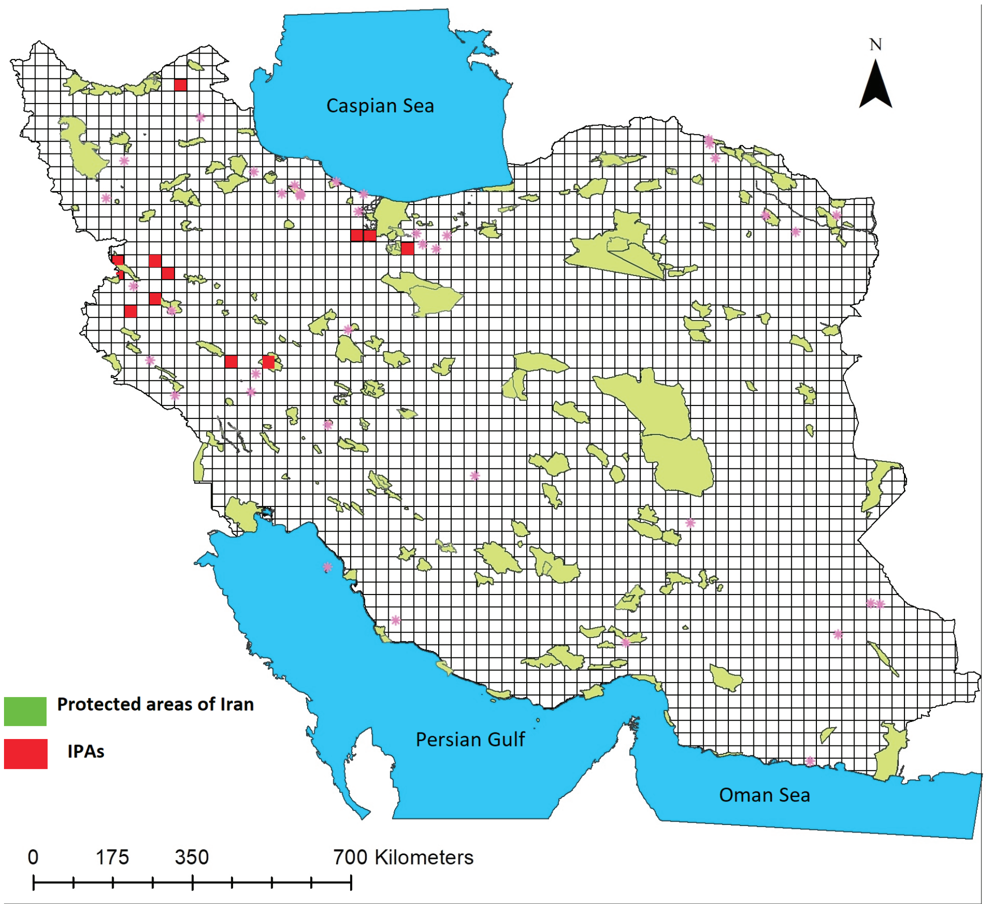


Fig. 6. Comparison of the map of protected areas of Iran and IPAs, AZE.

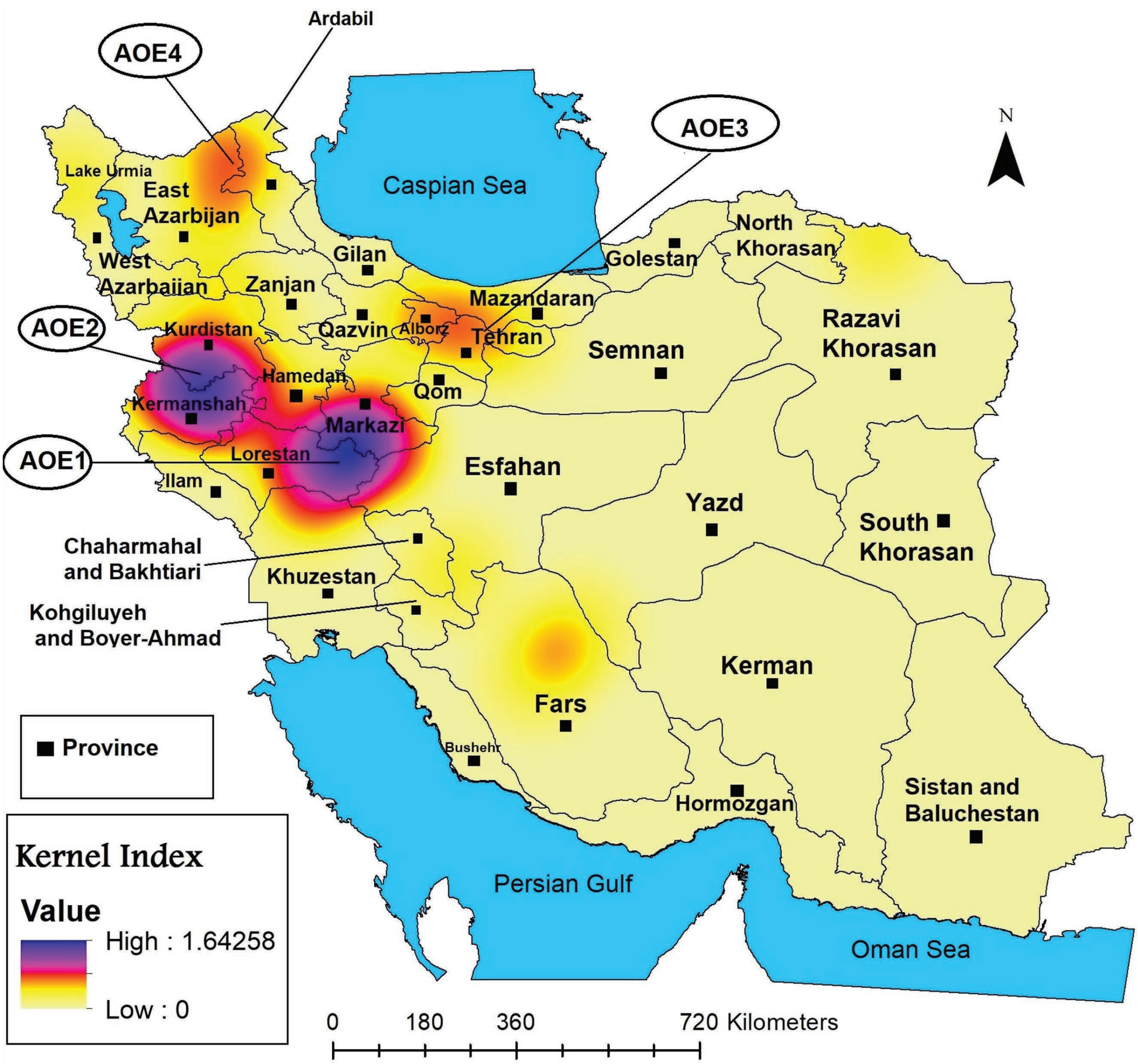


Fig. 7. Areas of endemism of *Onosma* in Iran, identified using GIE.

ness is associated with the highest IPAs index that occurred in Dalahu county. However, in a number of top-ranked IPAs, IPAs index does not show correlation with species richness (see IPAs and richness maps) due to the presence of grid with the high species index or presence of important habitats in some cells with lower species richness. Also by examining IPAs, AZE sites, total species richness and endemic species richness maps reveal that endemic species or endangered and critically endangered species don't necessarily exist where the total number of species is greater, so it is natural that the high IPAs index is not associated with the high richness index in some cells. Some studies in this field have the same result. For example, a study done on bryophyte diversity in the Peneda-Gerês National Park (Portugal) indicated that high species richness associated with high IPAs index, but this does not apply to all grid cells (Sérgio et al., 2012). Species richness is a key criterion in biogeographical studies and conservation strategies but alone is not enough to provide a comprehensive assessment of plant diversity.

## Conclusion

According to the findings of this research, we suggest that all the areas marked with these four approaches should be protected. We consider that this genus with a high percentage of endemic species is one of the most important genera of Iranian flora and only 46 % of the IPAs and areas of endemism specified in the research are located in protected areas, therefore, identification and protection of these areas are one of the most prevalent conservation planning. Finally, we suggest that plant protection research can not only be based on one approach and a new combination of quantitative methods should be used for conservation planning in the flora of Iran.

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Supplementary

The list of species that satisfy criterion A or SP_ index was based on three arbitrary scale: I. IUCN red list of species. II. Rarity III. Endemism.

| Species | IUCN score | Rarity score | Endemism score | Endemism chorology | The extent of occurrence (EOO) | RI |
|---|---|---|---|---|---|---|
| *Onosma albo-rosea* Fisch. et C. A. Mey. | 0 | 0 | 0 | 0 | LC | 0.1 |
| *Onosma ambigens* Lacaita | 1 | 2 | 0 | 0 | VU | 0.5 |
| *Onosma armena* DC. | 0 | 0 | 0 | 0 | LC | 0.09 |
| *Onosma asperrima* Bornm. | 0 | 0 | 1 | 3 | LC | 0.07 |
| *Onosma assadi* Mehrabian et Mozaff. | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma azarbaidjanensis* Mehrabian. | 2 | 2 | 3 | 1 | EN | 1 |
| *Onosma bakhteganensis* Mozaff. et Mehrabian | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma bilabiata* Boiss. | 0 | 1 | 2 | 2 | LC | 0.14 |
| *Onosma bisotunensis* Attar et Hamzeh'ee | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma bodeana* Boiss. | 0 | 0 | 0 | 0 | LC | 0.08 |
| *Onosma bulbotricha* DC. | 0 | 0 | 0 | 0 | LC | 0.03 |
| *Onosma caerulescens* Boiss. | 1 | 2 | 0 | 0 | VU | 0.5 |
| *Onosma cardiostegia* Bornm | 0 | 1 | 0 | 0 | LC | 0.12 |
| *Onosma chlorotricha*Boiss. | 0 | 0 | 0 | 0 | LC | 0.07 |
| *Onosma chrysochaeta* Bornm. | 1 | 1 | 2 | 2 | VU | 0.33 |
| *Onosma cornuta* H. Riedl. | 0 | 0 | 0 | 0 | LC | 0.07 |
| *Onosma dasytricha* Boiss. | 0 | 0 | 0 | 0 | LC | 0.05 |
| *Onosma demawendica* Riedl | 1 | 1 | 3 | 1 | VU | 0.25 |
| *Onosma dichroantha* Boiss. | 0 | 0 | 0 | 0 | LC | 0.04 |
| *Onosma elwendica* Wettst. | 0 | 0 | 0 | 0 | LC | 0.03 |
| *Onosma gaubae* Bornm. | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma hebebulba* DC. | 0 | 1 | 0 | 0 | LC | 0.16 |
| *Onosma iranshahrii* Ghahreman et Attar | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma kerendica* Attar et Mirtadz. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma khorassanica* Attar et Joharchi | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma khorramabadensis* Attar, Mirtadz. et Sotoodeh | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma kilouyense* Boiss. et Hausskn. | 0 | 0 | 2 | 2 | LC | 0.05 |
| *Onosma kotschyi* Boiss. | 0 | 0 | 1 | 3 | LC | 0.06 |
| *Onosma kurdica* Teppner. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma longiloba* Bge. | 1 | 1 | 0 | 0 | VU | 0.16 |
| *Onosma lorestanica* Attar et Sotoodeh | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma macrophylla* Bornm. | 0 | 0 | 0 | 0 | LC | 0.05 |
| *Onosma maculate* Ranjbar et Almasi | 0 | 1 | 3 | 1 | LC | 0.12 |

| Species | IUCN score | Rarity score | Endemism score | Endemism chorology | The extent of occurrence (EOO) | RI |
|---|---|---|---|---|---|---|
| *Onosma marivanensis* Mozaff. et Mehrabian | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma microcarpa* DC. | 0 | 0 | 0 | 0 | LC | 0.02 |
| *Onosma mousavi* Mehrabian et Amini Rad | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma mozaffariani* Mehrabian. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma nervosa* H. Riedl. | 1 | 1 | 0 | 0 | VU | 0.16 |
| *Onosma olivieri* Boiss. | 1 | 1 | 0 | 0 | VU | 0.25 |
| *Onosma pachypoda* Boiss. | 0 | 0 | 3 | 1 | LC | 0.07 |
| *Onosma platyphylla* H. Riedl. | 0 | 1 | 3 | 1 | LC | 0.12 |
| *Onosma rascheyana* Boiss. | 0 | 0 | 0 | 0 | LC | 0.07 |
| *Onosma rostellata* Lehm. | 0 | 0 | 0 | 0 | LC | 0.08 |
| *Onosma sabalanica* Ponert. | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma sahandica* Attar et Sotoodeh | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma sanandajensis* Mehrabian et Mozaff. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma sarvestanica* Mozaff. et Mehrabian | 2 | 2 | 3 | 1 | EN | 0.5 |
| *Onosma sericea* Willd. | 0 | 0 | 0 | 0 | LC | 0.03 |
| *Onosma sheidaii* Mehrabian. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma stenosiphon* Boiss. | 0 | 0 | 0 | 0 | LC | 0.04 |
| *Onosma straussii* Riedl Khatamsaz | 0 | 0 | 1 | 3 | LC | 0.08 |
| *Onosma subsericea*Freyn | 0 | 1 | 0 | 0 | LC | 0.16 |
| *Onosma targevarensis* Mozaff. et Mehrabian | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma wendelboi* Mehrabian et Mozaff. | 3 | 2 | 3 | 1 | CR | 1 |
| *Onosma zagrica* Dehshiri | 3 | 2 | 3 | 1 | CR | 1 |