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Research Article

Diversity centers and distribution patterns of Eudicot crop wild relatives of Iran: priorities for conservation and important plant areas

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Abstract
Crop Wild Relatives (CWR) have the potential to contribute to food security. These taxa can donate advantageous traits to counter biotic as well as abiotic stress and improve thequality of crops. This study aims to provide as many details as possible on distribution patterns and centers of diversity in order to identify and establish modern protected areas in Iran. In total, 539 species of CWR, from 258 genera and 75 plant families have been studied. Using prioritization criteria (gene pool level, range of distribution, and economic value) 17 families, 35 genera, and 94 species of CWR have been identified in Iran. The highest diversity was found in the central Alborz Mountains, the eastern Alborz, and the northern sections of the Zagros Mountains. Several geographic zones can be classified as national genetic reserves. Iranian CWR were distributed in nine classes, ranging in elevation from sea level to more than 4,000 m. Species with a high conservation value include *Rosa pimpinellifolia*, *Rosa webbiana*, *Pyrus turcomanica*, *Crataegus sanguinea*, *Vicia pannonica*, *Vicia grandiflora*, *Lathyrus pseudo-cicera*, *Lactuca wilhelmsiana*, *Cornus mas,* and, *Cornus sanguinea*. The main achievement of this study has been to identify the distribution patterns and priorities for the conservation of these valuable taxa for the first time. These prominent taxa of CWR have the potential not only to improve food and economic security at a national level but can also contribute to global food security. Thus, an urgent and cohesive plan for their management is critical.

Keywords: CWR, Domestication, Priority conservation, Distribution, Iran

Introduction

The increasing rate of population growth combined with the negative effects of climate change on crop production (Schmidhuber & Tubiello, 2007; Lobell *et al*., 2008; Palm *et al*., 2010) has triggered intense scrutiny on the issue of food security (IPCC 2007, FAO 2008) and sustainable resources (Fielder *et al*., 2015). Due to the increasing rate of population growth projected over the next 90 years (UN, 2011), global food production must increase by 70% (Godfray *et al*., 2011) in order to ensure food security. Several approaches have been proposed to this end and Crop Wild Relatives (CWR) have the potential to make a worthy contribution (FAO, 2012). These valuable taxa have been described as “a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop” (Maxted *et al*., 2006). These taxa can donate advantageous traits to common crops to counter biotic as well as abiotic stress and improve quality (Guarino & Lobell, 2011).

The first studies on CWR date back to a book published by De Candolle (1855) entitled *Origin of Cultivated Plants*. Vavilov (1926) then proposed a theory on centers of origin and centers of diversity and emphasized the important role of CWR as a plant genetic resource (PGR) for crop improvement (Loskutov, 1999, 2020). Vavilov (1926) introduced eight centers of origin for cultivated plants: Mexico-Guatemala, Peru-Ecuador-Bolivia, Southern Chile, Southern Brazil, Mediterranean, Middle East, Ethiopia, Central Asia, Indo-Mayanmar, Indo-Malayan, China, and Korea. The list has now been revised to include additional centers (Maxted & Vincent, 2021). Harlan (1975), Zhukovsky (1968), and Sinskaya (1969) have all discussed a wide range of opinions on the origin of crops and their diversity.

In 1985, The International Plant Genetic Resources Institute (IPGRI) proposed methodologies on the *in situ* conservation of CWR. Khoury *et al.* (2016) provided a prominent reference entitled “Origins of food crops connect countries worldwide.” Vincent *et al*. (2013) outlined the priorities for CWR regarding food security on a global scale. Meyer *et al*. (2012) reviewed 205 crops in the context of historical domestication and quantitative analysis. Moreover, there are two published papers (Hanelt, 1986) available as well as an online database (http://mansfeld.ipk-gatersleben.de) of agricultural and horticultural crops. Nevo (1992, 1995, 1998), and Nevo and Beile (1992) focused on the evolutionary structures of cereals (e.g. *Triticum* and *Hordeum*) with an emphasis on genetic diversity. Further studies on CWR emphasizing a checklist as well as the context for conservation have been undertaken by Fielder *et al.* (2015) and Maxted *et al.* (2015) in the United Kingdom; Khoury *et al.* (2013) in the United States; Magos *et al*. (2008) in Portugal; Zeven and Zhukovsky (1975), Heywood and Zohary (1995), Kell *et al*. (2005, 2008) and Maxted *et al.* (2013) in Europe; Hosseini et al. (2021) on CWR monocots in Iran; IBC (2012) and Yohannes (2016) in Ethiopia; Pandey *et al.* (2005) in India; Berlingeri and Crespo (2012) and Fitzgerald (2013) in Finland; Phillips *et al*. (2014) in Cyprus; Panella *et al*. (2014) in Italy; and Rubio *et al*. (2013).

In the Dictionary of Cultivated Plants and their Regions of Diversity, Zeven and Zhukovsky (1975) and Zeven and De Wet (1982) excluded most ornamentals, forest trees, and lower plants. Maxted *et al*. (2013) published a valuable reference on national plans for the conservation of CWR and landraces, which was made into an online toolkit (Brehm *et al.*, 2019).

Climatologic diversity, paleo-biogeographical events (Frey & Probst, 1986), complicated orography (Zohary, 1973), and particular soils (Hedge & Wendelbo, 1978) have altogether shaped numerous contradictory eco-regions (Takhtajan, 1986). This, in turn, has shaped Iran into an important area of endemism (Zohary, 1976). The country is an endemic center of the Irano-Turanian region (Leonard, 1991), and a global center of diversity for plants (Davis *et al.*, 1994; Barthlott, 1996, 1999; Kier *et al.*, 2005). Iran is home to roughly 8,200 vascular plants, among which approximately 2,140 taxa are restricted to Iranian geographical boundaries (endemic plant taxa). This area is classified as a phyto-diversity hotspot hosting many valuable plant taxa (food, medicinal, horticultural, and agricultural). In addition, Iran is in Vavilov's third center of endemism from which about 15% of cultivated plants have originated (Vavilov, 1992; Hummer & Hancock, 2015). According to Vincent *et al.* (2013), the range of CWR diversity in Iran is similar to those of the Anatoly Plateau, which has the highest range, and there are more than 200 priority CWR for conservation (Vincent *et al.*, 2013). These diverse genetic resources are comprised of several wild relatives of crops. Due to limited funds for conservation, it is essential to prioritize any projects involving plant taxa. CWR is the most important plant genetic resource in determining conservation priorities (Myers *et al.*, 2000). Interventions can be done *in situ* or *ex situ* based on, among other things, type of taxa and threatening factors. Certain steps are needed at the national level to achieve sustainable conservation of CWR (FAO, 2012) including 1) the Study phase: creating a national CWR checklist and inventory to prioritize CWR taxa, identify threats and key national CWR protected areas; and 2) the Executive phase: undertaking an eco-geographic and genetic diversity assessment of the priority CWR, implementing in situ/ex situ national conservation, establishing national protected areas, and utilizing, researching and educating on CWR.

Despite the high potential of CWR to ensure food security, these taxa have been severely threatened. Taking a current inventory in the target area is crucial. Due to numerous limitations, the focus should be on priorities of conservation. Since little attention has been paid to CWR patterns and centers of diversity in Iran, this study tries to provide as many details as possible on distribution patterns and centers of diversity in order to select the most important CWR as priorities for conservation management and to identify and establish modern protected areas (Important Plant Areas, plant micro reserves, and extra PA in situ conservation sites).

Material and methods

Study Area

The most important zone in the Iranian Plateau, Iran covers a total surface area of 1.6 million km^2 (Fig. 1). The country is comprised of numerous mountainous massifs including Zagros, Alborz, Kopet Dagh, and Makran as well as several scattered internal mountains. Zagros, a physical massif, is the most extensive orographic structure in Iran (Fischer, 1968). The Zagros Mountains are part of the Alpine-Himalayan orogenic structure with an NW to SE orientation resulting from the collision of the Iranian Eurasian Plate and the Arabian plate (Homke, 2007). Alborz, another prominent massif, is divided into six structural zones appearing from north to south. It forms a gently sinuous stretch across the southern zones of the Caspian Sea (Stöcklin, 1974) and is limited to the central plateau (Stöcklin, 1974). It is 950 km in length and varies from 15 to 110 km in width (Ghorbani, 2013). The Kopet-Dagh mountain system includes "a sequence of Jurassic-Pliocene folded sedimentary rocks" (Navab *et al*., 2006) and stretches 700 kilometers from the eastern boundaries of the Caspian Sea to the northeast of Iran, Turkmenistan, and north Afghanistan (Allen *et al*., 2003). There are scattered interior mountains in the central, southern, and eastern parts of Iran. The soils of the mountainous zones have originated from volcanic tuff in the Eocene (Stöcklin, 1974). The complexities in geological events and structures have shaped a broad range of physical conditions which have triggered the formation of several evolutionary-ecological zones of speciation and endemism in the area (Barthlott *et al*., 1999; Kier *et al*., 2005) (Fig. 1).

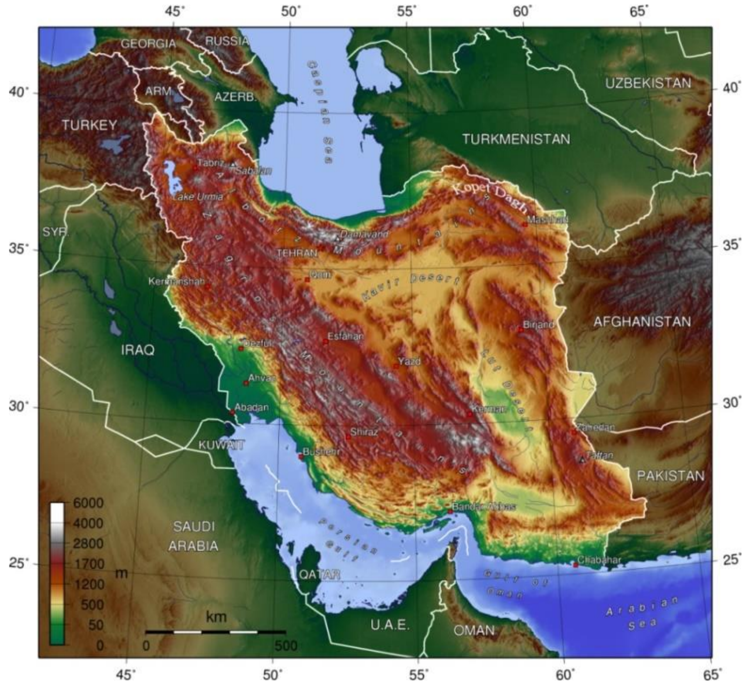

Figure 1. Geomorphological map of Iran (www.ngdir.ir)

Data collection

Distribution points were developed using 2,780 localities from HSBU, W, and WU (herbarium abbreviation according to Thiers, 2016) and scientific literature on the vegetation and flora of Iranian habitats in order to provide distribution and ecological data on CWR in Iran. *Flora Iranica* (Schönbeck-Temesy, 1972) and *Flora of Iran* (Assadi *et al*., 1988-2018) were the most important references used for species data. *The Mansfield Encyclopedia of Agricultural and Horticultural Plants* was the main reference used in determining the closest CWR, not including ornamentals (Hanelt *et al*., 2017), as well as *CWR: A Manual of in situ Conservation* (Hunter & Heywood, 2011). A checklist of critical taxa is based on FAO reports (2008, 2012) and includes the most important agricultural plants in terms of production and supply of human food needs**.**

Classification of CWR

Two approaches were used based on data available to identify the degree of affinity of CWR to crops including gene pool (Harlan, 1971) and taxonomic group concepts (Maxted *et al.*, 2008). Gene pool classification is based on phylogenetic analysis. Accordingly, these taxa (CWR) include three classes of gene pools. The primary gene pool (GP1) is the concept of CWR (near lineages that readily intercross with the crop). The secondary gene pool (GP2) includes all the biological species that can be crossed with the crop but where hybrids are usually sterile. The tertiary gene pool (GP3) are those species that can be crossed with the crop only with difficulty and where gene transfer is usually only possible using radical techniques. Taxonomic groups can be evaluated on the basis of reference Flora (e.g., Flora Europe, Flora Iranica, etc.). Thus, taxon groups are comprised of taxon group 1a (crop), taxon group 1b (same species as cra op), taxon group 2 (same series or section as crop), taxon group 3 (same subgenus as a crop), taxon group 4 (same genus as a crop), taxon group 5 (different genus to the crop) (Maxted *et al.* 2006).

Data analysis

Our study calculated the preliminary International Union for Conservation of Nature Red List categories on a regional scale (IUCN, 2011) presented by Kew GeoCAT (Geospatial Conservation Assessment Tool) (www.Kew.org). The Extent of Occurrence (EOO) was calculated to classify the threat categories. The distribution points were marked using ArcGIS version 10.3 (ESRI, 2014) on georeferenced maps (1/106) of Iran including 0.25° × 0.25° universal transverse Mercator grid cells (with the exception of 25 km^2 of boundary zones). Taxa conservation value (Tsiftsis *et al.*, 2009) was measured as the additive scoring of the following features: the Species Distribution Index (SDI) (Sapir *et al.*, 2003; Solymos and Feher, 2005) and the taxon Rarity Index (RI) (Williams *et al.*, 1996). These were calculated to determine conservation priorities. Scoring varied from zero (0) to one (1), in which higher scores show higher vulnerability. The RI=1/Ci, where Ci is the number of grid cells and l is the number of current species categorized as very rare (VR), rare (R), middle distribution (MD) and widespread (W). The SDI=l-Ci/C, where C is the total number of grid cells. Conservation value (CV) is the sum of RI and n (SDI of each grid cell). Thus, a higher score signifies an advanced CV. An Important Plant Area (IPA) is based on three criteria including the presence of threatened species, species richness, and threatened habitat. An IPA is “a natural or semi-natural site exhibiting exceptional botanical richness and/or supporting an outstanding assemblage of rare, threatened and/or endemic plant species and/or vegetation of high botanic value” (Langhamer, 2007). Plant micro reserves (PMRs) follow Laguna (2001) and include small zones up to 20 ha of peak value in terms of plant richness, endemism or rarity.

Results

The current study analyzed 201 grid cells including Iranian geographic boundaries. Fourteen taxa (15.73%) were recorded from one grid cell. The total number of studied CWR was 539 species belonging to 258 genera and 75 plant families. Using prioritization criteria (e.g. gene pool level, range of distribution, and economical values such as cropped hectares, value of the harvest as well as nutritional supply), 17 families, 35 genera and 94 species of CWR were identified (Table 1). A checklist of the most important taxa based on the FAO (2008, 2012) includes Gene pool 1 and Gene pool 2 or about 25% of the total species (Table 2).

Table 1. Production of valuable crops and area under cultivation

Crop	Production (tons)	Area under cultivation
Rhus coriaria	2,649	2,208
Pistacia vera	195,206	282,347
Berberis vulgaris	14,000	22
Morus alba	6,000	500
Ficus carica	87,000	60,000
Amygdalus communis	110,000	160,000
Solanum lycopersicum	5,250,000	150,000
Vicia sativa	85	650
Lens culinaris	450,000	16,500
Lathyrus sativus	1,200	980
Pisum sativum	93,500	3,100
Lactuca sativa	250,000	20,000
Punica granatum	670,000	60,000

Juglans regia	350,000	160,500
Vitis vinifera	7,780,000	308,000
Corylus avellana	25,000	21,000
Olea europaea	102,000	84,000

Table 2. Percentage of Gene pools (GPs) and taxonomic groups (TGs) in the studied species

Group	Number of species	Percent (%)
GP1	10	10.63
GP2	14	14.89
GP3	6	6.38
TG 1B	14	14.89
TG2	35	37.23
TG3	15	15.95
Total	**94**	**100**

Central Alborz, eastern Alborz as well as northern sections of the Zagros showed the highest diversity. *Rosaceae* (33), *Papilionaceae* (19), *Amaranthaceae* (7) had the highest richness of species. Iranian CWR were distributed in nine classes of elevation ranging from sea level to more than 4,000 m. In the context of richness in scale, the lowest zones were at 1,000 m - 2,000 m and the highest at more than 4000 m (Fig. 2). *Amaranthaceae* had the widest range of elevation and *Cornaceae* had the most limited (Fig. 3). On the basis of geomorphological classification (Kapos *et al.*, 2000), the CWR were distributed in six hierarchies as follows: basins (less than 300 m), lowlands (300 m - 1,000 m), semi-mountainous (1,000 m – 1,500 m), mountainous (1,500 m – 2,500 m), alpine (2,500 m – 3,500 m), and subnival (3,500 m – 4,500 m). The highest diversity in the context of genera and species is distributed mostly between latitudes 35° and 38° (Fig. 4).

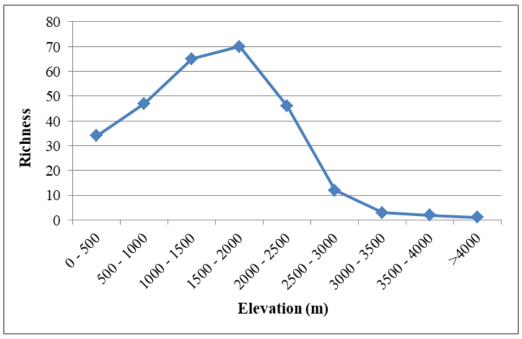

Figure 2. Species richness in altitudinal profile

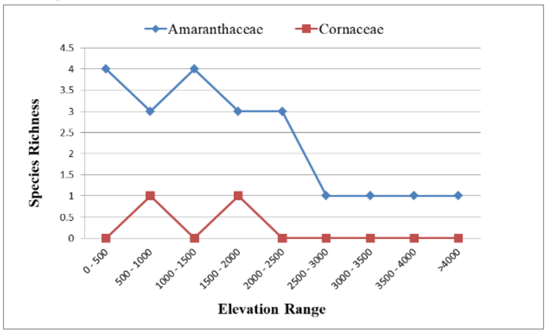

Figure 3. The widest and the most limited range of elevation

There are unique zones of endemism for each family. Convolvulaceae is found in the southern Zagros as well as the southwestern mountainous regions. Fagaceae is found in the middle as well as in some parts of southern Zagros. Lamiaceae is located mainly in the Zagros and the Alborz and restricted zones of the southwestern mountainous regions. Rhamnaceae is in the Alborz, Zagros and Kopet-Dagh. Rosaceae is located in a wide spectrum of regions with the exception of central Iran. Euphorbiaceae is distributed in the central mountains of Iran. The habitats of Amaranthaceae Sabkha, as well as Asteraceae, are distributed in the southern half of the country. The endemic taxa showed mostly a distribution within a diverse range of geological formations, with the exception of 20 (22.72%) that were established in only one geological formation (Tamaricaceae, Tiliaceae, Boraginaceae, Rosaceae, Lamiaceae, Polygonaceae).

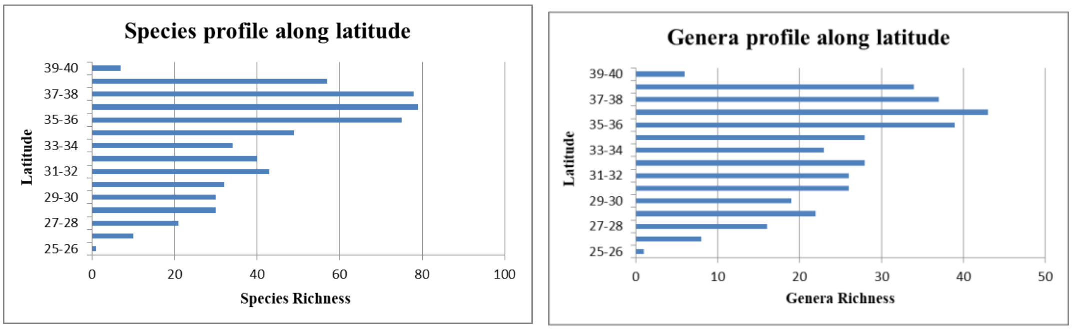

Figure 4. Species and Genera profile along latitude

Conservation status was marked critically endangered (CR) for 17 species, endangered (EN) for 3 species, and vulnerable (VU) for two species. There were 4 species that were near threatened (NT), and 68 were of least concern (LC) (Table 3). Both Papilionaceae and Rosaceae (7: 7.44%) covered the highest percentage of very rare and rare taxa, respectively (Fig. 5). These taxa showed high: 63.82% (60), medium: 28.72% (27) and low: 7.44% (7) habitat vulnerability. On the basis of conservation value, the following levels were obtained: very high (38: 40.42%), high (27: 28.72%), medium (24: 25.53%), low (3: 3.19%), and very low (2: 2.12%). The highest conservation values belonged to *Rosa pimpinellifolia* L., *Rosa webbiana* Royle., *Pyrus turcomanica* Maleev., *Crataegus sanguinea* Pall., *Vicia pannonica* Crantz., *Vicia grandiflora* Scop., *Lathyrus pseudo-cicera* Pampan., *Lactuca wilhelmsiana* Fisch. & Mey. ex DC., *Cornus mas* L., and *Cornus sanguinea* L. (Table 3). Accordingly, those taxa which were present in 1-5, 6-15, 16-30, and in more than 30 grid cells were considered VR (38: 40.42%), R (23: 24.46%), MD (24: 25.53%) and W (9: 9.57%) respectively. In the following sections, the taxa with the highest conservation values are described with a geo-botanical approach.

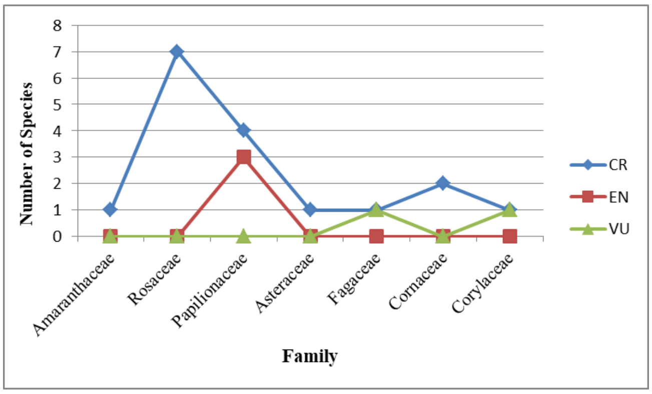

Figure 5. EN, CR and VU Richness in Families

Chronologically, 79 (77.45%) of the regions were Irano-Turanian, 15 (14.70%) Hyrcanian, and 8 (7.84%) Sudano-Zambezian. Furthermore, 63 (67.02%) were classified as Zonobiome III, 19 (20.21%) as Zonobiome VII, and 12 (12.76%) were classified as both.

Of these regions, 76 (18.49%) were distributed in the Mediterranean pluviseasonal-continental; 83 (20.19%) in the Mediterranean xeric-continental; 40 (9.73%) in the Mediterranean desertic-continental; and 212 (51.58%) in other bioclimatic units (Mediterranean pluviseasonal-oceanic, Tropical xeric and Tropical desertic). Areas with a mixture of all these zones were also distributed throughout. Geologically, 77 (25.66%) occurred in sediment; 69 (23.01%) in igneous rock; and 154 (51.33%) occurred in other geological formations or a combination of these. Furthermore, 26 (7.36%) occurred in Zagros; 69 (19.54%) in the north; 80 (22.66%) in the northwest; and 178 (50.42%) in other geological units. The phytogeographical units of Iranian Dicotyledon were as follows: 46 (16.60%) in Kurdistan-Zagros, 81 (29.24%) in Atropatenian, 41 (14.80%) in Khorasan, 10 (3.61%) in Fars-Kerman, 68 (24.54%) in Hyrcanian and 31 (11.19%) in bi- or multi-regional areas.

Discussion

Species richness is a significant criterion for prioritizing conservation (Kier & Barthlott, 2001; Huang *et al.*, 2012). The zones with the highest diversity of CWR are centered in the central and eastern Alborz as well as, to a lesser degree, in the northern sections of the Zagros. The Klein studies (1972) showed that the Alborz and Zagros ecosystems created a speciation area to the Irano-Anatoly center of endemism (Klein, 1972). This opinion is confirmed by newer studies (Rechinger, 1986; Mehrabian *et al.*, 2012, 2015). Altitudinal distribution of several endemic taxa (Mehrabian *et al.*, 2015; Sayadi & Mehrabian, 2016, 2017) mainly centered in mountainous zones (1,200 m – 2,300 m) show that those CWR have similar patterns in the area (Fig. 6). Additionally, our study confirms the opinions of Vavilov (1926) and Khoury *et al.* (2016) that have introduced Iran as a prominent center of diversity and cultivation of plant taxa and a botanical center of diversity (Vavilov, 1926; Khoury *et al.*, 2016; Davis *et al.*, 1994; Barthlott *et al.*, 1996; Kier *et al.*, 2005).

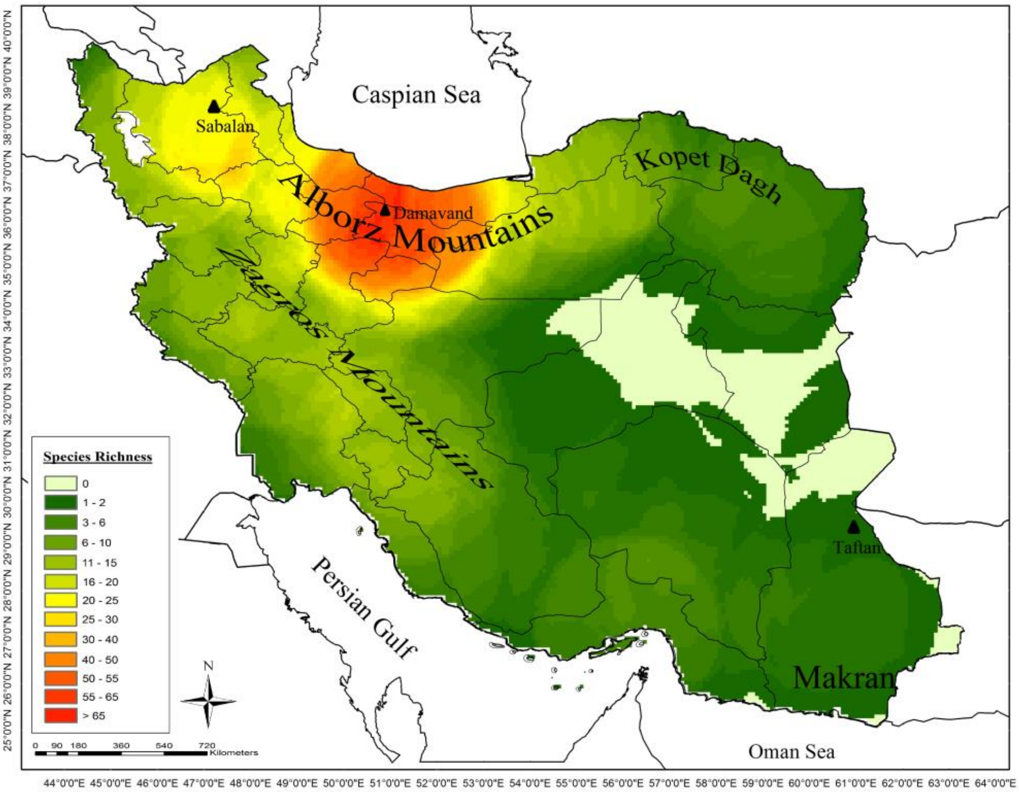

Figure 6. The richness Zonation map of Crop Wild Relatives in Iran

The main objective of the Red List is to provide prioritization based on categories of threat (critically endangered, endangered, and vulnerable) (Berg *et al*., 2014). Iranian CWR in restricted distributions in Iran are classified as critically endangered (Fig. 6) on a regional scale. These include *Chenopodium giganteum* D. Don. (Baluchistan, in the east and southwest), *Rubus saxatilis* L. (Azarbaijan in the northwest, Orumia, Arasbaran), *Rosa pimpinellifolia* L. (Azarbaijan, Ahar, Kalibar in the northwest), *Rosa webbiana* Royle. (Khorasan, Dar-e Gaz in the northeast), *Pyrus turcomanica* Maleev. (Golestan in the northeast), *Crataegus sanguinea* Pall. (Mazandaran, Siah Bisheh in the north), *Cerasus vulgaris* Mill. (Damavand in the north, Kurdistan in the west), *Vicia grandiflora* Scop. (Azarbaijan in the northwest), *Vicia hybrida* Georgi. (Kurdistan, Kermanshah, Sar Pol-e Zohab in the west), *Lathyrus gorgonii* Parl. (Kurdistan, Kermanshah, Lorestan in the west), *Lathyrus pseudo-cicera* Pampan. (Azarbaijan, Miandoab in the northwest), *Lactuca wilhelmsiana* Fisch. & Mey. ex DC. (Mazandaran, Panjab in the north), *Quercus robur*. (Azerbaijan in the northwest, Mashhad in the northeast) *Cornus mass* L. (Azerbaijan, Kalibar in the northwest), *Cornus sanguinea* L. (Kurdistan, Shahoo in the west), *Corylus colurna* L. (Lahijan in the north, Yazd in central Iran) and *Lathyrus tuberosus* L. (Azarbaijan, Khoy in the northwest), *Lathyrus vernus* (L.) Bernh. (Chalus, Manjil in the north) and *Vicia pannonica Crantz*. (Azarbaijan, Arasbaran, Kalibar in the northwest). These endangered taxa are at the top of conservation priorities. In other words, their ex-situ conservation is critical. Several local valuable genotype-ecotype of CWR (e.g. *Rhus coriaria*, *Pistacia vera*, *Berberis vulgaris*, *Ficus carica*, *Amygdalus communis*, *Vicia sativa*, *Pisum sativum*, *Punica granatum*, *Quercus brantii*, *Quercus infectoria*, *Quercus petraea*, *Juglans regia*, *Olea europaea*) have been severely damaged by anthropogenic pressures such as overgrazing, changes in land use, fire, overharvesting, (Akhani *et al.*, 2010; Mehrabian *et al.*, 2015) and long-term drought resulting from climate change throughout Iran (Jafari, 2010;

Valavi *et al.*, 2018). This has led to the high probability of gene erosion. These valuable gene reservoirs are disappearing. The distribution patterns of critically endangered and endangered CWR reveal that a great ratio of these taxa is distributed outside of protected areas and therefore, urgent action is needed to prevent their extinction (Figs. 7-8, Table 4).

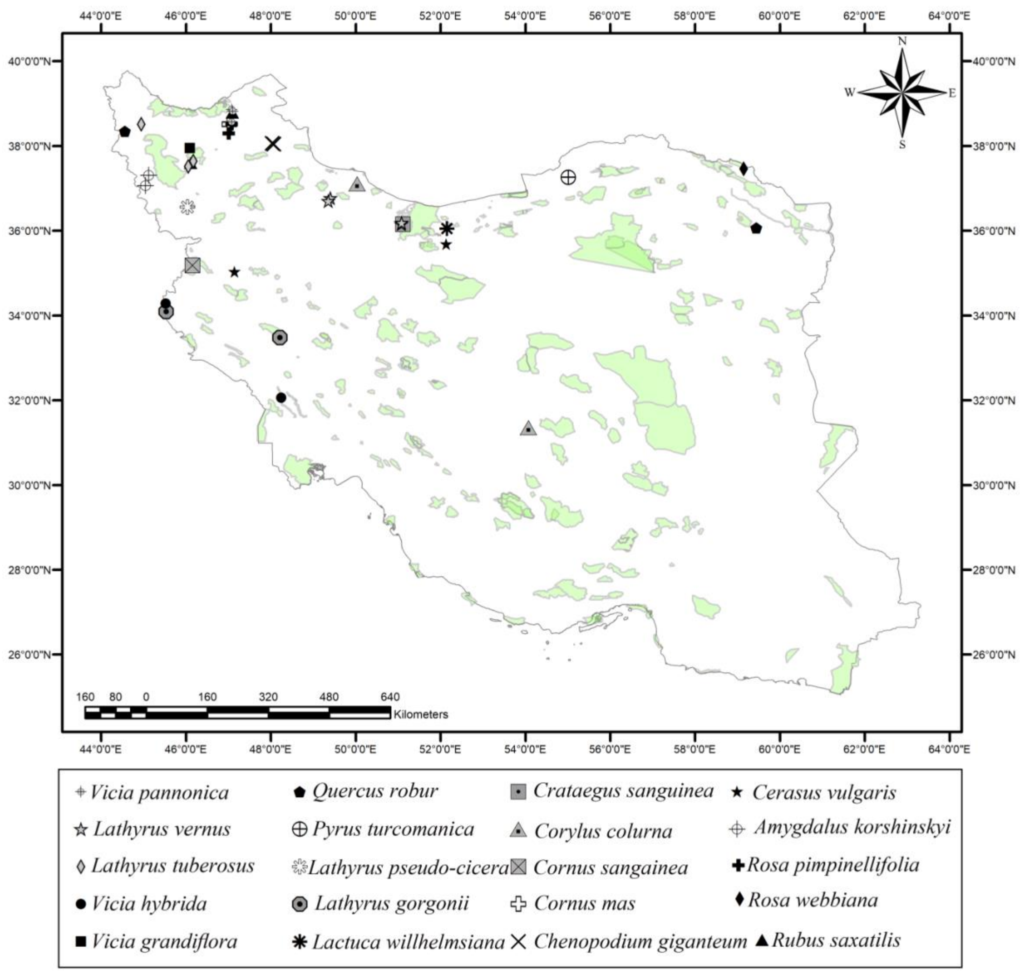

Figure 7. Critically endangered Eudicot CWR in accordance with the protected areas of Iran

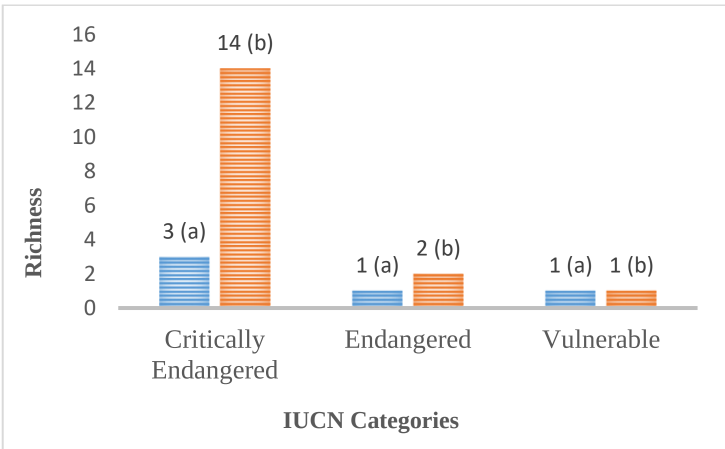

Figure 8. Number of species (a) Inside and (b) Outside of protected areas in Iran

Table 4. Location of endangered and critical species in relation to protected areas

Protected area	Species	Location	IUCN
Inside	*Rubus saxatilis*	Northwest, Azerbaijan, Orumieh and Arasbaran	CR
	Vicia grandiflora	Northwest, Azerbaijan	
	Vicia pannonica	Northwest, Azerbaijan, Kalibar and Arasbaran	EN
Outside	*Rosa pimpinellifolia*	Northwest, Azerbaijan, Ahar and Kalibar	CR
	Rosa webbiana	Northeast, Khorasan, Dareh-Gaz	
	Pyrus turcomanica	Northeast, Golestan	
	Crataegus sanguinea	North, Mazandaran, Siah Bisheh	
	Amygdalus korshinskyi	Northwest, Azerbaijan, Qasemlu and Naghadeh	
	Cerasus vulgaris	North (Damavand), West (Kordestan)	
	Lactuca willhelmsiana	North, Mazandaran, Panjab	
	Quercus robur	Northwest (Azerbaijan), Northeast (Mashhad)	
	Cornus mas	Northwest, Azerbaijan, Kalibar	
	Chenopodium giganteum	Southeast, Baluchestan, Zahedan	
	Corylus colurna	North (Gilan), Center (Yazd)	
	Vicia hybrida Georgi	West (Kermanshah, Kordestan)	
	Lathyrus gorgonii	West (Kermanshah, Lorestan)	
	Lathyrus pseudo-cicera	Northwest, Azerbaijan	
	Lathyrus tuberosus	Northwest, Azerbaijan, Orumieh	EN
	Lathyrus vernus	North, Mazandaran	

Several horticultural specimens (*Pistacia vera* L., *Pyrus communis* L., *Beta vulgaris* L. *Morus alba* L., *Ficus carica* L., *Malus communnis* Lam., *Punica granatum, Vitis vinifera* L.,*Prunus domestica* L., *Cerasus avium* (L.) Moench., *Cerasus vulgaris* Mill., *Lens culinaris* Medik., *Juglans regia* L. and *Corylus avellana* L.) have the highest national production (Iran Agricultural Statistics 2016), so their closest wild relatives are classified at the highest level of protection priority in Iran. These include: *Pistacia atlantica* subsp. *cabulica* (Stocks) Rech.f., *Pistacia atlantica* subsp. *mutica* (Fisch. & C.A. Mey.) Rech.f., *Pistacia atlantica* subsp. *kurdica* (Zohary) Rech.f., *Pistacia khinjuk* Stocks., *Pistacia vera* L., *Pyrus boissieriana* Buhse., *Pyrus turcomanica* Maleev., *Pyrus syriaca* Boiss.*Pyrus salicifolia* Pallas., *Pyrus elaeagrifolia* Pallas., *Beta vulgaris* subsp. *maritima* (L.) Arcang., *Morus alba* L., *Ficus carica* L., *Malus orientalis* Uglitzk., *Punica granatum* L., *Vitis sylvestris* C.C. Gmel., *Prunus spinosa* L., *Prunus divaricata* Ledeb., *Cerasus mahaleb* (L.) Mill., *Lens cyanea* (Boiss. & Hohen.) Alef., *Lens orientalis* (Boiss.) Schmalh., *Juglans regia* L., *Corylus avellana* L., and *Corylus colurna* L.

There is a rudimentary method for assigning conservation priority of valuable genetic resources (Maxted, 2006), the goal of which is to "identify a small number of priority sites **(**international = 100, regional = 25, national = 5) internationally, within each region and country, for the establishment of active CWR genetic reserves**.**" Measures toward this should include establishing biosphere reserves, protected areas and new genetic reserves (including genetic management units and gene sanctuaries). Based on recent criteria, some zones of central Alborz, as well as northern Zagros, can be eventually classified as regional genetic reserves. Several geographic zones (east, southeast, and restricted zones in the northwest) can be classified as national genetic reserves (Fig. 8).

If a region is refuge to an obvious amount of one or more globally-threatened species (Pressey *et al.*, 1994), it is classified as a key biodiversity area and recognized as irreplaceable and vulnerable (Langhammer *et al.*, 2007). If there are no protection measures in place for one of these species, it will be lost (Pressey *et al*., 1996). A recent paper on the levels of threat (CR, EN, and VU) reported that they are composed of four levels of important plant areas including areas that can be classified as the highest zones in the context of Important Plant Areas (Figs. 9-10). A total of 37 species qualify under Criterion A as globally threatened (critically endangered and endangered taxa) in the IPAs of trees and shrubs in Iran. Under Criterion A, 110 endemic monocots (Mehrabian *et al*., 2015) qualify as globally threatened. These zones are mainly in Alborz (Northern Iran), northern Zagros, and in the northwest geomorphologic units of Iran that cover the Irano-Armenian region (Takhtajan, 1986) (Fig. 9). Some IPA sites occur along the boundaries of protected areas where there are no suitable ecological conditions for viability or efficient action for their conservation. These habitats cover mountainous and alpine zones which are severely threatened by overgrazing, mountain climbing, overharvesting of medicinal and ornamental taxa, and extensive and rapid changes in land use (Noroozi *et al*., 2008; Akhani *et al.*, 2010; Mehrabian *et al.*, 2015). Some critically endangered species could also be protected by establishing plant micro-reserves (Fig. 11) (Gómez-Campo, 1981; Laguna *et al.*, 2004).

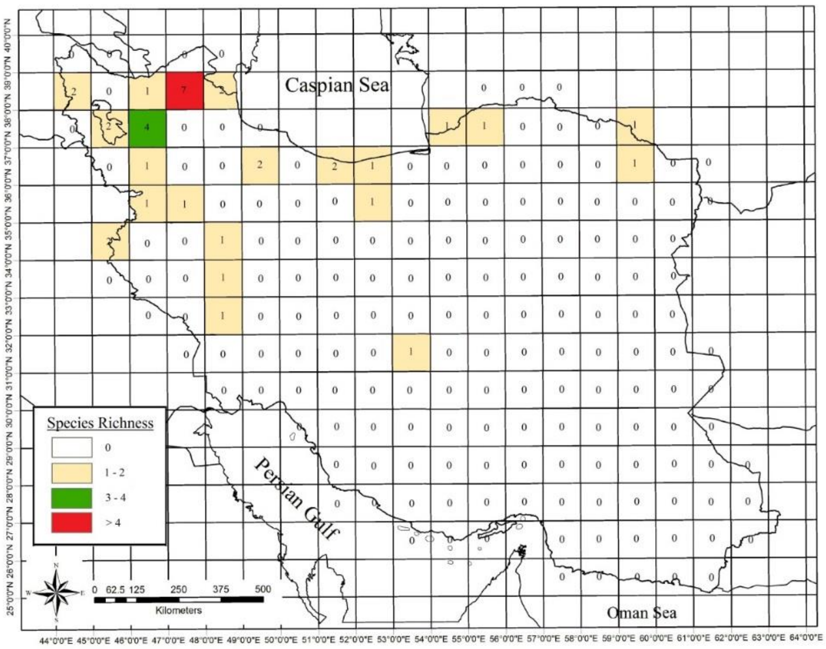

Figure 9. Distribution of critically endangered (CR) and Endangered (EN) species.

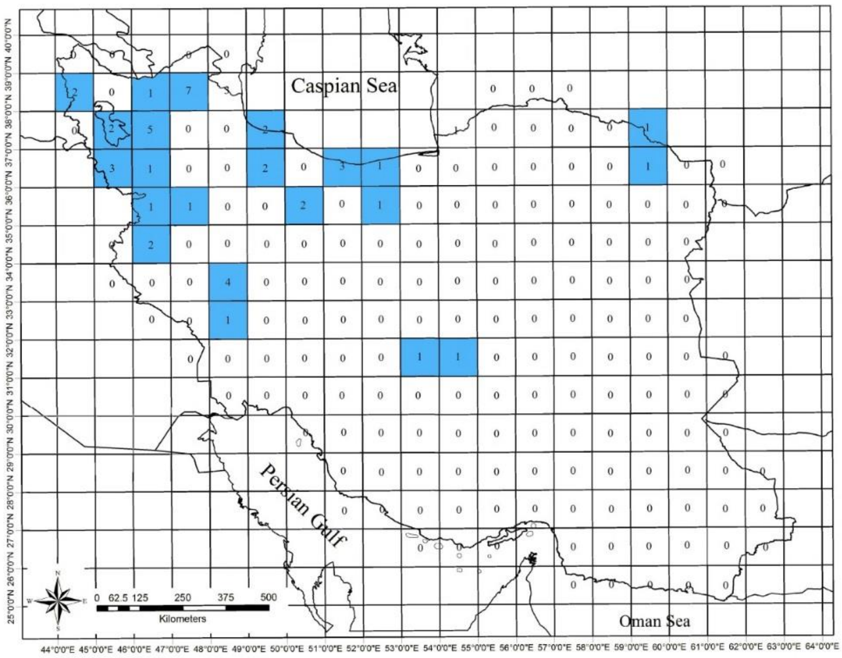

Figure 10. Conservation value of different parts of Iran based on distribution of all CR, EN and VU species.

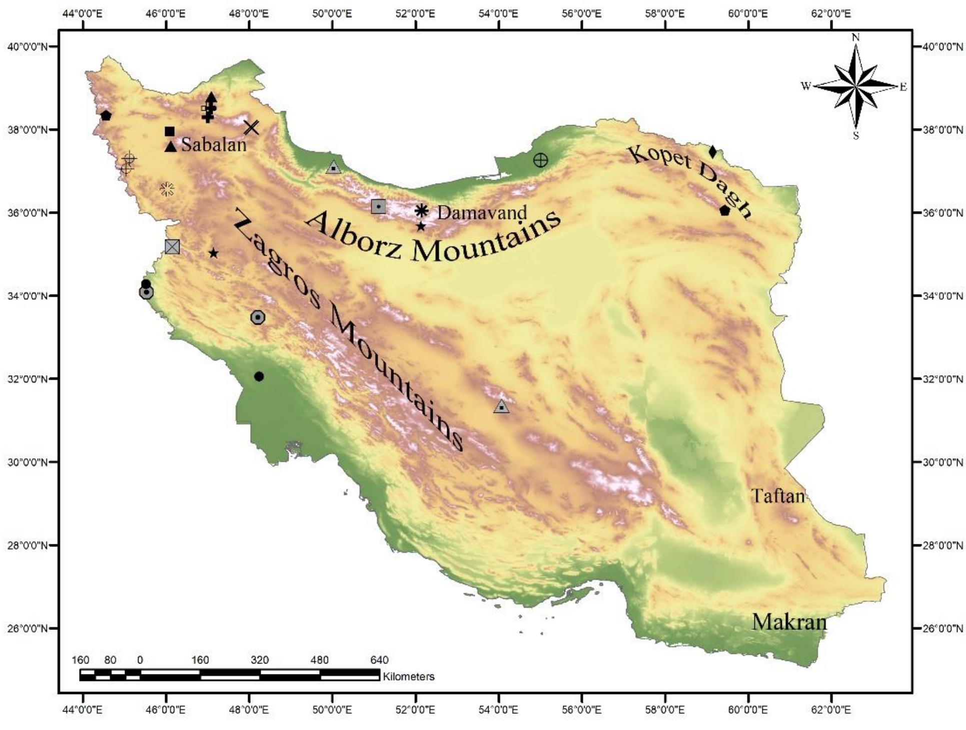

Figure 11. Critically Endangered CWR (suggested micro-reserves)

Conservation for CWR is limited on a global scale (EURISCO, 2018). Castañeda-Álvarez *et al.* (2016) reported that 70% of the 1,076 CWR relating to 81 globally important crops require broader ex situ conservation measures (Castañeda-Álvarez *et al.*, 2016). In situ conservation of CWR is also very weak (Maxted & Kell, 2009) and does not meet accepted global standards (Iriondo *et al.*, 2012).

Conclusion

A recent paper on the main classes of threat (CR, EN, and VU) reports four levels of important plant areas, including areas which can be classified as the highest zones of Important Plant Areas. These priority sites for conservation of Eudicot CWR cover mountainous and alpine zones which are severely threatened by overgrazing, mountain climbing, overharvesting of medicinal and ornamental taxa, and extensive and rapid changes in land use. Critically endangered species could be protected by establishing plant micro-reserves. The distribution patterns of critically endangered and endangered CWR reveal that a great ratio of these taxa is distributed outside of protected areas. Therefore, urgent action is needed to prevent their extinction. The main goal of this study is to identify the distribution patterns and priorities for conservation for the protection of these valuable taxa for the first time. These prominent taxa of CWR are valuable not only to improve crops and ensure economic security at a national level but also to help secure global food reserves. These CWR have been recognized as threatened genetic resources that have not been appropriately protected in Iran. Updating checklists, maintaining an ecological and conservation inventory and regular monitoring are the next vital steps to be implemented in Iran. Some of these species will be able to create new crops. Eco-geographic and genetic diversity assessment of the priority CWR, in situ and ex-situ CWR conservation actions, the establishment of national CWR protected areas as well as implementing the utilization, research, and education concerning CWR are crucial next steps needed to achieve sustainable development. These species must be preserved for future studies for the enhancement of agricultural products. Urgent and cohesive management is critical to safeguard their future.

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