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Review Article

Characteristics and utilization of plant diversity and resources in Central Asia

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A B S T R A C T

The geographical region of Central Asia comprises Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, and the Xinjiang Uygur Autonomous Region of China. Central Asia's temperate forests, steppes, and sandy deserts, including riparian tugai forests, have been identified by the World Wide Fund for Nature as Global 200 ecoregions, and the Mountains of Central Asia are considered biodiversity hotspots. Here, we describe and analyze the diverse characteristics and utilization of plant diversity and resources of the region. We confirm that there are 9520 species of higher plants, 20% of which are endemic species, belonging to 138 families and 1176 genera. The vegetation geography of Central Asia can be divided into 5 provinces and 33 districts, and more than 65% species have a Central Asian geographical distribution pattern. Plant resource utilization can be grouped into 5 categories and 31 subcategories, including food, medicine, industry, environmental protection, construction, and plant germplasm. In this review, we also discuss the principal threats to plant biodiversity in Central Asia posed by global climate change and offer recommendations for conservation strategies.

1. Introduction

The geographical region of Central Asia comprises the countries Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. It also includes the Xinjiang Uygur Autonomous Region of China, which has a landscape, climate, and vegetation conditions similar to those of the other regions of Central Asia (Fig. 1). Situated in the hinterland of the Eurasian continent, Xinjiang is a completely land-locked area characterized by ample grasslands, steppes, deserts, high mountain ranges, and a vast number of lakes. Precipitation in Central Asia occurs mainly during winter and spring, ranging from greater than 1000 mm annually in the Hissar and Fergana ranges in the west to less than 100 mm annually in the east. The Tianshan Mountains and Pamir Plateau act as a climatic division and intercept the moist Atlantic air moving from the northwest to the southeast before reaching the hyperarid Taklimakan Desert and Tarim Basin of Xinjiang, China. The variability of the biogeographic, topographic, and climatic habitats of Central Asia supports a wide array of landscapes and ecosystems that in turn support a wide diversity of flora, including 9520 species of higher plants belonging to 138 families and 1176 genera. The region's biodiversity is notable for its high degree of endemism, with up to 20% of its flora restricted to Central Asia (Zhang et al., 2013). Central Asian temperate forests, steppes, and sandy deserts, including riparian tugai forests, have been identified by the World Wide Fund for Nature as Global 200 ecoregions based on their species richness, levels of endemism, taxonomic distinctiveness, and unusual evolutionary history, as well as the global rarity of their major habitat types. The mountains of Central Asia

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Fig. 1. Geographic map of Central Asian countries and the Xinjiang Uygur Autonomous Region (China).

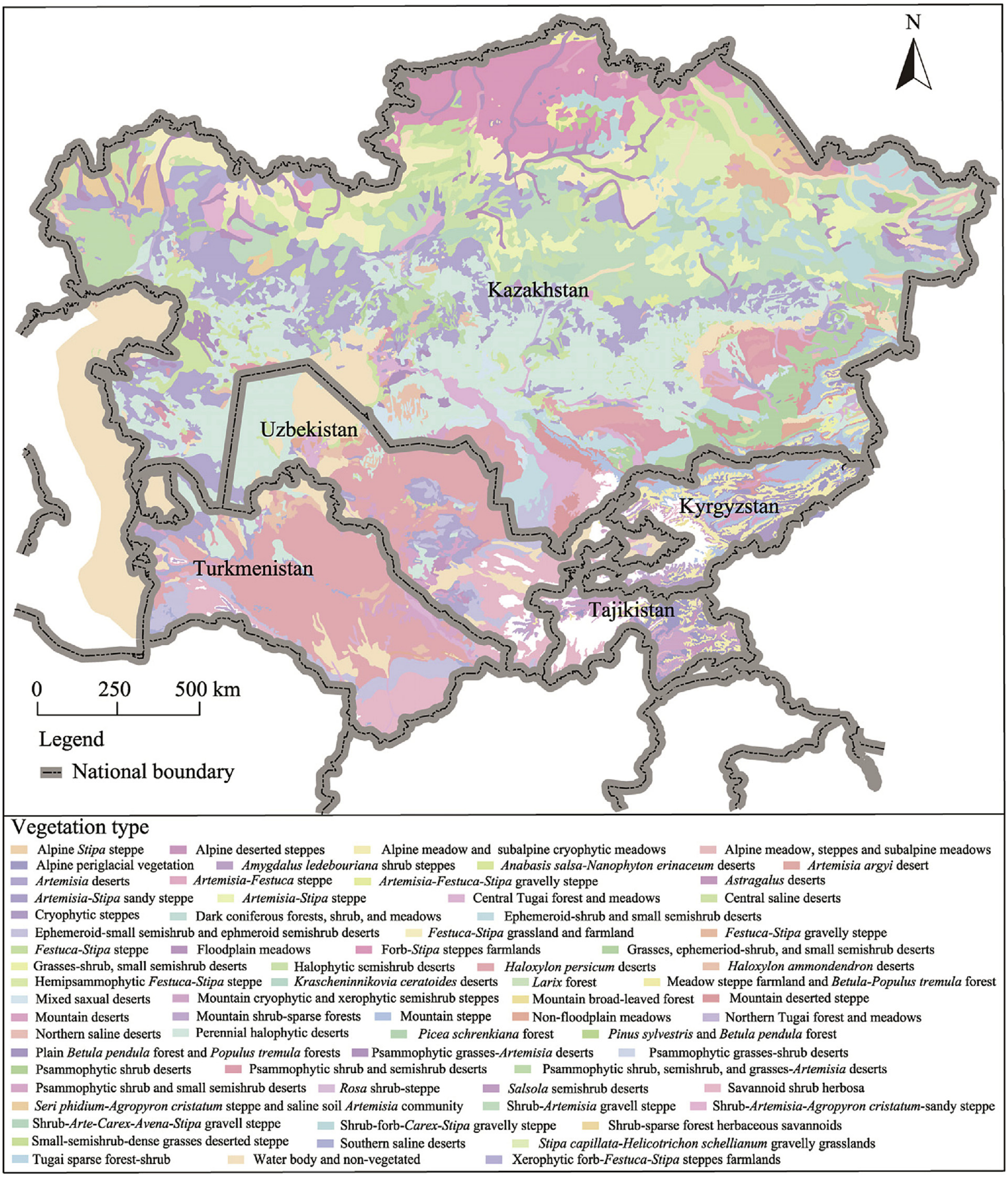

Fig. 2. Main vegetation types of Central Asian countries (not including Xinjiang of China).

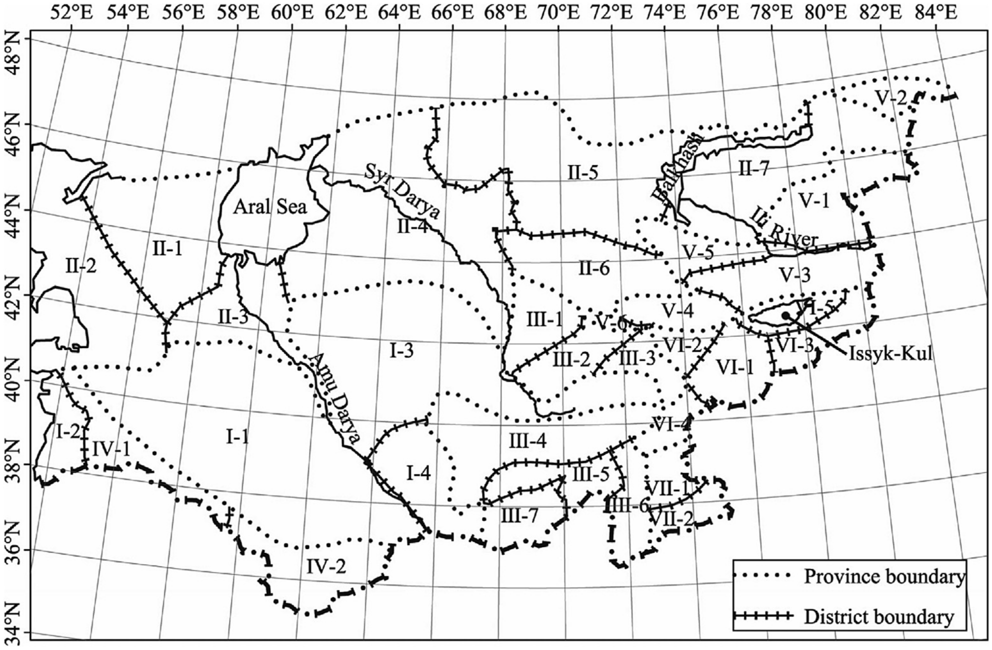

Fig. 3. Plant geographical divisions of Central Asia. I. Turan Province: 1, Karakum District; 2, Messerian District; 3, South Kyzylkum District; and 4, Bukhara District. II. Central Kazakhstan Province: 1, Ustyurt District; 2, Mangyshlak District; 3, Amu Darya River District; 4, North Kyzylkum District; 5, Betpakdala District; 6, Muyunkum District; and 7, South Balkhash District. III. South Turkestan mountains Province: 1, Karatau District; 2, West Tianshan District; 3, Ferghan District; 4, Kuhistan District; 5, Gissar-Darvaz District; 6, Badakhshan District; and 7, South Tajikistan District. IV. Turkmenistan-Iran Province: 1, Kopet Dag District; and 2, Bathyz District. V. Junggar-Tianshan Province: 1, Junggar forest meadow District; 2, Tarbagatai District; 3, Yili mountain District; 4, Kyrgyzstan District; 5, Chu-Ili District; and 6, Talas District. VI. Central Tianshan Province: 1, Southwestern steppe District; 2, Northwestern meadow District; 3, Eastern mountain District; 4, Alai steppe District; and 5, Issyk-Kul meadow-steppe District. VII. Eastern Pamir Province: 1, Northeastern District; and 2, Southeastern District.

are particularly important in this regard and have been listed as global biodiversity hotspots (Mittermeier et al., 2006).

2. Main types of ecosystems and vegetation

The predominant types of ecosystems in the region are deserts, semi-deserts, and steppes. These ecosystems cover nearly 75% of Central Asia and can be found throughout the lower mountain slopes and foothills and in some outlying ranges and major basins. The environmental heterogeneity and instability caused by wind erosion encourage plant growth and enrich the floral components. Fossil evidence from the Tertiary period suggests that vegetation is widespread and variable in the gravel desert (also known as the Gobi Desert) (Zhang et al., 2013). The gravel desert flora comprises more than 400 species, including representatives of the genera *Seriphidium*, *Anabasis*, *Atraphaxis*, and *Caragana*, along with the species *Halolachne songaricum*, *Krascheninnikovia ceratoides*, *Iljinia regelii*, *Salsola gemmascens*, and *Artemisia pectinate*.

In the Quaternary period that followed, the upper layer of surface sand and alluvial clay was subject to strong aeolian influences, and sands accumulated at lower levels, forming a large area of sandy deserts that are now home to approximately 350 species from 125

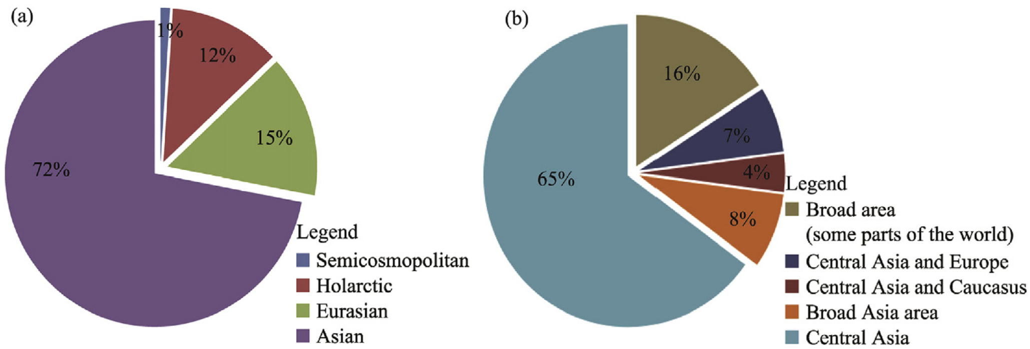

Fig. 4. Proportions of geographical groups of flora in Central Asia. (a), rough analysis; (b), detailed analysis.

Table 1
Floristic data of Central Asia.

Country/ region	Flora, checklist and Red Data Book	Species count	Reference
Central Asia	Conspectus Florae Asiae Mediae, 1–11	9341	Kovalevskaya (1968–1971), Bondarenko and Nabiev (1972), Pakhomova (1974–1976), Kamelin et al. (1981), Adylov (1983, 1987), Nabiev (1986), Adylov and Zuckerwanik (1993), Khassanov (2015)
	Plant Resources and Utilization in Central Asia	9346	Zhang et al. (2013)
	Checklist of Vascular Plants of Central Asia	9520	Li et al. (unpublished)
Kazakhstan	Flora Kazakhstana, 1–9	5631	Pavlov (1956–1966)
	Checklist of Vascular Plants of Kazakhstan	5658	
	Red Data Book of Kazakhstan, Volume 2: Plant	387	Baitulin (2014)
Kyrgyzstan	Flora Kirgizskoj SSR, 1–11; Supplementary 1–2	3576	Shishkin and Vvedensky (1950–1962)
	Checklist of Vascular Plants of Kyrgyzstan	3927	Lazkov and Sultanova (2014)
	The Red Data Book of the Kyrgyz Republic	87	Shukurov (2006)
Tajikistan	Flora Tadzikskoj SSR, 1–10	4445	Ovchinnikov (1957–1991)
	The Red Data Book of the Republic of Tajikistan Volume 1	267	Rahimi et al. (2017)
Turkmenistan	Flora Turkmenii, 1–7	2607	Fedtschenko et al. (1932, 1937, 1948– 1960)
	Manual of Vascular Plants of Turkmenistan	2800	Nikitin and Geldykhanov (1988)
	Red Data Book of Turkmenistan Volume 1: Plants and Fungi (3rd ed.)	115	Annabayramov (2011)
Uzbekistan	Flora Uzbekistanica, 1–6	4148	Schreder and Vvedenskyi (1941–1962)
	Flora of Uzbekistan, 1–3	375	Sennikov (2016, 2017, 2019)
	Red Data Book of Uzbekistan 1: Plants	324	Khassanov and Pratov (2009)
Xinjiang of China	Flora Xinjiangensis, 1–6	3875	Commissione Redactorum Flora Xinjiangensis (1993–2011)

genera, including *Acanthophyllum*, *Cousinia*, *Ferula*, *Eremurus*, *Jurinea*, *Heliotropium*, *Eremostachys*, and *Calligonum*. Endemic genera are represented by *Spirorrhynchus*, *Octoceras*, *Streptoloma*, *Cithareloma*, *Lachnoloma*, *Ammodendron*, *Eremosparton*, and *Ammothamnus*. In addition to psammophytes, some desert-adapted halophytes have colonized the sandy deserts, including several species of *Salsola* and other Chenopodiaceae species. Central Asian deserts are centers of origin and differentiation of ephemeral plants and contain more than 400 such species. The main vegetation types of Central Asia are mapped in Fig. 2.

In addition to deserts and semi-desert areas, the biodiversity hotspots of the mountains of Central Asia are crucial for maintaining the natural and domesticated biodiversity (CEPF, 2017). The geological evolution of the mountains, wide range of elevations, and extreme climatic variations have combined to produce a unique landscape and biotic diversity. Approximately 7000 species of vascular plants are found in the mountains of Central Asia, accounting for more than 75% of the total plant diversity in the region (Zhang et al., 2013). The number, extent, and sequence of vegetation zones vary across Central Asia as a function of temperature and moisture gradients, slope aspect, altitude, and latitude. Dryland ecosystems prevail at lower elevations and in foothills. Grasslands, shrubs, and forests are widespread at medium altitudes of mountain slopes. Meadows and tundra-like ecosystems are found at higher elevations. Spruce and birch forests occur mainly in the Tianshan Mountains, whereas old-growth juniper forests are more common in the Pamir-Alai Mountains. Many mountain and riverside forest ecosystems are legally protected, including the Western Tianshan, which is listed as one of the natural World Heritage Sites, and the Pamir-Alai initiative, which forbids any commercial exploitation of forests and regulates other economic activities.

The hotspots contain ancestors of domestic varieties of fruits and nuts such as apricots, plums, cherries, apples, pears, cherry plums, grapes, pistachios, almonds, walnuts, and pomegranates. Wild crop relatives of many herbaceous plants, such as wheat, barley, rhubarb, sorrel, anise, oats, onion, garlic, and tulips, are still found here, and some are on the International Union for Conservation of Nature Red List, making the region an important reservoir of crop diversity.

Patches of riverine woodland forest known as tugai survive along the Amu Darya, Zeravshan, Syr Darya, Chu, Talas, Ili, and Tarim rivers, among other places. Only a few species of trees and shrubs are found in tugai forests, and the floral diversity is poor. The predominant tree species found here are *Populus euphratica* and *Populus pruinosa*, although three species of *Elaeagnus* (*Elaeagnus oxycarpa*, *Elaeagnus turcomanica*, and *Elaeagnus sonarica*) also play important roles in riparian forests. The shrub layer is composed of several genera, including *Tamarix*, *Halimodendron*, and *Halostachys*. Approximately 50 species from the genera *Glycyrrhiza*, *Alhagi*, *Aeluropus*, *Karelinia*, and *Apocynum* constitute the herbaceous layer.

Table 2
Classification system of plant resources in Central Asia (according to the system by Wu et al. (1983)).

Category	Subcategory	Representative species
Edible plant resources	Starch plants	*Ulmus pumila*, *Agriophyllum squarrosum*, *Oryza sativa*, *Triticum petropavlovskyi*, and *Eremurus inderiensis*
	Protein plants	*Medicago sativa*, *Glycyrrhiza inflata*, and *Sophora alopecuroides*
	Edible oils and fats	*Juglans regia*, *Capparis spinosa*, *Carthamus tinctorius*, *Eruca sativa*, and *Brassica napas*
	Vitamin plants	*Nitraria tangutorum*, *Elaeagnus angustifolia*, *Hippophae rhamnoides*, *Rosa beggeriana*, and *Rubus idaeus*
	Beverage plants	*Crataegus songorica*, *Morus alba*, *Vitis vinifera*, *Punica granatum*, and *Cerasus fruticosa*
	Food pigment plants	*Daucus carota*, *Lycopersicon esculentum*, *Capsicum annuum*, *Urtica dioica*, and *Sambucas sibirica*
	Spice plants	*Cumimum cyminum*, *Mentha haplocalyx*, *Artemisia dracunculus*, *Origanam vulgare*, and *Carum carvi*
	Plant sweeteners	*Glycyrrhiza uralensis*, *Crataegus sanguinea*, *Vaccinium* sp., *Beta vulgaris*, and *Acer plantanoides*
	Forage plants	*Alhagi sparsifolia*, *Aristida pennata*, *Kochia prostrata*, *Sorghum sudanense*, and *Carex praecox*
	Honey plants	*Cirsium setosum*, *Ziziphora bungeana*, *Elsholtzia densa*, *Elaeagnus angustifolia*, and *Arctium lappa*
Medicinal plant resources	Chinese herbal medicine	*Astragalus membranaceus*, *Glycyrrhiza uralensis*, *Cistanche deserticola*, *Ephedra intermedia*, *Saussurea involucrata*, *Fritillaria walujewii*, *Ferula sinkiangensis*, and *Adonis amurensis*
	Plant pesticides	*Anabasis aphylla*, *Portulaca oleracea*, *Artemisia annua*, *Solanum nigrum*, and *Stellera chamaejasme*
	Toxic plants	*Astragalus variabilis*, *Oxytropis glabra*, *Ceratocephalus testiculatus*, *telleropsis tianschanica*, and *Aconitum* spp.
Plant resources for industry use	Timber plants	*Picea schrenkiana*, *Pinus sibirica*, *Populus tomentosa*, *Abies sibirica*, and *Populus tremula*
	Fibrous plants	*Achnatherum splendens*, *Poacynum hendersonii*, *Phragmites australis*, and *Typha* ssp.
	Tanning plant	*Polygonum bistorta*, *Epilobium angustifolium*, and *Limonium gmelinii*
	Aromatic plants	*Elaeagnus angustifolia*, *Calligonum mongolicum*, *Rosa rugosa*, *Lavandula angustifolia*, and *Syringa persica*
	Industrial oils and fats	*Sphaerophysa salsula*, *Cannabis sativa*, *Thalictrum simplex*, *Asparagus offieinalis*, and *Ricinus communis*
	Gum plants	*Sesnania cannabina*, *Astragalus membranaceus*, *Elaeagnus angustifolia*, *Amygdalus davidiana*, and *Armeniaca vulgaris*
	Plant dyes for industrial use	*Isatis indigotica*, *Arnebia euchroma*, *Carthamus tinctorius*, *Lycium ruthenicum*, and *Anthemis tinctoria*
	Energy plants	*Typha latifolia*, *Haloxylon ammodendron*, *Tamarix chinensis*, *Calligonum mongolicum*, and *Reaumuria soongoarica*
	Host plants of economic insects	*Fraxinus sodgiana* and *Brachythe reflexum*
	Other resources plants	*Betula pendula*, *Orostachys* sp., and *Suaeda glauca*
Protection/landscaping plant resources	Windbreak and sand-fixing plants	*Calligonum mongolicum*, *Haloxylon ammodendron*, *Tamarix chinensis*, *Inula salsoloides*, *Kalidium foliatum*, *Halimodendron halodendron*, *Nitraria sibirica*, and *Seriphidium santolinum*
	Plants for soil and water conservation	*Caragana leucophloea*, *Tamarix chinensis*, and *Ammodendron bifolium*
	Green manure plants	*Sophora alopecuroides*, *Medicago falcate*, *Melilotus albus*, and *Sphaerophysa salsula*
	Flower plants	*Limonium sinense*, *Acanthophyllum pungens*, *Aquilegia viridiflora*, *Anemone cathayensis*, *Clematis florida*, *Iris tectorum*, *Tulipa gesneriana*, and *Androsace umbellata*
	Indicator plants	Moss and *Salsola nitaria*
	Anti-polluting plants	*Tamarix Chinensis*, *Juniperus sabina*, *Hibiscus syriacus*, and *Punica granatum*
Plant germplasm resources	Endemic plants	*Salix burqinensis*, *Betula Halopyila*, *Atraphaxis jrtyschensis*, *Polygonum tianxchanicum*, *Pyrola xinjiangensis*, *Seseli grubovii*, *Stenocoelium popovii*, *Oxytropis przewalskii*, *Oxytropis bogdoxchanica*, *Calophaca chinensis*, *Stellaria divnogorskjae*, *Calligonum roborovskii*, and *Zygophyllum kaschgarica*
	Germplasm resources of crop variety	*Aegilops tauschi*, *Leymus racemosum*, *Eremopyrum* sp., *Learsia oryzoides*, *Aegopodium podagraria*, *Lactuca sativa*, *Lactuca altaica*, *Lactuca auriculata*, *Lactuca undulata*, *Lactuca serriola*, *Malus sieversii*, *Juglans regia*, *Arabidopsis tuemurica*, and *Arabidopsis qaranica*

3. Analysis of plant geographical divisions and components

The plant geographical divisions of Central Asia comprise 5 provinces and 33 districts (Fig. 3).

Central Asia is bordered by two different floristic regions: Irano-Turanean and Central-Asiatic. Additionally, because the entire region is situated in the Tethian (or Ancient Mediterranean) subkingdom, it includes the Altai-Sayan Province of the circumboreal region of the Boreal subkingdom (Takhtajan, 1978). Its position between two floristic subkingdoms has enriched the region's flora with boreal element characteristic of the taiga forest zone. Kamelin (1998) suggested that the flora of the Dzungar Alatau range is rich in boreal species that are more typical of boreal Siberian flora.

Of the dominant species whose distributions do not extend beyond Central Asia, 65% have a Central Asian distribution; Eurasia and Holarctic species represent 12% and 15%, respectively; and 16% are broadly distributed in more than three continents. Additionally, 7% of the species are distributed in both Central Asia and Europe and 4% are distributed in both Central Asia and Caucasus (Fig. 4).

4. Species diversity

The botanical investigation of Central Asia began in the 18th century, although the study boom occurred in the latter half of the 19th century (Frodin, 2001). Descriptions of Central Asian flora based on collections made during those investigations were published in Conspectus Florae Asiae Mediae (Kovalevskaya, 1968–1971; Bondarenko and Nabiev, 1972; Pakhomova, 1974–1976; Kamelin et al., 1981; Adylov, 1983, 1987; Nabiev, 1986; Adylov and Zuckerwanik, 1993), Flora Turkmenii (Fedtschenko et al., 1932, 1937, 1948–1960), Flora Uzbekistanica (Schreder and Vvedenskyi, 1941–1962), Flora Kirgizskoj SSR (Shishkin and Vvedensky, 1950–1962), and two supplements (Vykhodsev, 1967, 1970), Flora Kazakhstana (Pavlov, 1956–1966) and Flora Tadzikskoj SSR (Ovchinnikov, 1957–1991). Publication of Conspectus Florae Asiae Mediae (Vols. 1–11) began in 1963 and took 52 years to complete. Volume 11 can be treated as a checklist for Central Asia; it contains 9341 species of vascular plants belonging to 161 families and 1245 genera (Khassanov, 2015). Similar numbers were published by Zhang et al. (2013), who recorded 9346 species of vascular plants belonging to 127 families and 1279 genera across Central Asia (Table 1).

At 2.72×10^6 km^2, Kazakhstan is the largest country in Central Asia, and it contains the highest number of vascular plants. Flora Kazakhstana reported 5631 vascular plant species (Pavlov, 1956–1966). This number was updated to 5658 and to more than 5754 in Kazakhstan's fifth national report on the progress in the implementation of the Convention on Biological Diversity (CBD) (Ministry of Environment and Water Resources of the Republic of Kazakhstan, 2014). Tajikistan is the smallest of the five Central Asian countries, covering just 0.14×10^6 km^2, but it contains the second largest number of vascular plant species in Central Asia. In the Flora of Tajikistan, 4445 vascular plants were reported, of which more than 640 are endemic (Ovchinnikov, 1957–1991). The number of endemic species may now be approaching 882 species according to the CBD's national report for Tajikistan (Safarov et al., 2014).

A total of 4385 species were described in the first edition of the Flora of Uzbekistan, which was completed 58 years ago (Schreder and Vvedenskyi, 1941– 1962). Three volumes of a new project have been published (Sennikov, 2016, 2017, 2019). Approximately 4500 species of wild higher plants and more than 2000 species of fungi are found in Uzbekistan. Approximately 400 are rare, endemic, and relict species (10%–12% of all flora), and 378 are considered national endemics (Sennikov et al., 2016).

According to the Turkmenistan's fifth national report on the implementation of the UN CBD at National Level (Convention on Biological Diversity Report of Turkmenistan, 2014), 3140 higher plants species are distributed within the country, which is more than the 2800 reported in a previous list of flora (Fedtscihenko et al., 1932–1960; Nikitin and Geldykhanov, 1988). In 2014, Lazkov and Sultanova published a new list of vascular plants in Kyrgyzstan that includes 3927 species, of which 395 are endemic (Lazkov and Sultanova, 2014).

An updated checklist of vascular plants in Central Asia was recently completed (Li et al., unpublished data) and arranged according to Christenhusz et al. (2011), APG (2016), and PPG I et al. (2016). This list includes 9520 vascular species belonging to 138 families and 1176 genera in Central Asia, including 71 species of lycophytes and ferns, 34 species of gymnosperm, and 9415 species of angiosperm. The families with the top 10 number of species are Asteraceae, Fabaceae, Poaceae, Lamiaceae, Apiaceae, Brassicaceae, Caryophyllaceae, Amaranthaceae, Rosaceae, and Amaryllidaceae. Some genera, including *Allium* (Fritsch, 2016), *Tulipa* (Tojibaev and Beshko, 2015), *Gagea* (Peterson et al., 2016), *Juno* (Khassanov and Rakhimova, 2016), and *Hedysarum* (Nafisi et al., 2019) have Central Asian origin. A significant number of species and genera are endemic to this area, which contributes to the floristic irreplaceability of Central Asia (Takhtajan, 1978; Zhang et al., 2013).

5. Rare and endangered species

Under the auspices of the United Nations CBD, the five countries of Central Asia have ratified the main objectives of botanical research as the inventory of biodiversity and evaluation of endemic, rare, and endangered species at the national level (https://www.cbd.int/). Two editions of the Red Data Book of the five Central Asian countries have been published and updated. The Red Data Book promotes effective biodiversity monitoring and provides a foundation for discussions of all listed rare and endangered species. The main trends of biodiversity reduction are clearly reflected, and effective actions toward sustainable protection of rare and endangered species have been developed and implemented in the five countries.

The newest edition of the Red Data Book lists 387, 87, 267, 115, and 324 species of fungi, lichens, bryophytes, and vascular plants in Kazakhstan (Baitulin, 2014), Kyrgyzstan (Shukurov, 2006), Tajikistan (Rahimi et al., 2017), Turkmenistan (Annabayramov, 2011), and Uzbekistan (Khassanov and Pratov, 2009), respectively. Of the 1010 species (1119 in total, 112 repeats) of vascular plants representing 87 families and 384 genera, more than 20 are endangered. Fifteen families containing more than 20 endangered species are represented: Fabaceae (135), Asteraceae (130), Apiaceae (83), Liliaceae (59), Amaryllidaceae (50), Lamiaceae (48), Brassicaceae (43), Rosaceae (33), Amaranthaceae (28), Caryophyllaceae (28), Iridaceae (27), Ranunculaceae (27), Asphodelaceae (22), Boraginaceae (21), and Plumbaginaceae (20). The genus *Astragalus*, with 63 species, tops the list of genera of endangered species, followed by *Tulipa*, *Allium*, *Cousinia*, *Ferula*, *Eremurus*, *Oxytropis*, *Jurinea*, *Silene*, *Hedysarum*, *Acantholimon*, *Juno*, *Salvia*, and *Scutellaria*.

Many rare and endangered species are also sources of economically valuable medicines, ornamentals, food, fruit, livestock fodder, etc. As a result, they are threatened by human activities such as excessive pasturage and plowing as well as collection for use as medicines, food, firewood, and ornamentals. For example, extensive uprooting of *Ferula tadshikorum*, which is narrowly distributed in southern Tajikistan, has led to its listing as an endangered species (Rahimi et al., 2017).

6. Classification and utilization of plant resources

Central Asia comprises a vast territory and diverse landscapes with a rich diversity of plant resources, providing a wide array of ecosystem goods and services that are essential for the sustainable development of the entire region. These goods and services provide food, medical resources, habitats for flora and fauna, and space for leisure and recreational activities. They also regulate natural hazards and local climates and, perhaps most importantly, store and release water. In the Regional Sustainable Development Strategy of Central Asia (UNEP Interstate Commission on Sustainable Development of Central Asia, 2009), the governments officially acknowledged the role of mountains as "water towers" and storehouses of biodiversity.

According to a classification system proposed by Wu et al. (1983), plant resources of Central Asia can be grouped into 5 categories and 31 subcategories, as shown in Table 2.

6.1. Edible plant resources

There are 103 species of wild fruit trees, more than 200 species of large edible fungi, more than 50 species of vitamin plants, nearly 100 species of oil plants, and more than 500 species of plants that provide nectar and pollen for honeybees.

6.2. Medicinal plant resources

There are 2014 species of medicinal plants, of which 1451 are wild species and more than 120 are used in the manufacture of pesticides, and approximately 125 Chinese herbal medicinal plants that are purchased by pharmaceutical companies.

6.3. Plant resources for industry use

There are 100–150 species of timber tree, and over 380 species of fiber plants. More than 200 species yield tannin, spices, fat, gum and dyes for industrial use.

6.4. Environmental protection and landscape construction plant resources

There are more than 80 species of shelterbelt tree species, more than 100 species of sand-fixing plants, and more than 300 species of ornamental plants.

6.5. Plant germplasm resources

There are approximately 950 rare and endangered species and more than 1200 endemic species. In addition, crop-related germplasm resources include 87 species of wild cereal crops and 70 species of wild fruit trees. There are also plants with unique germplasms, including those that are salt-tolerant, drought-resistant, and disease-resistant. As for the classification of plant resources in Xinjiang of China, it has been clearly described by Shen (2010). There are 16 subcategories of 1320 species of economic values in Xinjiang of China, including 462 edible plants, 979 medicinal plants, 70 timber plants, 126 fibrous plants, 37 fuel plants, 171 dye plants, 115 tanning plants, 417 protection and landscaping plants, 259 toxic plants, 79 papermaking plants, 201 oil plants, 125 spice plants, 58 industrial oil and fat plants, 121 raw chemical material plants, 493 forage plants, and 303 honey plants.

7. Principal threats to plant diversity

Factors such as habitat change, biological invasions, and global climate change are likely to have significant effects on plant biodiversity in Central Asia. Conversion of steppes to arable agricultural and cotton fields has resulted in a direct loss of habitat, and unsustainable agricultural practices have accelerated the process of desertification. Unregulated deforestation in woodlands, riparian tugai forests, and mountain forests has greatly exacerbated deforestation (Khan et al., 2018). Overgrazing by domestic livestock on the remaining fragile habitats, such as stony and hilly steppe zones, has caused the conversion of steppes and wetlands to wastelands. In Xinjiang of China, serious overgrazing and pasture degradation began in the 1970s. Similar to overgrazing, the unregulated collection of plants for household or medicinal use or for sale (e.g., various tulip species) has led to widespread land degradation and has threatened the sustainability of some species. Loss and degradation of habitat have had a considerable influence on the plant resources of Central Asia. Some species, e.g., *Betula halophila*, have become extinct, leading to a high percentage of rare and endangered species (>10% of the total flora), thereby undermining ecological succession and community structures and threatening ecological stability and security. Changes in the water balance through poor water management and irrigation practices have caused large ecological disasters (Yu et al., 2019). For example, the Aral Sea has lost 75% of its volume over the past five decades, resulting in desiccation, salinization, and erosion of neighboring lands. High levels of fertilizers, pesticides, and herbicides in irrigation systems have resulted in severe water and soil pollution. Pollution is the greatest threat in the most industrialized areas or areas that are downstream of these systems. For example, the main freshwater basins of Lake Issyk-Kul, the Ferghana Valley, and the Ili Basin are at risk from persistent organic pollutants and toxic waste (CEPF, 2017).

As steppes and other natural ecosystems have been degraded, invasive plant species, including non-native species, have flourished. More common than the intentional introduction of species, however, is the spread of invasive species as a result of habitat change. Chen (2012) recorded the successful invasion of 942 alien higher plants belonging to 121 families and 469 generain the Xinjiang arid zone. The wild fruit forests of the Tianshan Mountains, the natural distribution range of the ancestors of various economically valuable fruit trees, have become an ecological disaster in modern times because of the damage caused by the exotic insect *Agrilus mali* (Zhang et al., 2020).

The long-term effects of global climate change pose a threat to Central Asian ecosystems, both directly as a disruptive factor and indirectly in combination with other threats. Two-thirds of the existing habitats of Kyrgyzstan and half of those of Tajikistan are at risk from global warming, either through outright loss or changes to another habitat type. Temperate evergreen and mixed forests and boreal coniferous forests are among the ecosystems most at risk because of the shrinking habitat size caused by global warming (Malcolm and Markham, 2000).

8. Perspectives

Our findings show that plant biodiversity and resources in Central Asia are both rich and unique. However, biodiversity in Central Asia is threatened by both natural and anthropogenic disturbances. The three drivers of global change we identified indicate a need to adopt different conservation strategies. Land-use changes can complicate species movement through increasing fragmentation and facilitate the establishment of invasive alien species by increasing habitat disturbance. In contrast, biological invasions are avoidable, and the most efficient conservation actions are the prevention of introduction of alien species and rapid responses (Simberloff et al., 2013). Climate change is inevitable, but its effects on biodiversity can be minimized, in part by facilitating the movement of native species to more climatically suitable areas (Hodgson et al., 2009). Establishing protected areas that are resilient to climate and land-use changes is an additional challenge (Bellard et al., 2014).

Global climate change poses a clear threat to the ecological diversity of Central Asia. Close monitoring of the theoretical estimates of the region's vulnerability based on its exposure to land-use changes, biological invasions, and climate change is needed to evaluate the response of biodiversity to future changes. The integration of mechanistic approaches and an increased focus on poorly studied drivers of biodiversity should also be prioritized. Strengthening international cooperation in biodiversity conservation and ecological security among the countries and regions of Central Asia and supporting the implementation of international joint protection actions are now of great importance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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