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Medicinal plant diversity in the southern and eastern Gobi Desert region, Mongolia

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Abstract

Background: The southern and eastern parts of the Gobi Desert area are a unique dry ecosystem with a diverse regional desert, semi-desert, and mountain dry steppe flora. This area habitat is located at the overlap of different floristic regions; on its northeast side, Central Asian desert flora is dominating, and on the eastern side, East Asian flora is observed. The comprehensive survey was carried out to find the floral diversity of the medicinal plants on the region.

Methods: All recorded species in this study were based on the collected voucher specimens between June and August in the year 2017.

Results: We recorded 23 families, 57 genera, and 78 species of vascular plants. The families Asteraceae (15 species), Fabaceae (10 species), and Amaranthaceae (10 species) were represented most in the study area, while *Caragana* (5 species), *Salsola* (4 species), and *Arnebia* (3 species) were the most common genera found.

Conclusion: Conservation status for remarkable species was also reviewed based on the literature. Around the study area, 24 species as "sub-endemic," 10 species as "very rare," 4 species as "rare," 1 species as "alien," 13 species as "relict," 10 species as "Red Book," 2 species as "endangered (EN)," 3 species as "vulnerable (VU)," 3 species as "near threatened (NT)," and 2 species as "least concern (LC)" plants are growing.

Keywords: Medicinal plant diversity, Conservation status, Southern and eastern Gobi Desert, Mongolia

Background

One of the most exotic and mysterious places in the world is the Gobi Desert (Fig. 1); it has always attracted adventurers and explorers. The Gobi is most notable in history as part of the great Mongol Empire, and as the location of several important cities along the Silk Road. Contrary to the popular belief, Gobi is not a desert in the usual sense; it is a sandy area completely devoid of vegetation. Mongols talk about many Gobis; in fact, they have 33 Gobis according to soil composition and color.

The Gobi is a large desert region in northern China and southern Mongolia. The desert basins of the Gobi are bounded by the Altai Mountains and the grasslands and steppes of Mongolia on the north, by the Tibetan Plateau to the southwest, and by the North China Plain to the southwest. The Gobi measures over 1600 km (1000 mi) from southwest to northeast and 800 km (500 mi) from north to south. The desert is widest in the west; it occupies an arc of land 1,295,000 km^2 (500,000 sq mi) in area as of 2007; it is the fifth largest desert in the world and Asia's largest. Much of the Gobi is not sandy but has exposed bare rock.

The Mongolian Gobi, a vast zone of desert and semi-desert, occupies almost 30% of the country's territory. One of the harshest environments on earth, with extreme temperature and seasonal changes, Gobi is surprisingly full of wildlife such as gazelle, wild ass, wild camel, endangered Gobi bear, and special plants (largely endemic and sub-endemic species). The Gobi Desert is a vast, arid region in northern China and southern Mongolia. It is known for its dunes, mountains, and rare animals like snow leopards and

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Fig. 1 Map of the Gobi Desert

Bactrian camels. In the Gobi Gurvansaikhan National Park, the Khongoryn Els sand dunes are said to "sing" when the wind blows. The park also features the deep ice field of Yolyn Am canyon. Dinosaur fossils have been found at the red "Flaming Cliffs" of Bayanzag.

The southern and eastern Gobi Desert extends from the Inner Mongolian Plateau (China and Mongolia), situated at 1000 to 1500 m elevation, northward into Mongolia. It is a broad ecotone. Boundaries are determined to the east and north by the relatively moist grasslands of Mongolia and Manchuria and to the west and south by the extensive semi-deserts of the Alashan Plateau. This ecoregion includes the Yin Shan, a mountain range that rises to an elevation of 1500 to 2200 m and many low-lying areas with saltpans and small ponds. Although the region appears rather desolate, it provides a potential habitat for many wildlife species and a human population of semi-nomadic herders.

The climate here is continental. Summers are warm to hot, depending on elevation, and winters are intensely cold. Winter conditions are harsher here than the other parts of China at similar altitude and latitude because there are no mountains to shelter the region from cold northerly winds. The mean annual temperature varies from − 2 to − 6 °C, with January mean temperatures of − 20 to − 28 °C. Annual precipitation here is about 100 to 150 mm, although total precipitation varies considerably from 1 year to the next. Most of this precipitation falls during summer.

Vegetation tends to be homogenous across vast areas of the eastern Gobi Desert and distinct from the vegetation of grasslands to the east and deserts to the west. It consists of drought-adapted shrubs and thinly distributed low grasses. Dominant shrubs include two *Caragana* species (*Caragana bungei* and *Caragana leucocephala*). Other shrubs include gray sparrow's saltwort (*Salsola passerina*), gray sagebrush (*Artemisia xerophytica*), *Potaninia mongolica*, and *Nitraria sibirica*. Low grasses include needle grass (*Stipa gobica* and *Stipa glareosa*) and bridlegrass (*Cleistogenes soongorica*).

Mongolia occupies an ecological transition zone in Central Asia where the Siberian Taiga forest, the Altai Mountains, Central Asian Gobi Desert, and the grasslands of the eastern Mongolian steppes meet.

Systematic exploratory studies including those on medicinal plant resources were undertaken from the 1940s when the Government of Mongolia invited Russian scientists including Drs. I. A. Tsatsenkin, A. A. Yunatov, and V. I. Grubov who focused on rare and useful plant species giving emphasis on plant species of medicinal value. A Joint Russian-Mongolian Complex Biological Expedition conducted since 1970 followed this.

Currently, it is estimated that about 3160 species (included 133 subspecies and 33 varieties), 684 genera, and 108 families of vascular plants exist in Mongolia (Urgamal et al. 2016). Of these, about 1100 species are medicinal plants, 150 species are rich sources of vitamins, 200 species contain essential oils, 250 species contain tanning matter, more than 200 species are plants that can be used for dyeing, 231 species are rich in flavonoid, 200 species are useful in many industries,

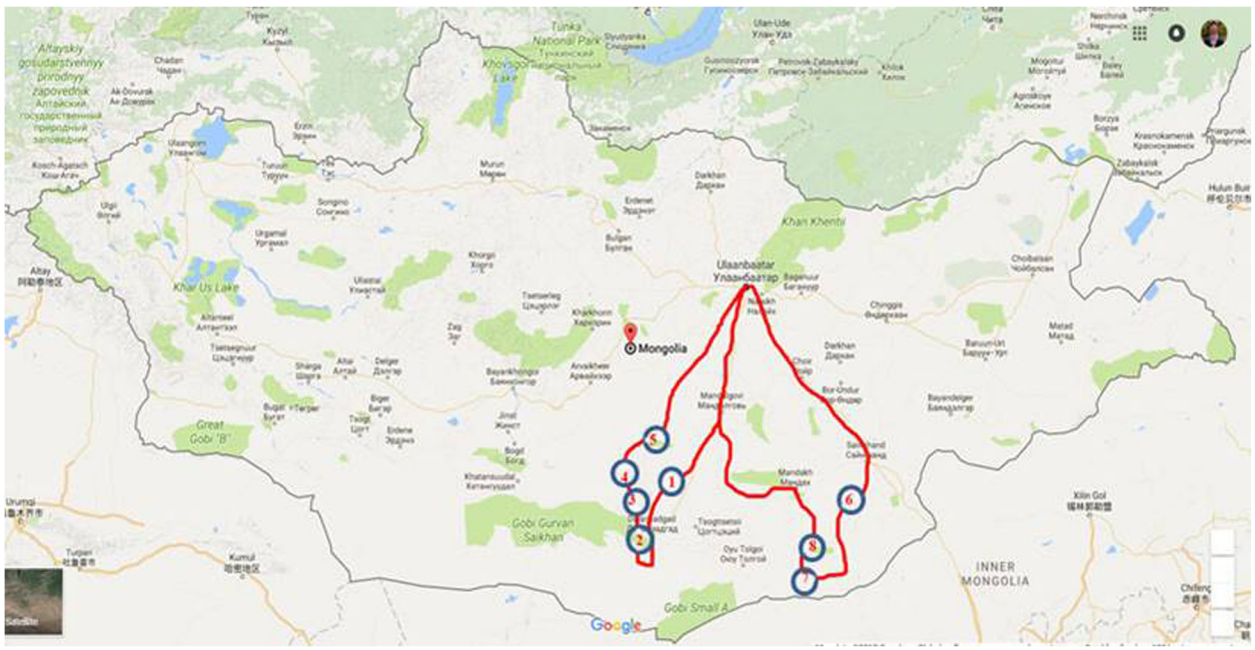

Fig. 2 Locations of our study route and site areas

more than 480 species are ornamental plants, 280 species contain alkaloids, 65 species contain coumarin, and 68 species are used to control sand movement (Ulziykhutag 1989). About 32% of the total vascular plants found in Mongolia are registered as medicinal plants, of which more than 200 plants species could be used for manufacturing modern western medicine. Although substantial work has been undertaken to identify and record the distributions of medicinal plants in Mongolia, studies in the Khuvsgul and Khangai mountains are incomplete.

The purpose of this study was to identify the medicinal plants in the southern and eastern Gobi Desert of Mongolia and record their distribution across the study area. The study also aimed to determine the species composition of vascular plants in the study area and compare their floral analysis, conservation status, ecological groups, the habitat type in which they were found, their distribution, and their usefulness based on traditional knowledge. The plant specimens were collected in joint surveys with our Mongolian partners in the southern and eastern Gobi Desert regions of Mongolia and taken to Korea for botanical investigations. Information on traditional knowledge was also collected in collaboration with our Mongolian partners.

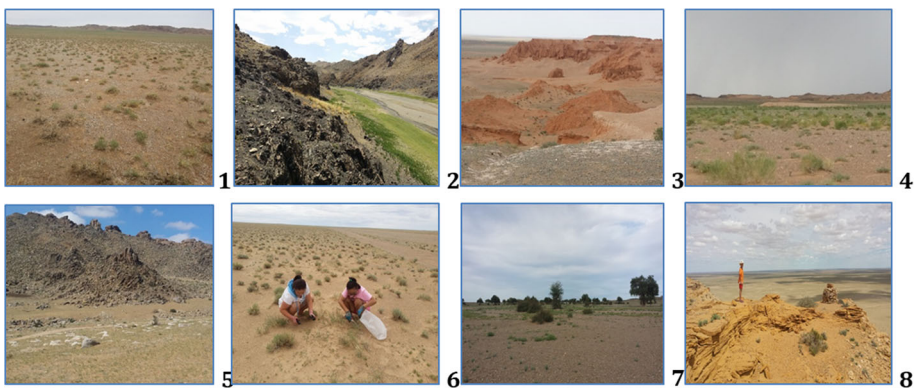

Fig. 3 Photos of our study sampling sites in the Gobi Desert, Mongolia. 1—Umnugobi, Tsogt-Ovoo sum, Onkhiin toirom; 2—Umnugobi, Dzunsaikhan mountain, Yoliin am; 3—Umnugobi, Bulgan sum, Bayanzag; 4—Umnugobi, Bulgan sum, Kholboogiin tal; 5—Dundgobi, Delgerkhangai sum, Delgerkhangai mountain; 6—Dornogobi, Khuvsgul sum, Khetiin tal; 7—Dornogobi, Khatanbulag sum, Ergen shand; 8—Dornogobi, Khatanbulag sum, Ergeliin Zoo

Fig. 4 Photos of our field surveys to the Gobi Desert, Mongolia

Methods

We conducted our field surveys in the southern and eastern Gobi Desert areas of the Umnugobi, Dundgobi, and Dornogobi provinces of Mongolia, two different time points to cover the full vegetation period in the summer of 2017 (Fig. 2). Within the framework of a scientific partnership between the access to the Herbarium (UBA) of Institute of General and Experimental Biology of Mongolian Academy of Sciences (MAS) and National Institute of Biological Resources (NIBR) of Korea, our botanical field survey to the Gobi Desert region in Mongolia has been carried out. The field research route went through the provinces of southern and eastern Gobi with altogether eight sampling sites (Figs. 2, 3, 4 and Table 1) in the Gobi Altai, East Gobi, and Alashan Gobi, three phytogeographical regions of Mongolia, according to Grubov (1982).

To cover all of the different habitats at differing elevations, we sampled plots from the desert (810 m.a.s.l.),

Table 1 Characterization of study sites for the southern and eastern Gobi of Mongolia

Site no.	Date	Geographical name	Place name	Coordinates	Elevation (m.a.s.l.)	Natural zone	Region name
1	17 Jun	Umnugobi province, Tsogt-Ovoo sum	Onkhiin toirom	N 44.41771, E 105.34325	1240	Desert steppe	S. Gobi
2	19 Jun	Umnugobi province, Dalanzadgad sum	Dungenee am	N 43.48442, E 104.09080	2120	Mountian steppe	S. Gobi
3	21 Jun	Umnugobi province, Bulgan sum	Bayanzag	N 44.17788, E 103.62114	1080	Desert steppe	S. Gobi
4	21 Jun	Umnugobi province, Bulgan sum	Kholboogiin tal	N 44.37214, E 103.71547	1150	Desert steppe	S. Gobi
5	22 Jun	Dundgobi province, Delgerkhangai sum	Delgerkhangai mountain	N 45.20295, E 104.42863	1380	Mountian steppe	S. Gobi
6	21 Jul	Dornogobi province, Khuvsgul sum	Khetiin tal	N 43.50215, E 109.39863	810	Desert	E. Gobi
7	22 Jul	Dornogobi province, Khatanbulag sum	Ergen shand	N 43.19029, E 109.19863	860	Desert	E. Gobi
8	24 Jul	Dorongobi province, Khatanbulag sum	Ergeliin Zoo	N 43.20295, E 109.20863	1042	Desert	E. Gobi

desert steppe (1080 m.a.s.l.) to mountain vegetation (until 2120 m.a.s.l.).

The geographic information system software ArcGis 10.2 was used to map and digitize the expedition route and collecting sites.

The nomenclature of the species followed the *Conspectus of the Vascular Plants of Mongolia* (Urgamal et al. 2014), which was based on the Angiosperm Phylogeny Group system (APG IV 2016) of plant classification. Families and species were listed in accordance with APG (The Angiosperm Phylogeny Group IV system 2016; Urgamal 2016), and species within them alphabetically; information on the conservation status according to the *Mongolian Law on Natural Plants* (1995), *International Union for Conservation of Nature* (IUCN) *Red List* was based on our results and representative references, *Conspectus of Vascular Plants of Mongolia* (Urgamal et al. 2014), *Mongolian Red List and Conservation Action Plans of Plants* (Nyambayar et al. 2011), *Preliminary analysis of the vascular flora of Mongolia* (Urgamal and Sanchir 2015), *Additions to the vascular flora of Mongolia – III/Since the "Conspectus of the vascular plants of Mongolia 2014"*/(Urgamal et al. 2016), and *Atlas of the Endemic Vascular Plants of Mongolia* (Urgamal and Oyuntsetseg 2017a, 2017b; Urgamal and Oyuntsetseg 2017a, 2017b).

All the collected herbarium materials were identified based on the *Key to the Vascular Plants of Mongolia* (Grubov 1982); *Flora of Mongolia* Volumes. 1, 10, 14a, 17 (Dariimaa et al. 2015; Urgamal 2009; Dariimaa 2014; Nyambayar 2009); *Conspectus of Vascular Plants of Mongolia* (Urgamal et al. 2014); *Conspectus of Flora of Outer Mongolia* (Gubanov 1996); *A Field Guide to the Trees and Shrubs of Mongolia* (Tungalag 2012); Tungalag (2016) as well as on electronic data of species distributional map and herbarium photos from Database of the Mongolian Flora (http://www.eic.mn/flora/). The identification of plant organs in МБС-2 binocular (× 8).

Data generated comprising of plant species' botanical and local name, family, plant part used, mode of preparation and ethnomedicinal uses were formulated in a matrix (MS excel worksheet) and summarized as proposed by Ligaa et al. (2009) and Urgamal and Kwon (2015). The collections were processed into voucher specimens and deposited in the Herbarium (UBA) of Institute of General and Experimental Biology of Mongolian Academy of Sciences (MAS) and the National Institute Biological Resources (NIBR) of Korea, and an additional data were used in this study.

Results

As a result, we recorded 23 families, 57 genera, and 78 species of vascular plants in the southern and eastern Gobi Desert of Mongolia (Appendix). Most of the families in the study area, Asteraceae (15 species), Fabaceae (10 species), and Amaranthaceae (10 species), were represented most while *Caragana* (5 species), *Salsola* (4 species), and *Arnebia* (3 species) were common genera founded of the medicinal plants collected in our study (Figs. 5 and 6 and Table 2).

Of the plant species that we collected, 30 species (38.46%) were found growing in the mountain, 34 species (43.58%) in the desert steppe, and 14 species (17.94%) in the desert (Fig. 7).

The medicinal plants found in the study sites in all parts of 4 species, in herbs of 39 species, in flowers of 5 species, in fruit and seeds of 7 species, and in the root of 9 species were used (Fig. 8).

Conservation status for remarkable species was also reviewed based on the literature. Within the investigated region, we recorded around the study area 24 species as "sub-endemic," 10 species as "very rare," 4 species as "rare," 1 species as "alien," 13 species as "relict," 10 species as "Red Book," 2 species as "endangered (EN)," 3 species as "vulnerable (VU)," 3 species as "near threatened (NT)," and 2 species as "least concern (LC)" plants are growing (Fig. 9 and Table 3).

The eight study sites were surveyed, and medicinal plants species were collected. Below, we list some important of these species:

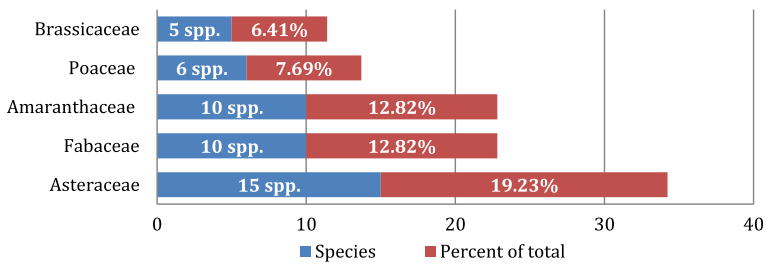

Fig. 5 The number of species representing the most common families in the study site

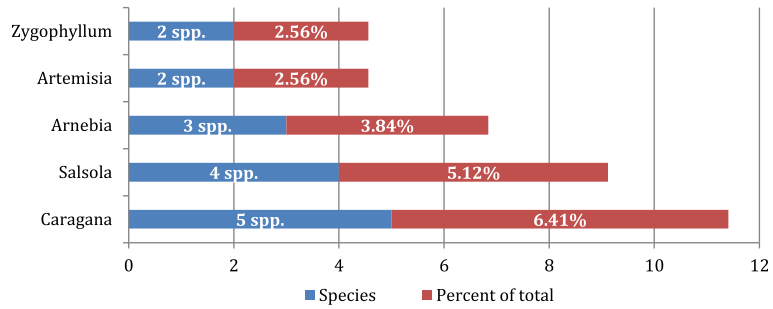

Fig. 6 The number of species representing the most common genera in the study site

Site 1. (Desert steppe in the southern Gobi)
The total collected species in this site is seven. The five sub-endemic plant species of *Allium polyrhizum* Turcz. ex Regel, *Iris bungei* Maxim., *Peganum nigellastrum* Bunge, *Reaumuria soongarica* (Pall.) Maxim., and *Salsola passerina* Bunge and one relict plant species of *Peganum nigellastrum* Bunge (Table 3) were found on this site.

Site 2. (Mountain steppe in the southern Gobi)
The total collected species in this site is 15. The three sub-endemic plant species of *Allium altaicum* Pall., *Euphorbia mongolica* (Prokh.) Prokh., *Thymus altaicus* Klokov & Desjat.-Shost., and one relict plant species of *Juniperus sabina* L. were found.

Site 3. (Desert steppe in the southern Gobi)
The total collected species in this site is five. The one sub-endemic plant species of *Thermopsis mongolica* Czefr. and two relict and rare plant species of *Calligonum mongolicum* Turcz. and *Zygophyllum xanthoxylon* (Bunge) Maxim. were found.

Site 4. (Desert steppe in the southern Gobi)
The total collected species in this site is ten. The three sub-endemic plant species of *Arnebia fimbriata* Maxim., *Stipa tianschanica* subsp. *gobica* (Roshev.) D.F. Cui, and *Zygophyllum rosowii* Bunge and one relict plant species of *Arnebia guttata* Bunge were found.

Table 2 The collected largest genera and families of the medicinal plants in our study

Family	Species	Percent of total	Genus	Species	Percent of total
1. Asteraceae	15	19.23	1. *Caragana*	5	6.41
2. Fabaceae	10	12.82	2. *Salsola*	4	5.12
3. Amaranthaceae	10	12.82	3. *Arnebia*	3	3.84
4. Poaceae	6	7.69	4. *Artemisia*	2	2.56
5. Brassicaceae	5	6.41	5. *Zygophyllum*	2	2.56

Site 5. (Mountain steppe in the southern Gobi)
The total collected species in this site is ten. One sub-endemic plant species of *Caragana stenophylla* Pojark. and one relict plant species of *Ulmus macrocarpa* Hance were found.

Site 6. (Desert in the eastern Gobi)
The total collected species in this site is 12. The six sub-endemic plant species of *Artemisia xerophytica* Krasch., *Calligonum gobicum* (Bunge ex Meisn.) Losinsk., *Caragana korshinskii* Kom., *Jurinea mongolica* Maxim., *Olgaea leucophylla* (Turcz.) Iljin, and *Scorzonera pseudodviaricata* Lipsch and one relict plant species of *Haplophyllum dauricum* (L.) G. Don were found.

Site 7. (Desert in the eastern Gobi)
The total collected species in this site is nine. The four sub-endemic plant species of *Asterothamnus alyssoides* (Turcz.) Novopokr., *Asterothamnus centraliasiaticus* Novopokr., *Brachanthemum gobicum* Krasch., *Caragana brachypoda* Pojark. and two relict

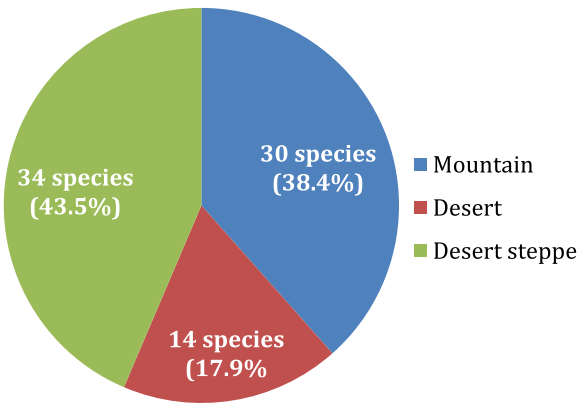

Fig. 7 Types of habitats from where the medicinal plants were collected from in the study site

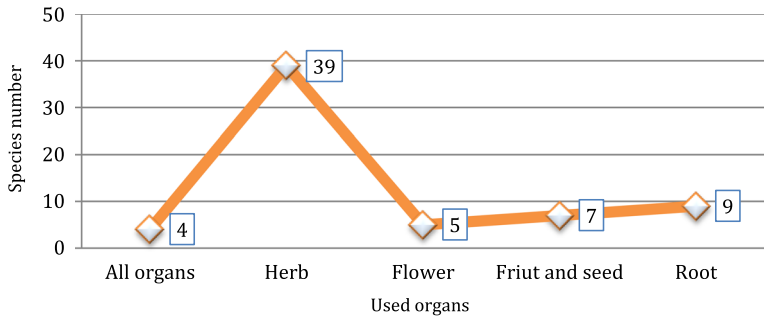

Fig. 8 The used parts of the collected medicinal plants that are known to have medicinal properties

and rare plant species of *Stipa inebrians* Hance and *Sympegma regelii* Bunge were found.

Site 8. (Desert in the eastern Gobi)

The total collected species in this site is five. The three sub-endemic plant species of *Hippolytia trifida* (Turcz.) Poljak., *Potaninia mongolica* Maxim., and *Spongiocarpella grubovii* (N. Ulzij.) Yakovlev and one relict and rare plant species of *Ephedra przewalskii* Stapf and *Spongiocarpella grubovii* (N. Ulzij.) Yakovlev were found.

Discussion

In this study, we reviewed the vascular plant diversity of the southern and eastern Gobi Desert in Mongolia. In the diverse habitats of this area, we recorded 78 species from 57 genera of 23 families, indicating that the flora of the surveyed region shows high diversity. In fact, we often found a number of species from a certain small area, which differed in habitat condition from its surroundings. In addition, widely varying ecological conditions found within the surveyed area along different altitudes (the desert, Gobi Steppe, foothills, and mountainside) were associated with different plant communities.

Records in Herbarium (UBA) and National Institute of Biological Resources (NIBR) documented all collected specimens together, sometimes with seeds and photographs. In order to list all vascular plant species accurately, we chose different collection periods (from June to August) according to plant phenology. The different phenological aspects of the plants helped for vital interpretation and determination of the species in a laboratory later (Forman and Bridson 1989). Most of the genera and some species identification have been done based on the identification keys during the field trip. Therefore, some of the early spring plants could only be recognized when flowering in late May or early June, whereas some late flowering plants were revealed in late August. Our field trip also allowed us to obtain a full herbarium collection with reproductive organs such as flowers and fruits for later precise identification.

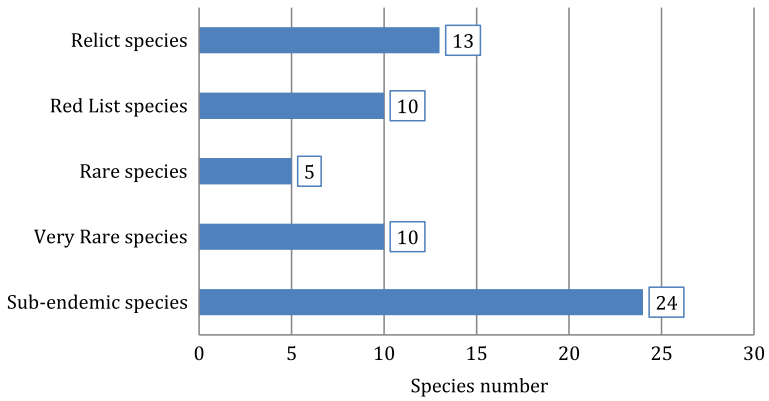

Fig. 9 The number of species representing the plant conservation status in the study site

Table 3 List of the conservation status of our collected plant species

Id	Species name	SE	RL	VR	R	AL	RB	Local red list
1	*Allium altaicum* Pall. 1773	1		1	1			VU
2	*Allium polyrhizum* Turcz. ex Regel 1875	1						
3	*Arnebia fimbriata* Maxim. 1881	1						
4	*Arnebia guttata* Bunge 1840			1			1	LC
5	*Artemisia xerophytica* Krasch. 1922	1						
6	*Asterothamnus alyssoides* (Turcz.) Novopokr. 1950	1						
7	*Asterothamnus centraliasiaticus* Novopokr. 1950	1		1			1	LC
8	*Brachanthemum gobicum* Krasch. 1933	1		1			1	NT
9	*Calligonum gobicum* (Bunge ex Meisn.) Losinsk. 1927	1	1		1			
10	*Calligonum mongolicum* Turcz. 1832		1					
11	*Caragana brachypoda* Pojark. 1950	1		1			1	VU
12	*Caragana korshinskii* Kom. 1908	1						
13	*Caragana stenophylla* Pojark. 1945	1						
14	*Ephedra przewalskii* Stapf 1889		1					
15	*Euphorbia mongolica* (Prokh.) Prokh. 1949	1						
16	*Haplophyllum dauricum* (L.) G. Don 1831		1					
17	*Hippolytia trifida* (Turcz.) Poljak. 1957	1						
18	*Iris bungei* Maxim. 1880	1						
19	*Juniperus sabina* L. 1753			1			1	EN
20	*Jurinea mongolica* Maxim. 1874	1		1			1	VU
21	*Melilotus officinalis* (L.) Lam. 1778					1		
22	*Olgaea leucophylla* (Turcz.) Iljin 1922	1		1			1	NT
23	*Peganum nigellastrum* Bunge 1835	1	1					
24	*Potaninia mongolica* Maxim. 1881	1	1	1			1	NT
25	*Reaumuria soongarica* (Pall.) Maxim. 1889		1					
26	*Salsola passerina* Bunge 1843	1	1					
27	*Scorzonera pseudodviaricata* Lipsch 1933	1						
28	*Spongiocarpella grubovii* (N. Ulzij.) Yakovlev 1987	1	1	1			1	EN
29	*Stipa inebrians* Hance 1876				1			
30	*Stipa tianschanica* subsp. *gobica* (Roshev.) D.F. Cui 1996	1						
31	*Sympegma regelii* Bunge 1879		1					
32	*Thermopsis mongolica* Czefr. 1954	1			1		1	
33	*Thymus altaicus* Klokov & Desjat.-Shost. 1936	1						
34	*Ulmus macrocarpa* Hance 1868		1					
35	*Zygophyllum rosowii* Bunge 1843		1					
36	*Zygophyllum xanthoxylon* (Bunge) Maxim. 1889		1					

Revealing the endemics, new distributional records, conservation status of species based on the compilation of literature materials, and our result strongly support the floristic importance of the region. From our collection, 36 species, which is about 40%, are under a certain threat level, which shows the relatively high specificity with regard to the surveyed area. In addition, during the fieldwork, we took some sub-endemic species and samples of specific genera, such as *Allium*, *Arnebia*, *Asterothamnus*, and *Caragana*.

Owing to our extensive sampling efforts in the southern and eastern Gobi area, the complete species list and our revision of rare, endangered, and vulnerable species as well as new species records give a good notion about the wealth of floral diversity and reasons for the conservation of

Fig. 10 The photos of the plant species in the southern Gobi regions of Mongolia. 1—*Nitraria sibirica* Pall.; 2—*Allium altaicum* Pall.; 3—*Arnebia guttata* Bunge; 4—*Peganum nigellastrum* Bunge; 5—*Caragana leucophloea* Pojark.; 6—*Calligonum mongolicum* Turcz.; 7—*Reaumuria soongarica* (Pall.) Maxim.; 8—*Convolvulus gortschakovii* Schrenk; 9—*Clematis tangutica* (Maxim.) Korsh.; 10—*Zygophyllum xanthoxylon* (Bunge) Maxim.; 11—*Salsola arbuscula* Pall.; 12—*Ephedra przewalskii* Stapf; 13—*Zygophyllum rosowii* Bunge; 14—*Thermopsis mongolica* Czefr.; 15—*Salsola passerina* Bunge

the southern and eastern Gobi regions of Mongolia (Figs. 10, and 11).

Among these plants, the following medicinal species of liquorice were found to be in great demand and were in grave danger of being lost in the wild: *Allium altaicum* Pall., *Allium polyrhizum* Turcz. ex Regel, *Anabasis brevifolia* C.A. Mey., *Arnebia guttata* Bunge, *Artemisia macrocephala* Jacq. ex Besser, *Artemisia xerophytica* Krasch., *Asterothamnus centraliasiaticus* Novopokr., *Caragana korshinskii* Kom., *Caragana stenophylla* Pojark., *Ephedra przewalskii* Stapf, *Euphorbia mongolica* (Prokh.) Prokh., *Haplophyllum dauricum* (L.) G. Don, *Iris bungei* Maxim., *Juniperus sabina* L. *Medicago sativa* L., *Melilotus officinalis* (L.) Lam., *Neopallasia pectinata* (Pall.) Poljakov, *Nitraria roborowskii* Kom., *Nitraria sibirica* Pall., *Olgaea leucophylla* (Turcz.) Iljin, *Peganum nigellastrum* Bunge, *Reaumuria soongarica* (Pall.) Maxim., *Rheum nanum* Siev. ex Pall., *Salsola abrotanoides* Bunge, *Salsola laricifolia* Turcz. ex Litv., *Salsola passerina* Bunge, *Scorzonera pseudodviaricata* Lipsch, *Sphaerophysa salsula* (Pall.) DC., *Spongiocarpella grubovii* (N. Ulzij.) Yakovlev, *Stipa inebrians* Hance, *Stipa tianschanica* subsp. *gobica* (Roshev.) D.F. Cui, *Sympegma regelii* Bunge, *Taraxacum sinicum* Kitag., *Thermopsis mongolica* Czefr., *Thymus altaicus* Klokov & Desjat.-Shost., *Zygophyllum rosowii* Bunge, and *Zygophyllum xanthoxylon* (Bunge) Maxim.

These plants are very widely used by local people for food (*Allium altaicum* Pall., *Allium polyrhizum* Turcz. ex Regel, *Nitraria roborowskii* Kom., *Nitraria sibirica* Pall., etc.), traditional medicine (*Arnebia guttata* Bunge, *Artemisia macrocephala* Jacq. ex Besser, *Artemisia*

Fig. 11 The photos of plant species in the eastern Gobi regions of Mongolia. 1—*Anabasis brevifolia* C.A. Mey.; 2—*Arnebia decumbens* (Vent.) Coss. & Krali; 3—*Arnebia fimbriata* Maxim.; 4—*Krascheninnikovia ceratoides* (L.) Gueldenst.; 5—*Asterothamnus centraliasiaticus* Novopokr.; 6—*Brachanthemum gobicum* Krasch.; 7—*Caragana brachypoda* Pojark.; 8—*Caragana korshinskii* Kom.; 9—*Convolvulus tragacanthoides* Turcz.; 10—*Rheum nanum* Siev. ex Pall.; 11—*Hippolytia trifida* (Turcz.) Poljak.; 12—*Olgaea leucophylla* (Turcz.) Iljin; 13—*Sympegma regelii* Bunge; 14—*Spongiocarpella grubovii* (N. Ulzij.) Yakovlev; 15—*Salsola abrotanoides* Bunge

xerophytica Krasch., *Ephedra przewalskii* Stapf, *Euphorbia mongolica* (Prokh.) Prokh., *Haplophyllum dauricum* (L.) G. Don, *Iris bungei* Maxim., *Juniperus sabina* L. *Neopallasia pectinata* (Pall.) Poljakov, *Olgaea leucophylla* (Turcz.) Iljin, *Peganum nigellastrum* Bunge, *Salsola laricifolia* Turcz. ex Litv., *Scorzonera pseudodviaricata* Lipsch, *Taraxacum sinicum* Kitag., *Thermopsis mongolica* Czefr., *Thymus altaicus* Klokov & Desjat.-Shost., *Zygophyllum rosowii* Bunge, *Zygophyllum xanthoxylon* (Bunge) Maxim.), and livestock fodder (*Anabasis brevifolia* C.A. Mey., *Salsola passerina* Bunge, *Stipa inebrians* Hance, *Stipa tianschanica* subsp. *gobica* (Roshev.) D.F. Cui, *Medicago sativa* L., *Melilotus officinalis* (L.) Lam., *Reaumuria soongarica* (Pall.) Maxim., *Rheum nanum* Siev. ex Pall., *Salsola abrotanoides* Bunge, *Salsola passerina* Bunge, etc.) and are usually harvested without any official permission and control.

Conclusions

Our study showed to identify and determine the species composition of vascular plants in the study area and compare their floral analysis, ecological groups, the habitat type in which they were found, their distribution, and their usefulness based on the traditional knowledge of the the medicinal plants that both in the southern and eastern Gobi Desert of Mongolia were combined and record their distribution across the study area. The investigated species composition of medicinal vascular plants in the southern and eastern Gobi Desert was classified and described to the flora of Mongolia.

This may contribute to this species predominance in various three (desert, desert steppe, and mountain ranges) ecosystems where medicinal vascular plants dominate Mongolia.

Appendix

Table 4 List of all collected specimens in the southern and eastern Gobi Desert of Mongolia

No.	Taxon name	Family	Habitat	Herbarium and site no.
1	*Agropyron michnoi* Roshev. 1929	Poaceae	Mountain	002 (2)
2	*Allium altaicum* Pall. 1773	Amaryllidaceae	Mountain	003 (2)
3	*Allium polyrhizum* Turcz. ex Regel 1875	Amaryllidaceae	Desert steppe	001 (1)
4	*Anabasis brevifolia* C.A. Mey. 1829	Amaranthaceae	Mountain	002b (5)
5	*Aquilegia viridiflora* Pall. 1779	Ranunculaceae	Mountain	004 (2)
6	*Arnebia decumbens* (Vent.) Coss. & Kralik 1857	Boraginaceae	Desert steppe	005 (4)
7	*Arnebia fimbriata* Maxim. 1881	Boraginaceae	Desert steppe	006 (4)
8	*Arnebia guttata* Bunge 1840	Boraginaceae	Desert steppe	007 (4)
9	*Artemisia macrocephala* Jacq. ex Besser 1836	Asteraceae	Mountain	008 (2)
10	*Artemisia xerophytica* Krasch. 1922	Asteraceae	Desert steppe	009 (6)
11	*Asparagus trichophyllus* Bunge 1832	Asparagaceae	Desert steppe	011 (6)
12	*Asterothamnus alyssoides* (Turcz.) Novopokr. 1950	Asteraceae	Desert	012 (7)
13	*Asterothamnus centraliasiaticus* Novopokr. 1950	Asteraceae	Desert	013 (7)
14	*Atriplex sibirica* L. 1762	Amaranthaceae	Mountain	015 (5)
15	*Bassia hyssopifolia* (Pall.) O. Kuntze 1891	Amaranthaceae	Mountain	016 (2)
16	*Brachanthemum gobicum* Krasch. 1933	Asteraceae	Desert	017 (7)
17	*Bromus japonicus* Thunb. 1784	Poaceae	Mountain	018 (5)
18	*Calligonum gobicum* (Bunge ex Meisn.) Losinsk. 1927	Polygonaceae	Desert steppe	019 (6)
19	*Calligonum mongolicum* Turcz. 1832	Polygonaceae	Desert steppe	020 (3)
20	*Cancrinia discoidea* (Ledeb.) Poljakov 1961	Asteraceae	Desert steppe	022 (4)
21	*Caragana brachypoda* Pojark. 1950	Fabaceae	Desert	024 (7)
22	*Caragana korshinskii* Kom. 1908	Fabaceae	Desert steppe	025 (6)
23	*Caragana leucophloea* Pojark. 1945	Fabaceae	Mountain	026 (5)
24	*Caragana pygmaea* (L.) DC. 1825	Fabaceae	Mountain	027 (5)
25	*Caragana stenophylla* Pojark. 1945	Fabaceae	Mountain	028 (5)
26	*Carex duriuscula* C.A. Mey. 1831	Cyperaceae	Mountain	029 (5)
27	*Catolobus pendulus* (L.) Al-Shehbaz 2005	Brassicaceae	Mountain	030 (2)
28	*Cleistogenes squarrosa* (Trin.) Keng 1934	Poaceae	Desert steppe	031 (1)
29	*Clematis tangutica* (Maxim.) Korsh. 1898	Ranunculaceae	Mountain	033 (2)
30	*Convolvulus gortschakovii* Schrenk 1841	Convolvulaceae	Desert steppe	034 (4)
31	*Convolvulus tragacanthoides* Turcz. 1832	Convolvulaceae	Desert steppe	035 (4)
32	*Cotoneaster neopopovii* Czer. 1981	Rosaceae	Mountain	037 (5)
33	*Crepidiastrum akagii* (Kitag.) J.W. Zhang & N. Kilian 2011	Asteraceae	Desert steppe	038 (4)
34	*Dontostemon crassifolius* (Bunge) Maxim. 1858	Brassicaceae	Mountain	039 (5)
35	*Ephedra przewalskii* Stapf 1889	Ephedraceae	Desert	040 (8)
36	*Eragrostis minor* Host 1809	Poaceae	Mountain	041 (5)
37	*Erysimum cheiranthoides* L. 1753	Brassicaceae	Mountain	042 (2)
38	*Euphorbia mongolica* (Prokh.) Prokh. 1949	Euphorbiaceae	Mountain	043 (2)
39	*Haloxylon ammodendron* (C.A. Mey.) Bunge 1852	Amaranthaceae	Desert steppe	044 (3)
40	*Haplophyllum dauricum* (L.) G. Don 1831	Rutaceae	Desert steppe	045 (6)
41	*Hippolytia trifida* (Turcz.) Poljak. 1957	Asteraceae	Desert	046 (8)
42	*Iris bungei* Maxim. 1880	Iridaceae	Desert steppe	047 (1)

Table 4 List of all collected specimens in the southern and eastern Gobi Desert of Mongolia *(Continued)*

No.	Taxon name	Family	Habitat	Herbarium and site no.
43	*Juniperus sabina* L. 1753	Cupressaceae	Mountain	048 (2)
44	*Jurinea mongolica* Maxim. 1874	Asteraceae	Desert steppe	049 (6)
45	*Krascheninnikovia ceratoides* (L.) Gueldenst. 1772	Amaranthaceae	Desert	007b (7)
46	*Lactuca tatarica* (L.) C.A. Mey. 1831	Asteraceae	Mountain	050 (2)
47	*Limonium chrysocomum* (Kar. & Kir.) Kuntze 1891	Plumbaginaceae	Desert steppe	052 (4)
48	*Limonium flexuosum* (L.) Kuntze 1891	Plumbaginaceae	Desert steppe	053 (3)
49	*Medicago sativa* L. 1753	Fabaceae	Mountain	055 (2)
50	*Melilotus officinalis* (L.) Lam. 1778	Fabaceae	Mountain	056 (2)
51	*Neopallasia pectinata* (Pall.) Poljakov 1955	Asteraceae	Desert	057 (7)
52	*Nitraria roborowskii* Kom. 1908	Nitrariaceae	Desert	058 (7)
53	*Nitraria sibirica* Pall. 1784	Nitrariaceae	Desert steppe	008b (1)
54	*Olgaea leucophylla* (Turcz.) Iljin 1922	Asteraceae	Desert steppe	059 (6)
55	*Peganum nigellastrum* Bunge 1835	Nitrariaceae	Desert steppe	009b (1)
56	*Potaninia mongolica* Maxim. 1881	Rosaceae	Desert	062 (8)
57	*Ptilotrichum dahuricum* Peschkova 1978	Brassicaceae	Mountain	065 (5)
58	*Ptilotrichum tenuifolium* Steph. 1800	Brassicaceae	Desert steppe	066 (6)
59	*Reaumuria soongarica* (Pall.) Maxim. 1889	Tamaricaceae	Desert steppe	010b (1)
60	*Rheum nanum* Siev. ex Pall. 1796	Polygonaceae	Mountain	067 (2)
61	*Salsola abrotanoides* Bunge 1879	Amaranthaceae	Desert steppe	074 (6)
62	*Salsola arbuscula* Pall. 1771	Amaranthaceae	Desert steppe	075 (6)
63	*Salsola laricifolia* Turcz. ex Litv. 1913	Amaranthaceae	Desert steppe	076 (6)
64	*Salsola passerina* Bunge 1843	Amaranthaceae	Desert steppe	011b (1)
65	*Scorzonera pseudodviaricata* Lipsch 1933	Asteraceae	Desert steppe	012b (6)
66	*Scorzonera radiata* Fisch. 1833	Asteraceae	Mountain	079 (5)
67	*Sphaerophysa salsula* (Pall.) DC. 1825	Fabaceae	Desert	081 (8)
68	*Spongiocarpella grubovii* (N. Ulzij.) Yakovlev 1987	Fabaceae	Desert	083 (8)
69	*Stipa inebrians* Hance 1876	Poaceae	Desert	085 (7)
70	*Stipa tianschanica* subsp. *gobica* (Roshev.) D.F. Cui 1996	Poaceae	Desert steppe	084 (4)
71	*Sympegma regelii* Bunge 1879	Amaranthaceae	Desert	086 (7)
72	*Taraxacum sinicum* Kitag. 1933	Asteraceae	Mountain	090 (5)
73	*Thermopsis mongolica* Czefr. 1954	Fabaceae	Desert steppe	091 (3)
74	*Thymus altaicus* Klokov & Desjat.-Shost. 1936	Lamiaceae	Mountain	092 (2)
75	*Thymus michaelis* (Klokov) Kamelin & A.L. Budantzev 1990	Lamiaceae	Mountain	093 (5)
76	*Ulmus macrocarpa* Hance 1868	Ulmaceae	Mountain	094 (5)
77	*Zygophyllum rosowii* Bunge 1843	Zygophyllaceae	Desert steppe	100 (4)
78	*Zygophyllum xanthoxylon* (Bunge) Maxim. 1889	Zygophyllaceae	Desert steppe	013b (3)

Abbreviations
APG: Angiosperm Phylogeny Group; NIBR: National Institute of Biological Resources; UBA: Ulaanbaatar Academy

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Availability of data and materials
Please contact the author for data requests. The data are not publicly available due to sensitive information regarding surface information of the study area.

Authors' contributions
UM carried out the survey in Mongolia. KN, SK, MT, EB, and TI participated and worked together to collect the specimen in the field. KH helped to organize the manuscript. OK conceived of the study and helped to draft the manuscript. All authors read and approved the final manuscript.

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