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ECOLOGICAL AND GEOGRAPHICAL FEATURES OF ASTRAGALUS AMMODENDRON (FABACEAE) IN KAZAKHSTAN

The study examines the ecological and geographical characteristics of *Astragalus ammodendron*, a typical species of desert ecosystems in Central Asia. The species is distributed in Kazakhstan, Uzbekistan, Turkmenistan, and China, preferring sandy and clay deserts, where it forms stable phytocenoses. The aim of the study is to analyze the ecological and geographical plasticity of *A. ammodendron*, its adaptive mechanisms, and its role in ecosystem stabilization. The research employs route reconnaissance, ecological-systematic, and ecological-geographical methods. A comparative analysis of contemporary and historical herbarium data from collections in Kazakhstan, Russia, and Uzbekistan was conducted, along with cartographic modeling of the species' range using QGIS 3.34. The obtained data confirm the species' drought resistance, its ability to stabilize sandy substrates, and its formation of specific communities with *Haloxylon aphyllum*, *Calligonum leucocladum*, and *Artemisia terrae-albae*. In some areas, population fragmentation has been observed due to anthropogenic factors, including livestock grazing and changes in the hydrological regime. This study contributes to understanding the ecological and geographical patterns of desert plants and their phytocenotic role. The practical significance of the results lies in their potential application for monitoring, conservation, and restoration of ecosystems undergoing degradation due to climate change and anthropogenic impact.

Keywords: *Astragalus*, *Fabaceae*, ecology, geography, herbarium.

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Astragalus ammodendron (fabaceae) түрінің Қазақстандағы экологиялық-географиялық ерекшеліктері

Бұл зерттеу *A. ammodendron* түрінің экологиялық-географиялық ерекшеліктерін қарастырады. *A. ammodendron* Қазақстан, Өзбекстан, Түрікменстан және Қытайдың шөлді аймақтарында таралған, негізінен құмды және сазды шөлдерді мекендейді, онда тұрақты фитоценоздар түзеді. Зерттеудің мақсаты – түрдің экологиялық икемділігін, бейімделу механизмдерін және шөл экожүйелерін тұрақтандырудағы рөлін зерттеу. Зерттеуде маршруттық-рекогносцировкалық, экологиялық-жүйелік және эколого-географиялық әдістер қолданылды. Қазақстан, Ресей және Өзбекстан гербарий қорларының қазіргі және тарихи мәліметтері салыстырылды, QGIS 3.34 көмегімен ареалдың картографиялық талдауы жүргізілді. Нәтижелер *A. ammodendron*-ның құрғақшылыққа төзімділігін, құмды субстраттарды тұрақтандыру қабілетін және *Haloxylon aphyllum, Calligonum leucocladum, Artemisia terrae-albae* сияқты өсімдіктермен тұрақты қауымдастықтар түзетінін көрсетеді. Кейбір аймақтарда антропогендік әсерлерге байланысты популяциялардың фрагментациясы байқалады, оған мал жаю және гидрологиялық режимнің өзгеруі ықпал етеді. Зерттеу шөл өсімдіктерінің таралу заңдылықтарын және олардың фитоценоздағы рөлін тереңірек түсінуге үлес қосады. Практикалық маңызы – климаттың өзгеруі мен антропогендік фактор-

лардың әсерінен деградацияға ұшыраған экожүйелерді мониторингтеу, қорғау және қалпына келтіру шараларын әзірлеуге негіз болуында.
Түйін сөздер: *Astragalus*, Fabaceae, экология, география, гербарий.

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Эколого-географические особенности Astragalus Ammodendron (Fabaceae) в Казахстане

В исследовании рассматриваются эколого-географические характеристики *A. ammodendron* – типичного вида пустынных экосистем Центральной Азии. Вид распространен в Казахстане, Узбекистане, Туркменистане и Китае, предпочитая песчаные и глинистые пустыни, где формирует устойчивые фитоценозы. Цель исследования – проанализировать эколого-географическую пластичность *A. ammodendron*, его адаптационные механизмы и роль в стабилизации экосистем. В работе применены маршрутное рекогносцировочное, эколого-систематическое и эколого-географическое методы. Проведен сравнительный анализ современных и исторических гербарных данных из коллекций Казахстана, России и Узбекистана, а также картографическое моделирование ареала вида с использованием QGIS 3.34. Полученные данные подтверждают засухоустойчивость вида, его способность стабилизировать песчаные субстраты и формировать специфические сообщества с *Haloxylon aphyllum*, *Calligonum leucocladum* и *Artemisia terrae-albae*. В ряде районов отмечена фрагментация популяций из-за антропогенных факторов, включая выпас скота и изменения гидрологического режима. Данное исследование способствует пониманию эколого-географических закономерностей пустынных растений и их фитоценотической роли. Практическая значимость результатов заключается в их потенциальном применении для мониторинга, сохранения и восстановления экосистем, подвергающихся деградации в результате климатических изменений и антропогенного воздействия.
Ключевые слова: *Astragalus*, Fabaceae, экология, география, гербарий.

Introduction

The genus Astragalus L. is one of the most polymorphic taxa within the Fabaceae family, characterized by extensive species diversity and high ecological plasticity [1; 2]. The Fabaceae family includes woody, shrub, liana, and herbaceous life forms, demonstrating considerable morphological variability. A distinctive feature of many Fabaceae members is the formation of root nodules, resulting from the interaction between proliferating parenchymal tissue and nitrogen-fixing bacteria. Currently, the family comprises about 700 genera, with Astragalus being the largest, represented by approximately 2,200 species worldwide [1; 2; 4].

The study of Astragalus began with its first formal description by Carl Linnaeus, who classified its representatives into three morphological groups based on shoot architecture: (1) species with leafy, erect stems; (2) species with leafy, branched stems; and (3) species with bare, leafless stems [5].

In Central Asia, unique representatives of Astragalus occur, many of which form dense cushion-like dwarf shrubs adapted to arid environments. These species demonstrate a variety of anatomical and morphological adaptations, such as dense pubescence on leaves, calyxes, and petals, which reduces water loss and protects against overheating. The cushion growth form also minimizes excessive evaporation and helps withstand strong insolation, allowing these plants to dominate the vegetation structure of arid landscapes [6; 7].

Several Astragalus species are narrow-range endemics and are listed in the Red Data Book. At the same time, mesophilic species occur in more humid habitats, typically as perennial herbaceous plants with well-developed stems, larger leaves, and reduced pubescence [1; 8]. The polymorphism of the genus is expressed in the coexistence of various morphological forms—ranging from herbaceous types to dwarf shrubs—within limited geographical areas. Unlike some other representatives of Fabaceae, Astragalus does not include tree-like or liana forms and does not develop specialized underground storage organs [7; 8].

Most representatives of the genus are light-loving and are widely distributed in steppes, deserts, tundras, and well-lit forest edges. Despite their dominance in arid regions, Astragalus species generally do not exhibit extreme xeromorphic specialization typical of some other Fabaceae taxa [9]. Annual species complete their active life cycle during wet seasons, whereas perennial species may shed leaves during drought. Only a small number exhibit succulent traits characteristic of gypsum-loving plants, and no hydrophilic forms are known within the genus [9; 10].

The arid ecosystems of Kazakhstan provide a unique setting for studying plant adaptations, as these environments promote the development of specific mechanisms of survival under limited water availability and high temperatures [11]. One of the key species in these ecosystems is Astragalus ammodendron, a dwarf shrub with high ecological plasticity that thrives under desert and semi-desert conditions [12].

Despite its wide distribution in Kazakhstan, the ecological and geographical characteristics of *A. ammodendron* remain insufficiently studied [13]. Comprehensive data on its spatial distribution, the influence of climatic factors, and adaptation mechanisms are currently lacking. Considering accelerating climate change and increasing anthropogenic pressure (overgrazing, habitat degradation), the study of this species has become particularly relevant [14; 15].

The relevance of this research lies in the need to conduct a systematic analysis of the ecological and geographical factors determining the distribution of *A. ammodendron* in Kazakhstan, its ecological preferences, and adaptive strategies. Such an analysis will help assess the resilience of the species to changing environmental conditions and contribute to the development of scientifically grounded conservation strategies [1; 2; 5; 16; 17].

The object of the study is the *A. ammodendron* populations in Kazakhstan, while the subject encompasses their ecological and geographical characteristics, including distribution patterns, habitat conditions, adaptive mechanisms, and ecological plasticity; the aim of the research is to determine the ecological and geographical features of *A. ammodendron* and to identify its distribution patterns and adaptation strategies across natural zones, for which the study sets the following tasks: reviewing existing literature on the ecology and geography of the species, delineating its distribution in Kazakhstan using field records and cartographic data, assessing key ecological and physiological traits such as soil preferences, water and light requirements, and temperature tolerance, and evaluating its ecological role in desert and semi-desert ecosystems; the working hypothesis assumes that the distribution of *A. ammodendron* is shaped by ecological and climatic factors, with its adaptive mechanisms enhancing resilience to arid conditions and influencing population differentiation; the scientific significance lies in improving understanding of distribution patterns and adaptive potential of this ecologically important species, whereas the practical significance is reflected in the study's ability to support predictions of climate-driven range shifts and to provide guidance for ecosystem restoration and sustainable rangeland management.

Materials and methods

The object of the study is *A. ammodendron* (Fabaceae), growing within the territory of Kazakhstan (Figure 1).

In the course of the research, classical botanical methods were used, including route reconnaissance, ecological-systematic, and ecological-geographical approaches. Herbarium materials from the collection funds of the Institute of Botany and Phytointroduction (AA, Almaty, Kazakhstan), Lomonosov Moscow State University (MW, Moscow, Russia), Komarov Botanical Institute (LE, St. Petersburg, Russia), and the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan (TASH, Tashkent, Uzbekistan) were studied.

For the identification of collected material, fundamental references such as *Flora of Kazakhstan*, *The Plant Identifier of Central Asia and Kazakhstan*, and others were used. Latin and Russian names follow the nomenclature of the International Plant Names Index (IPNI, URL: https://www.ipni.org/) and Plants of the World Online (POWO, URL: https://powo.science.kew.org/). The map was created using the QGIS 3.34 software.

Figure 1 – *A. ammodendron* in nature

Results and discussion

The genus *Astragalus* is one of the largest and most polymorphic among the representatives of the Fabaceae family. The diversity of life forms within this family, including herbaceous plants, shrubs, and trees, is explained by their wide geographical distribution and adaptation to various ecological conditions. This genus demonstrates a high degree of ecological plasticity, which is expressed in the presence of both mesophilic and xerophilic species, as well as rare representatives included in the Red Data Book [21; 22].

Particular attention should be given to the morphological and anatomical characteristics of legumes, among which specific features of flower and fruit structure stand out [23]. The butterfly-shaped corolla, the presence of a staminal tube, and specialized pollination mechanisms make Fabaceae one of the most successful plant groups in co-evolution with insect pollinators. In some cases, self-pollination and cleistogamy mechanisms have been noted, contributing to successful reproduction even under limited pollinator access [24-26].

The study of the *Astragalus* genus dates back to ancient times when representatives of this genus were first described by early botanists. Over time, the systematics and classification of *Astragalus* have undergone changes, and today, about 2,200 species are known. Herbarium collections and literature sources indicate their wide distribution, from the arid zones of Central Asia to the temperate latitudes of Europe and Siberia [1-5; 27; 28].

Studies on the Anatomy and Ecology of *Astragalus*

Anatomical studies of the *Astragalus* genus reveal adaptive features aimed at reducing moisture evaporation, protecting against high temperatures, and efficiently utilizing limited water resources [29]. Xerophytic species are particularly noteworthy, exhibiting dense leaf pubescence, modified leaf blades, and cushion-like structures that enhance survival in arid conditions. At the same time, some *Astragalus* species retain mesophilic characteristics, growing in regions with moderate humidity [30].

Geobotanical studies indicate that representatives of the *Astragalus* genus form plant communities in various ecosystems, including steppes, deserts, foothills, and mountain zones. A significant ecological feature of these species is their high photophilous nature, explaining their preference for open spaces, canyon slopes, and semi-desert areas [1-5; 21-25; 31].

During field research conducted in 2024, we recorded five populations of the studied species, *A. ammodendron*, within Kazakhstan. Additionally, screening of literature sources and examination of available herbarium specimens from major collections—including the Institute of Botany and Phytointroduction (AA, Almaty, Kazakhstan), Lomonosov Moscow State University (MW, Moscow, Russia), the Komarov Botanical Institute (LE, Saint Petersburg, Russia), and the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan (TASH, Tashkent, Uzbekistan)—enabled us to create a preliminary distribution map of the species within Kazakhstan (Figure 2).

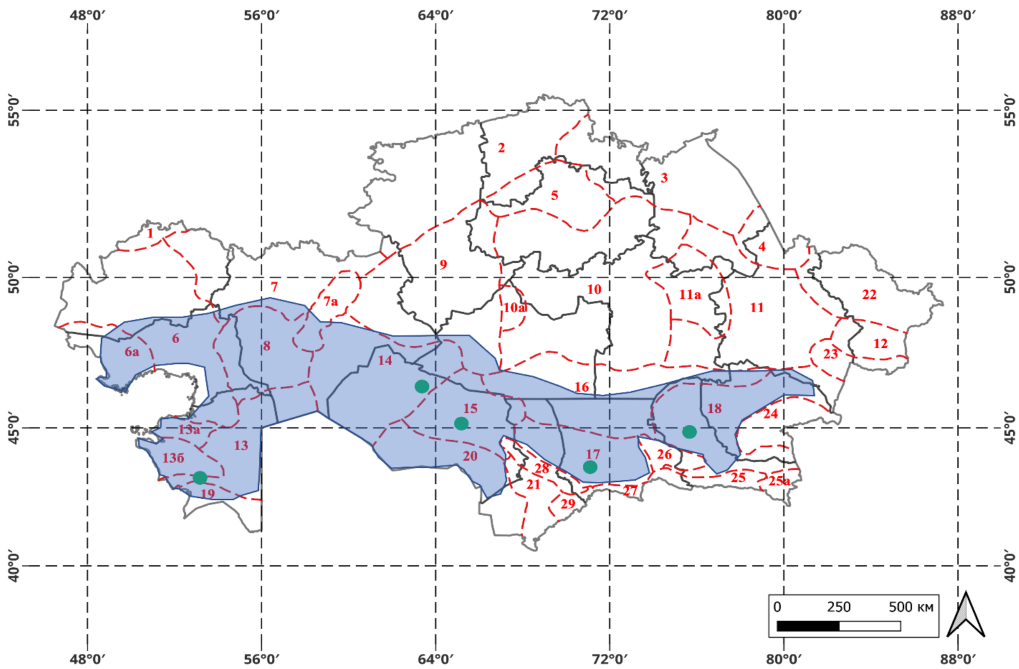

Figure 2 – Distribution map of *A. ammodendron* in Kazakhstan

The herbarium specimens (AA, LE, MW, TASH) of *A. ammodendron* (Figure 3) include records from various regions.

In the Pre-Caspian Flora Region, specimens were collected from Koilebay (hilly sands, T. Astapova, 31 May 1930, MW0844660), Western Kazakhstan (Urdinsky District, 30 km northwest of Ushtagan, Gilkomova, 24 May 1952, LE; Glikemova, 30 May 1952, LE), and Guryev Region (Novobogashinsky District, 1 km east of Koilak, Shvyryaeva, 11 September 1957, MW0411700; Novobogatinsky District, 1 km east of Koshalak, clay hill, Shvyryaeva, 11 September 1957, MW0411703). Another specimen was recorded in Atyrau Region in a saline clay desert between Dossor and Kulsary (N47°24′19″ E53°43′38″, V. G. Onipchenko, 6 May 2011, MW0844659).

In the Aktobe Flora Region, specimens were collected from Tabak-Bulak (V. Pelts, E. Ispolatov, 12 March 1914, LE) and the Temir District of Aktobe Province (Martuk, in basin depressions, S. A. Nikitin, 11 June 1925, LE).

In the Mugodzhar Flora Region, a specimen was recorded 10 km northeast of Karabau in Ural, Guryev, and Aktobe Regions (I. N. Safronova, M. P. Andreev, N. M. Kalibernova, A. P. Mishenkova, 24 May 1975, LE).

In the Emba Flora Region, collections include multiple records from the Bolshie Barsuki Sands near the Cheklkar railway station (N. V. Androsov, 25 May 1908, LE), the Kum-Kuduk Sands in the Temir District (D. N. Borodin, B. P. Uvarov, V. M. Shits, 30 May 1908, LE), and the Kuan-Kuduk Sands in the same district (D. N. Borodin, B. P. Uvarov, V. M. Shits, 30 May 1908, LE). Additional specimens were collected on the Aral Peninsula, Kos-Aral, on the sandy northeastern shore of the bay (M. Kuilyus, scattered, I. Raykova, M. G. Popov, 3 July 1921, LE), and from the Emba River, Kum-Tugai basins in Ural Province (S. A. Nikitin, N. Bazevskaya, 21 June 1927, LE).

Herbarium specimens from the Turgay Flora Region were collected in the following locations: on the outskirts of the Air-Kyzyl Sands in the Turgay Region (*V. Savich, S. Kucherovskaya*, 04 May 1909, LE) and 22 km downstream along the Turgay River from the village of Amangeldy and the town of Turgay, at the foot of hilly sands (*Yu. D. Soskov, P. A. Lubenets*, 17 July 1971, AA).

In the Northern Ustyurt Flora Region, specimens were collected in various locations, including the Kara-Kum Sands in the Ural Region (*V. Dubyansky*, 01 June 1904, LE), sands near the banks of the Emba River (*V. Dubyansky*, 08 June 1904, LE), the Aya-Daparbi Sands between the Emba River and Ustyurt in the Aday District (*Bash-Ragbil, R. Rozhevits, M. Ilyin, M. Avramchik*, 08 June 1926, LE), the eastern part of Ustyurt, south of Asmantay-Matay Lake (*R. Yu. Rozhevits, A. O. Heinrichson*, 08 October 1926, LE), and in the Turaumbet Tract, Mangystau District, Guryev Region (*Vashchenok*, 16 May 1956, LE).

Additional specimens from the Guryev Region in Kazakhstan were recorded at the northern outskirts of the Kara-Kum Sands, 20–25 km south of Kulsary village (*I. I. Rusanovich, A. E. Matsenko, S. M. Udintseva*, 06 May 1983, MHA0148606), as well as 70–75 km south of Kulsary, in dense turf-covered sands (*I. I. Rusanovich, A. E. Matsenko, S. M. Udintseva*, 06 May 1983, MHA0148607).

Collected from various locations within the Mangyshlak floristic region, these specimens include those collected by A. Bekker in 1869 in *Mangyshlak* (MW0844664); K. Inuryushchenko on April 16, 1912, in the *Trans-Caspian region* (*Dzhebel Balla-Ishem*) on clay soils (LE); V. Drobov on April 24, 1916, in the *Dzhebel region* of the *Trans-Caspian region* (TASH00204258); M. D. Spiridonov on June 5, 1926, between the *Cham spring* and *Ayrakty tract* on loose gypsum-bearing clays (AA); F. N. Rusanov on June 7, 1926, on the northeastern slope of a cliff 3 versts east of the *Udyak colony* (AA); and A. D. Gozhev and N. N. Gratz-Guseva on June 7, 1937, on the coast of the *Kulandy Peninsula* in an area of hilly sands (LE).

Additionally, the figure includes specimens collected by U. K. Kisyakov on May 4, 1951, in the *Dzhelgimai tract* on sandy loam soils (AA); G. Cherkasova on July 21, 1973, in the *Northern Aktau Ridge*, near the village of *Tigen*, at the base of chalk slopes on sandy soil with chalk gravel (MW0844661); G. M. Kudabaeva on June 3, 1986, in the vicinity of *Aksu village* on sandy soils (AA); as well as specimens recorded in the *Munaily District of Aktau* on April 21, 2009(coordinates N43°27'41" E51°19'22", iNaturalist Observation) and in the *Mangystau region* on May 20, 2009(coordinates N43°27'56" E51°18'36", iNaturalist Observation).

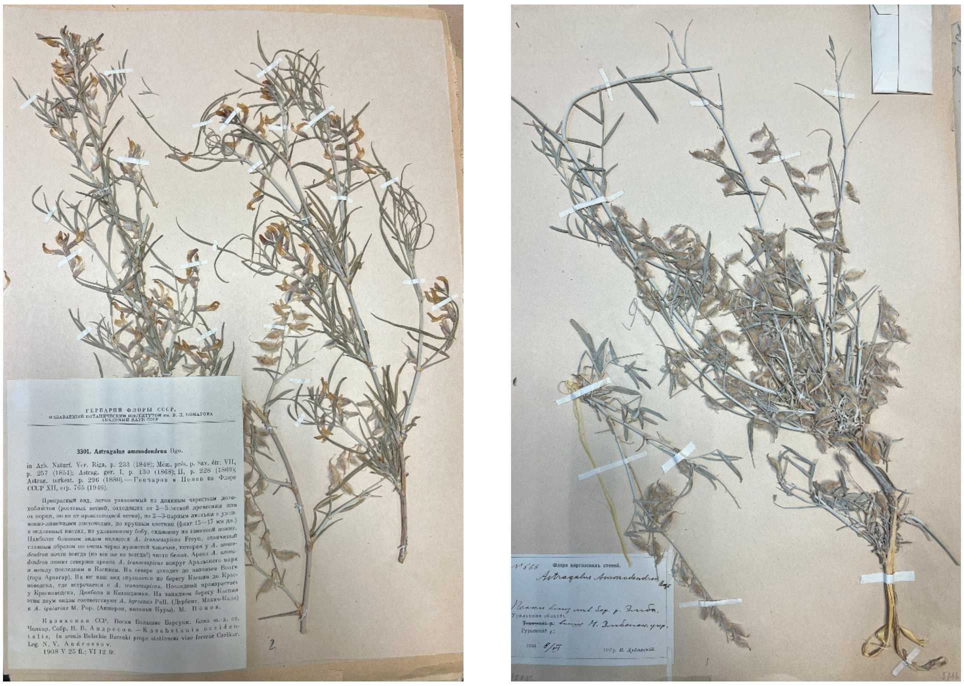

Figure 3 – Herbarium specimens stored at the Komarov Botanical Institute (LE, St. Petersburg, Russia)

Aral Sea region: “Turgay Province, Irgiz County, B. Baranki. V. Dubyansky. 27 IV 1904” (LE); “Turgay Province, Irgiz County, near the Aral Sea. V. Dubyansky. 04 V 1904” (LE); “Turgay Province, Irgiz County, S. part of B. Baranki. V. Dubyansky. 08 V 1904” (LE); “Turgay Province, Irgiz County, Kashkar-Ata. V. Dubyansky. 12 V 1904” (LE); “Turgay Province, Irgiz County. V. Dubyansky. 12 V 1904” (LE); “Turgay Province, Bolshie Barsuki Sands, Chelykar Station. N. V. Androsov 21 V 1907” (LE); “Bolshie Barsuki Sands near Chelykar railway station. Androsov N. V. 25 V 1908” (AA); “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov 25 V 1908” (LE); “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov. 25 V 1908” (LE); “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov 25 V 1908 (MW0844665-1)”; “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov 25 V 1908 (MW0844665-2)”; “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov 25 V 1908 (MW0844666-1)”; “Kazakh SSR. Bolshie Barsuki Sands. Near Chelykar railway station. N. V. Androsov 25 V 1908 (MW0844666-2)”; “Turgay Province, Irgiz County, Eastern part of Mal. Barsuki. Sand dunes. N. A. Desyatova. 04 V 1914” (LE); “Turgay Province, Irgiz County, Isen-Chagyl Sands. Mobile sand dunes. N. A. Desyatova 15 V 1914” (AA); “Turgay Province, Irgiz County, Isen-Chagyl Sands. Mobile sand dunes. N. A. Desyatova. 15 V 1914” (LE); “Tashkent Railway, between Sapak and Chumysh Stations. V. Titov. 19 V 1914” (LE); “Turgay Province, Irgiz County, between Barbi Kum Sands and Nary Kyzyl. Sand dunes. Sary Bas depression. N. A. Desyatova. 14 VI 1914” (LE); “Between Aral Sea Station and Aralsk city. Slightly hilly sands. Malo. I. Raykova, M. G. Popov. 28 V 1921” (LE); “Between Aral Sea Station and Aralsk city. Slightly hilly sands. Malo. I. Raykova, M. G. Popov. 28 V 1921” (LE); “Between Aral Sea Station and Aralsk city. Slightly hilly sands. Malo. I. Rachkova, M. G. Popov. 29 V 1921” (TASH00204286); “Aktobe Province, Chelkar County, Muyn-Kumy Sands, top of a sand dune. M. D. Spiridonov. 11 VI 1927” (AA); “Aktobe Province, Chelkar County, Western spurs of the northwestern end of the sands. O. E. Knorring, N. P. Belov. 11 VI 1927” (LE); “Aktobe Province, Chelkar County, 7 versts to the east of Ak-Iin. O. E. Knorring, N. P. Belov. 16 VI 1927” (LE); “Aktobe Province, Chelkar County, Karatokay District, 22 km southeast from the shores of the Tshe-Zae Bay, re-blown sands of Karatyuben. A. A. Sergeev. 04 VII 1927” (LE); “Aktobe Province, Chelkar County, Kashkar-Ata Sands. Lowlands between dunes. G. I. Rilenko. 28 VII 1927” (LE); “Aktobe Province, Chelkar County, west of Kurgan-Tuz. Plain terrace of a lake basin, sandy steppe. T. A. Spiridonov. 07 VIII 1927” (LE); “Near Aral Sea Station. Protected island on the Aral Sea. S. G. Gorshkova. 29 V 1930” (LE); “Near Aral Sea Station. Protected island on the Aral Sea. S. G. Gorshkova. 30 V 1930” (LE); “Malye Barsuki. Koilebay. Sand dunes. T. Astapova. 31 V 1930 (MW0844669)”; “Bolshie Barsuki. A. D. Gozhev, N. N. Gratz-Guseva, A. V. Mizerov. 02 VI 1930” (LE); “Malye Barsuki, small almost bare basin, N47°24′43″ E60°50′30″. E. Serova, N. Pavlov. 23 V 1931 (MW0844668)”; “Malye Barsuki, large basin. N47°24′43″ E60°50′30″. E. Serova, N. Pavlov. 29 V 1931 (MW0844662)”; “On a sand dune near the shore of Tamerlane. N47°25′58″ E60°48′15″. E. Serova, N. Pavlov. 07 VI 1931 (MW0844663)”; “Western Kazakhstan, Urdinsky District, 30 km northwest of Ushtagan. Gilkomova. 24 V 1952” (LE); “Western Kazakhstan, Urdinsky District, 30 km northwest of Ushtagan. Gilkomova. 30 V 1952” (LE); “Northern Aral Sea region, Aktobe Region, southeast of Chelkar, near Lake Jamankultuz. O. U. Lushpa. 07 V 1957” (AA); “Northern Aral Sea region. Kyzylorda Region, Aral Karakum Sands. O. U. Lushpa. 27 V 1957” (AA); “Kazakh SSR. Aktobe Region, Chelkar District. Isen-Chagyl Sands. Tas-Kura. Semi-fixed sand dunes. Nukhimovsky. 07 VI 1963 (MW0844667)”; “Northern Aral Sea region, Malye Barsuki Sands. B. A. Bykov. 11 V 1967” (AA); “Malye Barsuki Sands, Northern Aral Sea region. B. A. Bykov. 14 VII 1967” (AA); “Aral District, N46°24’16” E59°35’25” 13 V 2010. (https://www.inaturalist.org/observations/98167829)”

Kyzylorda floristic region: “Kazakhstan. Priaral Karakums. Sandy overgrown hills near Ashchesay. A. Yarmolenko, M. Mikulin. 23 VI 1930” (LE).

Betpak-Dala floristic region: “Island in the northern part of B. Chiganak, formed by station, settlement, and several unnamed bays. Scattered. I. Rachkova, M. G. Popov. 03 VI 1921” (TASH00204287).

Moyynkum floristic region: “Syr-Darya region. (Tian-Shan) Moyunkum. A. Golbek. 20 V 1910” (LE); “Syr-Darya region. (Tian-Shan) Moyunkum. A. Golbek. 20 V 1910” (LE); “Suzak district, N 44°31’15” E 68°38’23” 11 V 2010 (https://www.inaturalist.org/observations/98168930)”.

Balkhash-Alakol floristic region: “Sands of the Lepsy River valley. K. N. Paraskiv. 14.06.1956” (AA); “Zhambyl district, N 44°19’52” E 75°33’07”, 11 V 2021, A. Bazdyrev. (iNaturalist); “Zhambyl district. N 44°25'46" E 75°29'52" B. B. Osmonali. 03 V 2024 (iNaturalist).

Southern Ustyurt floristic region: "Ustyurt, Kugusem tract. A. P. Gamayunova. 06 V 1965" (AA); "Southern Ustyurt. 50 km south of Sarykamysh Lake, in saxaul groves. V. V. Fisyun. 04 V 1978" (AA); "Southern Ustyurt. Near the Tokhlenkum station, on overgrown sands, among fruiting juzguns. V. V. Fisyun. 13 V 1978" (AA); "Ustyurt. Vicinity of Aisu settlement. On sands. G. M. Kudabaeva. 03 VI 1986" (AA).

Kyzylkum floristic region: "Turkestan. Near Aral. Bulyuk-Kulk. L. Berg. 04 V 1900" (LE); "Turkestan. Near Aral. Bulyuk-Kulk. L. Berg. 04 V 1900" (LE); "Turkestan. Near Aral. Tuguń. L. Berg. 08 V 1900" (LE); "Kyzyl-Kums. Soft deposits of the slopes of Altyn-Tau. F. N. Rusanov. 07 X 1928" (AA); "Turkestan. Near Aral. Barsa-Kelmes. L. Berg. 25 VI 1900" (LE); "Turkestan. Near the Aral Sea. L. Berg. 07 V 1902" (LE); "Amu-Darya district, Kuduk-Vansbay. N. I. Smirnov. 19 IV 1914" (LE); "Amu-Darya district, Kuduk-Vansbay. N. I. Smirnov. 19 IV 1914" (LE); "Amu-Darya district of the Syr-Darya region. Kyzyl-Kums between Sultan-Uiz-Beg and Talyk-Bay tract. I. Krasheninnikov. 01 IV 1915" (LE); "Amu-Darya district of the Syr-Darya region. Mount Kube-Tau, steppe dominated by Artemisia. I. Krasheninnikov. 18 IV 1915" (LE); "Bank of the Syr-Darya River; near Kanl-Oryn. On sandy hills near Karaul-Tyube, N 44°54′18″ E 65°31′22″ M. I. Nazarov. 12 V 1930 (MW0844658)"; "Aral Sea, Perovsky Bay, Sary-Basat tract, coastal sands. Astapova. 05 VI 1930. (MW0844657)".

The genus *Astragalus*, being one of the most polymorphic genera in the *Fabaceae* family, is represented by various life forms, ranging from herbaceous plants to shrubs. The study confirmed the widespread distribution of *A. ammodendron* Bunge in the arid and semi-arid zones of Kazakhstan, indicating the high ecological plasticity of the species [1-5; 21-28; 32-34].

Based on herbarium data and literature sources, *A. ammodendron* is found in various regions of Kazakhstan, including the Precaspian, Aktobe, Mugodzhar, Embinsky, Turgay, and Ustyurt floristic regions. This indicates its ability to adapt to different conditions of arid ecosystems. In particular, the densest populations of this species have been recorded in the sands of Bolshie Barsuki, Karakum, and Malye Barsuki, as well as in the saline and clay deserts of the Atyrau region [1-5; 22; 25; 28; 35-37].

The ecological adaptation of *A. ammodendron* is expressed in its xerophytic traits— a deep root system, a well-developed leaf surface covered with trichomes to reduce evaporation, and the ability to fix nitrogen symbiotically. These characteristics provide the plant with competitive advantages in sandy and semi-sandy soils [1-3; 25-28; 38; 39].

Additionally, herbarium specimens collected in the 20th century and in recent decades were analyzed, allowing an assessment of the distribution dynamics of *A. ammodendron* under anthropogenic impact and climate change. The data show that the species' range remains relatively stable; however, local populations may undergo fragmentation due to landscape changes and habitat degradation [1-5; 25; 28; 40-41].

A comparative analysis of herbarium data indicates the predominance of *A. ammodendron* in sandy and clay deserts, where competition from other species is low. Under these conditions, the plant forms stable phytocenoses, where it can act as a dominant or subordinate component within desert communities.

An interesting observation is the presence of *A. ammodendron* populations in Southern Ustyurt and Kyzylkum, which suggests its ability to survive in extremely arid climates. This may be attributed to its high degree of adaptation to sandy soils and its deep-rooting system, which allows access to moisture from deep soil horizons.

Thus, based on herbarium data and the analysis of phytocenotic conditions, it can be concluded that *A. ammodendron* is a resilient component of Kazakhstan's desert ecosystems. However, due to increasing anthropogenic pressure and climate change, further research is needed to monitor population status and develop conservation measures.

The results of the analysis of herbarium data and literature sources indicate that *A. ammodendron* has a broad distribution range covering various regions of Kazakhstan, including the Precaspian, Aktobe, Mugodzhar, Embinsky, Turgay, North and South Ustyurt, Kyzylkum, Betpak-Dala, Moyynkum, and Balkhash-Alakol floristic regions.

The species' primary habitats are confined to arid, sandy, and semi-desert territories, highlighting its adaptation to extreme conditions. In particular, *A. ammodendron* prefers hummocky sands, stabilized dunes, and sandy plains with varying levels of salinity. In some locations, its populations have been recorded in clay and saline deserts, further demonstrating its high plasticity to different soil types.

The phytocenotic role of *A. ammodendron* varies depending on the region. In some areas, it acts as a dominant species in plant communities, forming characteristic phytocenoses, while in other locations, it occurs in a scattered distribution. In Western Kazakhstan and the Mangyshlak region, it is more frequently found as isolated individuals on sandy and clay soils. In the Aral Sea region and Kyzylkum, it is more commonly found on shifting sands, indicating its role in substrate stabilization and erosion prevention.

A comparative analysis of historical herbarium data shows that *A. ammodendron* populations in some areas are subject to anthropogenic impact. For example, in Northern Priaralye, its populations may be declining due to intensive economic activity, grazing pressure, and changes in the hydrological regime. At the same time, in remote and hard-to-access areas such as Ustyurt and Moyynkum, its population remains stable.

Thus, this species represents a key component of plant communities in the desert and semi-desert zones of Central Asia, demonstrating high adaptability to extreme conditions and a broad range of ecological strategies.

Phytocenoses involving *A. ammodendron* develop under arid conditions on sandy and sandy loam soils in Central Asia and Kazakhstan, most commonly within desert and semi-desert ecosystems. This species often plays the role of a subdominant or associated component in plant communities, forming stable groupings with other xerophytic and psammophytic species (Figure 4).

Kyzylorda Region, Kazaly District,
Priaralye Floristic Region

Almaty Region, Balkhash District,
Balkhash-Alakol Floristic Region

Figure 4 – Phytocenoses with the participation of *A. ammodendron*

A. ammodendron is most frequently found in association with *Haloxylon aphyllum*, a key woody component of desert communities, forming patchy woodlands with an open herbaceous layer. In sandy desert conditions, its constant companions include *Calligonum leucocladum* and *Atraphaxis replicata*, which form a shrub layer, as well as *Krascheninnikovia ceratoides* and *Artemisia terrae-albae*, which contribute to the stabilization of sandy substrates. *Bassia prostrata* is often present in the herbaceous cover, creating a mosaic phytocenotic structure.

In addition to these species, the phytocenoses involving *A. ammodendron* exhibit significant diversity of herbaceous and shrubby plants from various families. Among the shrubs and subshrubs, *Calligonum aphyllum* and *Ephedra intermedia* are present, demonstrating resilience to arid conditions.

Among grasses and sedges, *Carex physodes*, *Poa bulbosa*, *Eremopyrum orientale*, and *Eremopyrum distans* play a dominant role due to their high adaptation to sandy and saline soils.

Ephemeral and ephemeroid species exhibit different ecological strategies. For example, the spring ephemeroids *Eremurus inderiensis* and *Eremurus anisopterus* are essential components of the early spring vegetation aspect. Other typical elements of the ephemeral layer include *Descurainia sophia*, *Scorzonera sericeolanata*, *Heliotropium dasycarpum*, *Delphinium camptocarpum*, *Alyssum desertorum*, and *Erysimum siliculosum*, which contribute to a temporary increase in phytocenotic productivity during favorable seasons.

The herbaceous cover also frequently includes representatives of the Fabaceae family, such as *Astragalus flexus* and *Astragalus physocarpus*, which, along with *Ceratocarpus arenarius*, are capable of nitrogen fixation, enriching the soil. Xerophilous and psammophilous species are often part of the plant communities, including *Erodium oxyrhinchum*, *Nonea caspica*, *Neotrinia splendens*, *Salsola tragus*, and *Lappula squarrosa*, which play a crucial role in forming stable sandy ecosystems.

Thus, *A. ammodendron* is a significant component of phytocenoses in sandy and semi-desert areas, forming complex interactions with xerophytic and psammophytic species. Its ability to fix nitrogen and stabilize the soil substrate contributes to maintaining biodiversity and ecosystem resilience under the extreme conditions of arid landscapes.

Conclusion

A. ammodendron has a vast range, encompassing sandy and semi-desert ecosystems of Kazakhstan, indicating its high ecological and geographical plasticity. The species prefers stabilized and shifting sands, as well as saline clay soils, playing a crucial role in landscape stabilization and erosion prevention. In some regions (e.g., the Aral Sea region, Kyzylkum), it serves as a key component of plant communities, whereas in others (e.g., Mangyshlak, Northern Ustyurt), it occurs in a more scattered distribution.

Anthropogenic factors such as livestock grazing and changes in the hydrological regime may negatively impact *A. ammodendron* populations, particularly in Northern Priaralye. To ensure the conservation of this species, it is recommended to monitor its distribution, especially in areas with intensive economic activities, and to develop conservation measures.

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