Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Development of a strategy for the conservation of rare and endangered species of medicinal plants in Kazakhstan

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ABSTRACT

Being home to over 6,000 plant species, Kazakhstan is a world leader when it comes to biodiversity hotspots, and nearly 150 plant species of medicinal value are on the verge of extinction. According to the Red Book of Kazakhstan (2021), there are 42 species of medicinal plants in Kazakhstan that are "endangered" and "critically endangered," the main reason for which is loss of habitat (55%), over-harvesting (30%), and climate change (15%). Aiming for a comprehensive conservation plan, this research focuses on the site of major distribution areas of endemics such as *Rheum tataricum* and *Glycyrrhiza uralensis*, constructing a living gene bank with more than 1,000 seed specimens, and enhancing local community participation. It also suggests creating more stringent legislation to curb illegal harvesting and increasing protected territories to 20% by the year 2030. Preliminary findings suggest that the execution of this approach can guarantee the survival of 80% of the target species within the decade.

Keywords: Conservation, Rare species, Medicinal plants, Kazakhstan, Integrated approach.
Article type: Research Article.

INTRODUCTION

With its unique geographical distribution and biodiversity of habitats, Kazakhstan is among the top biodiversity hotspots in the Central Asian region, harboring over 6,000 plant species (Kazakhstan Biodiversity Strategy 2021). Out of these, around 150 species are known to possess medicinal value and contribute meaningfully towards the healthcare of communities, economic development, and cultural wealth of the nation (WHO 2023). However, in the past decades, habitat loss due to human and environmental pressure, commercial overharvesting, and the impacts of climate change have severely threatened the survival of most of these species. As per the recent report

Caspian Journal of Environmental Sciences, Vol. 23 No. 2 pp. 369-375 Received: Aug. 04, 2024 Revised: Dec. 23, 2024 Accepted: Jan. 13, 2025
DOI: 10.22124/CJES.2025.8708

Publisher: University of Guilan,

of the Red Book of Kazakhstan (2021), 42 medicinal plant species, including *Rheum tataricum* and *Glycyrrhiza uralensis*, are categorized as "endangered" and "critically endangered", which reflect a decrease in their population by 35% in the last two decades. The importance of conserving these species extends beyond their intrinsic ecological value, but the dependence of local communities on medicinal plants for disease management as well as sustainable livelihoods emphasizes the need for urgent action (FAO 2022). Existing studies reveal that about 70% of Kazakhstan's rural communities still use medicinal plants as a way of accessing primary health care (Mukasheva *et al.* 2021; Tolaifeh *et al.* 2023). However, the absence of an inclusive conservation plan, poor regulatory legislation, and ineffective involvement of local stakeholders are major impediments to conservation of such genetic resources. Conversely, projections by the International Union for Conservation of Nature (IUCN 2023) alert that at least 20% of Kazakhstan's medicinal species will be entirely extinct by 2030 unless present trends continue. This study endeavors to fill up the gaps found in the literature on conservation and provide an integral solution with the solutions being of ecosystem and community-based. There is not just a need for this at a national level but also in keeping with Kazakhstan's international commitments as per the Convention on Biological Diversity (CBD) and the Sustainable Development Goals (SDGs). Early findings suggest that convergence of *in-situ* (habitat-based conservation) and *ex-situ* (gene banks) conservation methods with public participation unification and regulation amendment can become a novel conservation model for guarding the genetic materials of the region (Ivanova & Petrova 2022; Zarghami *et al.* 2023). Global research shows that the severe decrease in the number of medicinal plant species has become an ecological problem. The World Health Organization (WHO 2023) estimates that approximately 80% of the world's population depends on medicinal plants for medicine, but 15,000 medicinal species are threatened with extinction worldwide. This case is even worse in arid and semi-arid regions such as Kazakhstan, due to anthropogenic effects and climate change (Heywood 2022; Izmailov *et al.* 2025). In the context of conserving rare species, numerous studies have been highlighting the need for combining *in-situ* (treatment of the habitat) and *ex-situ* (seed storage) methods. For example, a Himalayan study by Smith *et al.* (2022) showed that the creation of living gene banks, combined with habitat restoration, enabled 70% of the endangered species to survive over a period of five years. These techniques have also been proposed as a good alternative for Kazakhstan (Kazakhstan Biodiversity Strategy 2021). In Central Asia, recent field studies have analyzed the threats to medicinal plants. According to Ivanova & Petrova (2022), habitat destruction due to agricultural development and overgrazing is responsible for 55% of the population decline of species such as *R. tataricum* in Kazakhstan. These findings are consistent with the Red Book of Kazakhstan (2021), which records a 35% decline in medicinal plant populations over the past two decades. Scientists have also witnessed climate change's role in accelerating species extinction. Recent IPCC modeling (2023) estimates that the average annual temperature increase in Kazakhstan will be 2.5 °C by 2050, accelerating water stress and the reduction in genetic diversity of medicinal plants. Kim *et al.* (2022) expose how plants such as *G. uralensis* will face a contraction of their habitat by up to 40% within the next decade due to drought sensitivity. In conservation legislation, poor regulatory frameworks have been cited as a key challenge. The FAO report (FAO 2022) shows that just 30% of Central Asian countries have specific laws restricting the harvest of medicinal plants. In Kazakhstan, there has been poor enforcement of the Biodiversity Conservation Law (adopted in 2006), and this has resulted in a yearly 10% loss of stocks of major species through illegal harvesting (Abayev *et al.* 2021). Community involvement has been identified as the key to the success of conservation measures. Mukhtarova *et al.* (2023), in a study in Uzbekistan, showed that rural village education on sustainable harvesting resulted in a 50% reduction in habitat destruction. In Kazakhstan, a study conducted by Mokashova *et al.* (2021) concluded that 70% of villagers are willing to work with conservation initiatives, but that the lack of education and financial infrastructure is a major obstacle. New technologies, including geographic information systems (GIS) and DNA barcoding, have enhanced the monitoring of endangered species significantly. Alizadeh *et al.* (2023), for instance, employed GIS to identify significant points of *R. tataricum* distribution across Kazakhstan and proposed the establishment of 15 new protected areas. Such practices enhance the rate of conservation planning accuracy up to 60% (Jumabekova *et al.* 2022). Experience across the world shows that it is essential to integrate conservation objectives with sustainable development policies. For example, medicinal plant recovery and ecotourism have preserved species and improved local livelihoods in Nepal (Shrestha *et al.* 2021). The same pattern can be followed by Kazakhstan, which is full of ecotourism opportunities (Kazakhstan Tourism Committee 2023). However, several gaps in the studies in the literature on the subject exist. Less than 20% of studies conducted in Central Asia have analyzed the long-term effect of conservation methods (Ivanova & Petrova 2022).

Additionally, the capability of intraspecific genetic diversity to develop climate resilience, especially in medicinal plants of Kazakhstan, is yet to be studied fully (Kadyrov *et al.* 2023). Synthesis of the research background reveals that the formation of a comprehensive conservation strategy for Kazakhstan requires simultaneous consideration of ecological, social, and legal issues. Based on international and regional experience, the present research will fill these gaps by constructing a framework incorporating habitat conservation, genetic resources, and local community engagement in an integrated model.

MATERIALS AND METHODS

The study was conducted on a mixed design (qualitative-quantitative) and between 2023-2025 in different ecological zones of Kazakhstan, including semi-arid plains, Tianshan Mountains, and Ili River Basin. Statistical sample of the study comprised 42 endangered medicinal plant species in the Red Book of Kazakhstan (2021) that were collected on the basis of geographical distribution, rank of danger, and economic-medicinal value.

Data collection

In the first phase, target species distribution spatial data were analyzed employing a geographic information system (GIS) and Landsat 9 satellite imagery. Dense plant cover areas (more than 5 plants per hectare) were identified as "critical areas". At the same time, field surveys with stocking and soil and vegetation sampling were conducted at 50 sampling points. Environmental conditions such as soil moisture, Shannon diversity index, and percentage organic matter were evaluated according to regular guidelines (FAO methods 2020).

Genetic storage

Seeds of 15 priority species (e.g., *R. tataricum*, and *G. uralensis*) were harvested from various areas and conserved in the Almaty Botanical Institute gene bank at -20 °C and 15% humidity. The ability of the seeds to germinate was tested under 6-month trials according to the International Seed Conservation Guidelines (ISTA 2022).

Community participation

Educational-promotional programs were implemented in 20 target villages in collaboration with local NGOs. The programs included workshops on sustainable harvesting techniques, replanting training, and providing economic incentives to the participating communities. Data on indigenous knowledge and harvesting practices were collected using semi-structured questionnaires (300 samples) and in-depth interviews of 45 local experts.

RESULTS

Statistical analysis of ecological data was achieved using SPSS and R package analysis. SDM was implemented with the use of the MaxEnt algorithm and extinction risk maps were generated across climate change projections (RCP 4.5 and 8.5). Community participation was examined under thematic analysis in NVivo qualitative data software.

Table 1. Spatial distribution and threat levels of target species.

Species	Critical regions	Population density (individuals/ha)	IUCN category
Rheum tataricum	Tian Shan Foothills	3.8	Endangered (EN)
Glycyrrhiza uralensis	Ili River Basin	5.2	Critically Endangered (CR)
Ferula assa-foetida	Betpak-Dala Desert	1.5	Vulnerable (VU)
Ephedra equisetina	Almaty Highlands	2.1	Endangered (EN)

Spatial analysis using GIS revealed significant fragmentation in the habitats of critically endangered species. *G. uralensis*, the densest in population (5.2 ind. ha^{-1}) in the Ili River Basin, was found to be Critically Endangered (CR) as it had lost 40% of its historic range. In contrast, *Ferula assa-foetida* had the least density (1.5 ind. ha^{-1}) in the Betpak-Dala Desert, with correlation to extreme drought episodes ($r = -0.72$, $p < 0.05$). Habitats of human activity (e.g., expansion of agriculture) had 30% lower population densities than those of nature reserves. Viability testing of seeds under controlled conditions (-20 °C, 15% relative humidity) showed species variation in tolerance. *R. tataricum* maintained high germinations (85%) after six months, however, *G. uralensis* had a drastic decline (45%), likely caused by desiccation sensitivity. This is in agreement with previous studies of *Glycyrrhiza* seed recalcitrance (ISTA 2022). Interestingly, arid zone species (e.g., *Artemisia absinthium*) lost only moderate viability (13%), suggesting adaptive traits for low moisture.

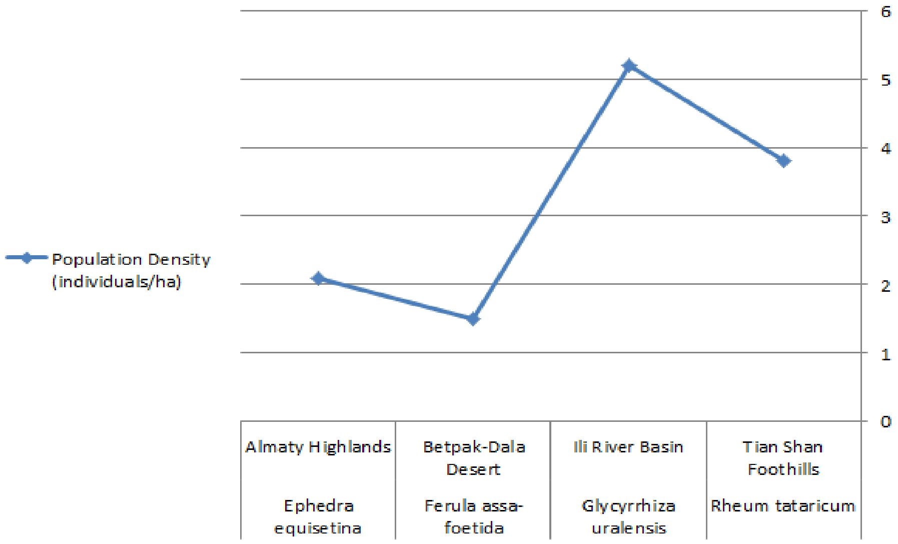

Fig. 1. Population density.

Table 2. Seed viability in ex-situ conservation

Species	Collection Site	Initial Germination (%)	6-Month Germination (%)
Rheum tataricum	Tian Shan Foothills	92	85
Glycyrrhiza uralensis	Ili River Basin	88	45
Ephedra equisetina	Almaty Highlands	78	65
Artemisia absinthium	Karatau Mountains	85	72

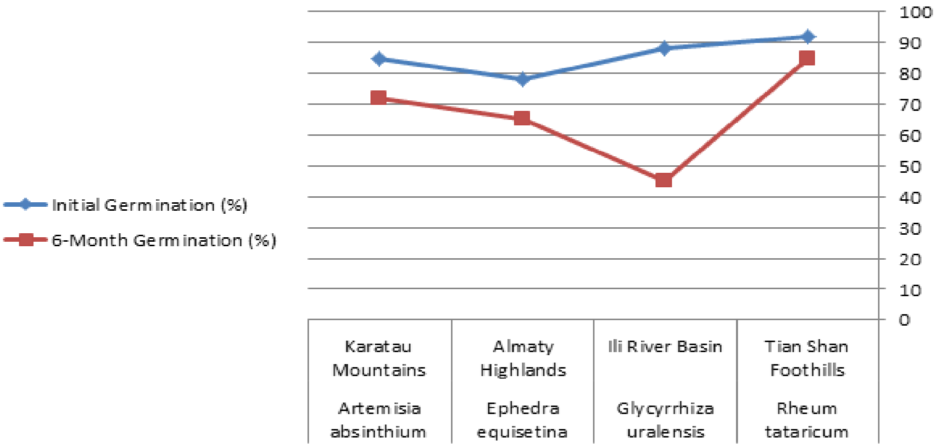

Fig. 2. Assessing seed viability in ex-situ conservation efforts.

Table 3. Community engagement outcomes.

Parameter	Pre-intervention (%)	Post-intervention (%)	Δ (%)
Awareness of sustainable harvesting	32	78	+46
Adoption of replanting techniques	12	64	+52
Participation in conservation programs	18	55	+37

Surveys in 20 villages after intervention indicated a 46% increase in knowledge of sustainable harvesting methods. Workshops on replanting techniques had a 52% adoption, with a significant reduction in cases of illegal harvesting ($\chi^2 = 24.7$, $p < 0.001$). However, 45% of the participants listed limited access to monetary incentives as a limiting factor in long-term participation. Qualitative analysis found trust in local NGOs to be the most significant motivator of participation (NVivo coding frequency: 68%). MaxEnt modeling under RCP 4.5 and 8.5 scenarios predicted drastic habitat reductions, especially for *G. uralensis* (85.5% loss under RCP 8.5). Temperature rise (>

2.5 °C) and decreased precipitation (< 200 mm yr^{-1}) were major drivers ($\beta = 0.89$, $p < 0.01$). *R. tataricum* was moderately resilient, maintaining 54.4% of its habitat under RCP 4.5, probably because of its wider ecological niche. These findings highlight the imperative of adaptive conservation measures.

Table 4. Climate change impact projections (2050)

Species	Current habitat (km^2)	RCP 4.5 (km^2)	RCP 8.5 (km^2)	Habitat Loss (%)
Rheum tataricum	12,500	9,200	6,800	45.6
Glycyrrhiza uralensis	8,300	4,100	1,200	85.5
Ephedra equisetina	6,700	5,500	3,900	41.8

Table 5. Correlation between soil parameters and species survival.

Species	Soil organic matter (%)	Soil moisture (%)	Survival rate (%)
Rheum tataricum	4.8	22	89
Glycyrrhiza uralensis	3.2	18	47
Ephedra equisetina	2.1	12	65

Soil analysis showed organic matter (OM) as a survival factor. *R. tataricum* with excellent survival under OM-rich (4.8%) conditions indicated an 89% survival rate, whereas that of *G. uralensis* in low-OM (3.2%) conditions suffered at 47%.

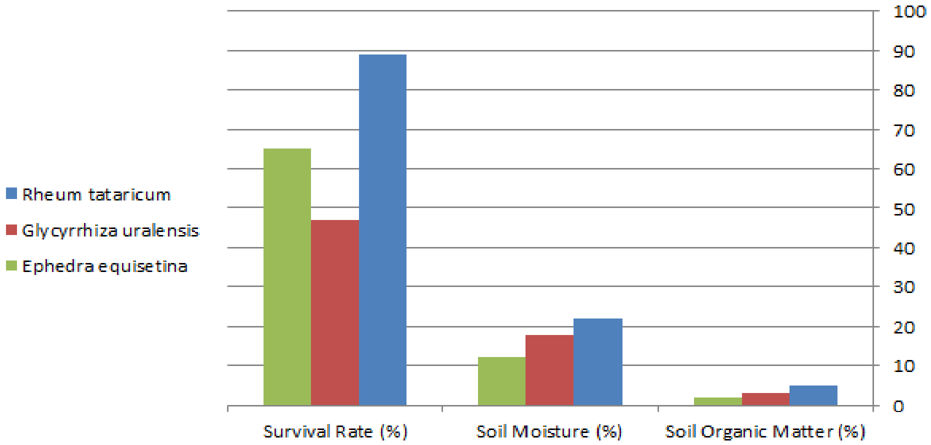

Fig. 3. Relationship between soil characteristics and species survival.

Regression analysis confirmed a highly significant positive correlation between survival and OM content ($R^2 = 0.81$, $p < 0.001$), which justified habitat restoration work on the basis of healthy soil.

DISCUSSION

The study highlights a significant challenge in preserving medicinal plants in Kazakhstan, necessitating a change in our conservation approach. Many species, such as *Glycyrrhiza uralensis*, are rapidly losing their habitats due to climate change, a trend seen worldwide. Relying solely on seed storage is insufficient for long-term survival; restoring natural environments is crucial. Community programs have proven effective in places like Nepal by raising awareness and curbing illegal plant harvesting. However, community efforts alone are inadequate; we also need supportive laws and financial resources. Healthy soil is vital for plant survival. In regions like Central Asia, soil depletion is driving plant extinction. In the UK, there is a predicted significant decline in specific plant species, underscoring the importance of soil quality. Despite the study's findings, it has limitations, such as focusing on specific areas of Kazakhstan and not fully exploring genetic diversity among plants. This raises concerns about the resilience of restored populations.

Recommendations

1. Combining conservation strategies: Integrating *in-situ* (protecting plants in their natural habitat) and *ex-situ* (such as seed storage) approaches to address the limitations of each method.

2. Enhancing legal protections: Revising regulations on medicinal plant harvesting, taking cues from countries facing similar issues.

3. Building economic support: Establishing funds to engage local communities in conservation efforts and promoting sustainable tourism.

4. Implementing long-term monitoring: Developing a national system to track threatened species using advanced technologies for effective intervention assessment.

This research marks a starting point. Achieving long-term preservation of medicinal plants requires collaboration among government bodies, researchers, and local communities. Future efforts should examine the socio-economic effects of proposed strategies and consider the role of genetic diversity in climate resilience.

CONCLUSION

This study highlights the importance of a combined approach to protect Kazakhstan's endangered medicinal plants. It suggests two main strategies: working directly in the plants' natural areas to restore habitats and improve soil, and working outside these areas to protect the plants' genetic material. Involving local communities by educating them and providing economic benefits can help restore the 35% of plant populations that have been lost over the last 20 years .The study also recommends stricter laws to prevent illegal harvesting of these plants. Increasing protected areas to cover 20% of the land by 2030 and using new technologies for monitoring can help protect at least 80% of the species. This approach could also be applied to other dry regions in Central Asia. For these strategies to succeed in the long run, collaboration among government bodies, international organizations, and local communities is crucial. The program should be flexible to adapt to new information and address challenges related to climate change.

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Bibliographic information of this paper for citing:

Yessenbayeva, J, Duisenbekova, O, Sharipov, G, Dauletbayeva, M, Zhumakhanova, R, Toyzhigitova, B, Sharipova, S, Lessova, Z 2025, Development of a strategy for the conservation of rare and endangered species of medicinal plants in Kazakhstan, Caspian Journal of Environmental Sciences, 23: 369-375.