# ANALYSIS OF THE RESOURCE POTENTIAL OF MEDICINAL PLANTS DEPENDING ON SOIL TYPES (A CASE STUDY OF SOUTHERN UZBEKISTAN)

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## Abstract

The article provides a comprehensive analysis of the resource potential of medicinal plants found in southern Uzbekistan. An assessment conducted in the Kashkadarya and Surkhandarya regions revealed significant differences in the area and volume of reserves, influenced by species composition and soil-climatic conditions. Species in the first category are predominantly associated with Lithosol-type soils, with the exception of *Ferula foetida*, which is adapted to carbonate soils such as Calcic Xerosols and Calcic Yermosols. In the Surkhandarya region, *Ajuga turkestanica*, *Hypericum perforatum*, and *Hypericum scabrum* exhibited high edaphic plasticity, successfully growing on Calcic Xerosols. The edaphic factor is identified as a key determinant in shaping resource potential and is essential in planning sustainable natural resource management. Species with a broad ecological amplitude, such as *Ungernia victoris* and *Ajuga turkestanica*, are of particular interest for further research and potential cultivation.

Special attention is given to species with limited distribution and conservation concern, such as *Rhus coriaria* and *Ungernia victoris*, which require strict harvesting controls to ensure population stability and the preservation of the region's biodiversity.

**Keywords:** medicinal plants, resource potential, soil types, edaphic factor, southern Uzbekistan

## Introduction

In recent years, the popularity of herbal medicines has grown significantly, leading to increased demand for wild medicinal, edible, and certain technical plant resources harvested across large areas of the Republic of Uzbekistan [1].

Currently, a new worldview is emerging, centered on understanding the unique role of humans in relation to their environment. A fundamental principle of this new perspective is the preservation of the planet's biodiversity, which ensures a high quality of life for humanity. In this context, studies focusing on the impact of anthropogenic factors on biological systems particularly wild resource plant species are of high relevance. These species are subjected to various stressors, among which

anthropogenic activity plays a leading role, primarily through exploitation pressure and technogenic pollution [1].

Today, nearly half of all medicinal drugs are produced from plant-based raw materials, with more than 50% derived specifically from wild plant species. Interest in phytotherapy and herbal remedies has grown significantly among both healthcare professionals and the general public, leading to the depletion and unsustainable exploitation of natural reserves of medicinal plants. This situation underscores the urgent need for conservation measures and the development of sustainable harvesting practices that support the regeneration of wild plant populations [3].

Between 2021 and 2024, the Institute of Botany of the Academy of Sciences of Uzbekistan, in collaboration with the Ministry of Ecology, Environmental Protection, and Climate Change, conducted a scientific project titled "Management of the State Cadastre of Plant World Objects." As part of this initiative, a complete inventory of the flora of protected natural areas in all regions of the republic was carried out. Additionally, a database was created, cataloguing the resources and distribution areas of 62 promising plant resource species across Uzbekistan and the Republic of Karakalpakstan.

The research assessed the current status of natural resources of medicinal plants found in the national flora, including *Inula grandis* [4], *Capparis spinosa* [5], *Ferula tadshikorum* [6], *F. foetida* [7], *F. varia* [8], *Ungernia victoris* [9], *Rosa canina* [10], *Berberis integerrima* [11], *Peganum harmala* [12], *Pistacia vera* [13], and others.

Given the urgency of implementing a system for the rational use and continuous monitoring of plant resources, the Institute of Botany developed a "Digital System of Categories and Utilization of Resource Plants of Uzbekistan's Flora." This system was designed to enable a systematic approach to managing the country's plant resources. In developing the classification of resource species, several criteria were considered: average raw material demand over the past five years, regeneration period of plant populations (in years), type of plant material used (e.g., aboveground or underground parts, seeds, fruits), utilization importance, and the life form of the species.

The resource species were divided into four categories, each with its own set of criteria:

**Category 1**: Species with high demand for raw material, primarily using aboveground and underground organs; natural resources are limited and require annual scientific monitoring.

**Category 2**: Species with high demand for raw material, using mostly aboveground parts, seeds, or fruits; monitoring is needed every two years.

**Category 3**: Species with medium demand, using both aboveground and underground parts, seeds, or fruits; studies are recommended every 3–4 years.

**Category 4**: Species used individually and locally (without regulation), mainly in traditional medicine; low demand and typically rare.

It is important to note that the composition of species in each category is not fixed and may change. Inclusion or exclusion of a species from a category requires at least three years of scientific monitoring of its resource potential dynamics [14].

The total number of categorized resource species is 71. Of these, Category 1 includes mostly perennial species and comprises 26.76%; Category 2 – 19.71%; Category 3 – 35.21%; and Category 4 – 18.30%. Continuous monitoring is recommended for species in Category 1; biennial monitoring for Category 2; once every 3–4 years for Category 3; and permanent monitoring for rare species in Category 4 [14].

Based on these studies, it became possible to analyze the distribution and resource potential of medicinal species by region or specific territory.

Given the observed patterns, there is now a pressing need to analyze the resource potential of medicinal plants across different soil types. Accordingly, this study aims to evaluate the natural resources of medicinal plant species distributed in southern Uzbekistan, taking into account variations in soil types.

In previous studies, we developed a detailed soil map of southern Uzbekistan. Furthermore, we assessed the underground phytomass of *Inula grandis* in this region. The edaphic optimum for *Inula grandis* in southern Uzbekistan was found to be stony mountain soils (Lithosols), at elevations of 1300–1500 meters above sea level [4].

This study analyzes the natural resources of 18 medicinal plant species in high demand for raw materials, with a focus on their distribution across various soil types in southern Uzbekistan.

## Materials and Methods

The study examined 18 medicinal plant species occurring in southern Uzbekistan, selected based on their high demand for raw materials (Table 1).

**Table 1.** Objects of the Study

| № | Species | Importance of Use | Life form | Harvested Part | Average Annual Demand (tons) |
|---|---|---|---|---|---|
| | | | **First category:** | | |
| 1 | *Allium stipitatum* Regel | Medicinal, Edible | Perennial | Bulb | 46,75 |
| 2 | *Ajuga turkestanica* (Regel) Briq. | Medicinal | Semi-shrub | Aboveground part | 19,25 |
| 3 | *Codonopsis clematidea* (Schrenk) C.B.Clarke | Medicinal | Perennial | Aboveground part | 6,25 |
| 4 | *Ferula foetida* (Bunge) Regel | Medicinal | Perennial | Natural resin, Seeds | 138,8 |
| 5 | *Hypericum perforatum* L. | Medicinal | Perennial | Aboveground part, Seeds | 91,75 |
| 6 | *Mediasia macrophylla* (Regel et Schmalh.) Pimenov | Medicinal | Perennial | Aboveground part, Seeds | 8,05 |
| 7 | *Rhodiola hetrodontha* (Hook.et Thoms.) Boriss. | Medicinal | Perennial | Rhizomes | 19,75 |
| 8 | *Ungernia victoris* Vved. Ex Artjush. | Medicinal, Rare Species | Perennial | Leaves | 22,5 |
| 9 | *Ziziphora clinopodioides* Lam. | Medicinal | Perennial | Aboveground part | 42,5 |

| | | | | | |
|---|---|---|---|---|---|
| **Second category:** | | | | | |
| 10 | *Berberis integerrima* Bunge | Medicinal, Edible, Essential Oil-bearing | Shrub | Fruits, Seeds | 14,95 |
| 11 | *Crataegus turkestanica* Pojark. | Medicinal, Edible | Tree | Inflorescences, Fruits | 248,7 |
| 12 | *Hippophae rhamnoides* L. | Medicinal, Edible | Shrub | Fruits | 7,75 |
| 13 | *Rosa canina* L. | Medicinal, Edible, Honey Plant | Shrub | Fruits | 280,5 |
| 14 | *Rheum maximowiczii* Losinsk. | Medicinal, Edible | Perennial | Aboveground part | 59,75 |
| **Third category:** | | | | | |
| 15 | *Pistacia vera* L. | Edible, Medicinal | Tree | Fruits | 2,5 |
| 16 | *Alcea nudiflora* (Lindl.) Boiss. | Medicinal | Perennial | Roots and Rhizomes | 2,45 |
| **Fourth category:** | | | | | |
| 17 | *Rhus coriaria* L. | Medicinal, Honey Plant, Rare Species | Tree | Leaves | 0,56 |
| 18 | *Hypericum scabrum* L. | Medicinal, Essential Oil-bearing, Honey Plant | Perennial | Aboveground part, Seeds | 12,5 |

## Research Methods

To determine the natural resources of plants within the Republic of Uzbekistan, the manual on “Resource Science and Standardization of Medicinal Plant Raw Materials” [3] was used. Raw material reserves were assessed during the vegetation period of each plant. For the analysis of soil types in the studied areas, the international soil classification system was applied for soil diagnosis and creation of soil map legends [15]. Statistical processing of the obtained results was carried out using the software Past and Origin Pro, while ArcGIS Map software was used to create distribution maps of areas with species reserves by soil types. Ward’s clustering method with Manhattan distance was applied to develop clusters of resource potential by soil types.

### *Study Area*

Southern Uzbekistan comprises the Kashkadarya and Surkhandarya regions, located in the southernmost part of the country. The region borders the Samarkand and Bukhara regions to the north, Tajikistan to the east, Turkmenistan to the west, and Afghanistan to the south. The southern boundary follows the Amu Darya River, which also serves as the natural border between Uzbekistan and Afghanistan (Fig. 1).

In recent years, several scientific studies have been conducted in this region on the cultivation of medicinal plants in rainfed areas, based on the study of their bioecological characteristics [16, 17].

From a botanical-geographical perspective, the territory of Kashkadarya region belongs to the Urgut district of the Kuhistan area, Kashkadarya and Tarkapchigay districts of the Western Gissar area of the Gorno-Middle Asian province, and the Karshi-Karnabchul district of the Bukhara area of the Turan

province. Surkhandarya region includes Kashkadarya, Tarkapchigay, Baysun, Kugitang, and Surkhan-Sherabad districts of the Western Gissar area of the Gorno-Middle Asian province, Sangardak-Tupalang district of the Gissar-Darvaz area, and Babatag district of the Pyandj area [18].


**Figure 1.** Study Area

The natural resource potential of medicinal plant species in southern Uzbekistan was assessed based on their categorization by abundance, ecological range, and economic importance. Species classified in the first category those with high raw material value and limited distribution were evaluated in detail in both the Kashkadarya and Surkhandarya regions. According to resource indicators for *Allium stipitatum* in the Kashkadarya region, reserves were identified across an area of approximately 45.0 hectares, with an estimated potential harvest volume of 1.5285 tons of raw material. In contrast, in the Surkhandarya region, the reserves covered about 10.0 hectares, yielding a lower estimated volume of 0.5095 tons. These differences are likely influenced by regional variations in soil-climatic conditions and anthropogenic pressures. Reserves of *Codonopsis clematidea* and *Ungernia victoris*, both also classified in the first category, were found exclusively in the Surkhandarya region. This limited distribution highlights the importance of targeted conservation and habitat protection measures for these species. Conversely, populations of *Ferula foetida* were recorded only in the Kashkadarya region, primarily on carbonate soils such as Calcic Xerosols and Calcic Yermosols, consistent with its edaphic preferences.

The remaining species in this category demonstrated resource potential in both regions, reflecting a broader ecological amplitude and adaptability to varying soil and climatic conditions. These findings underscore the importance of region-specific

management strategies that account for both the ecological requirements and conservation status of each species (Fig. 2).

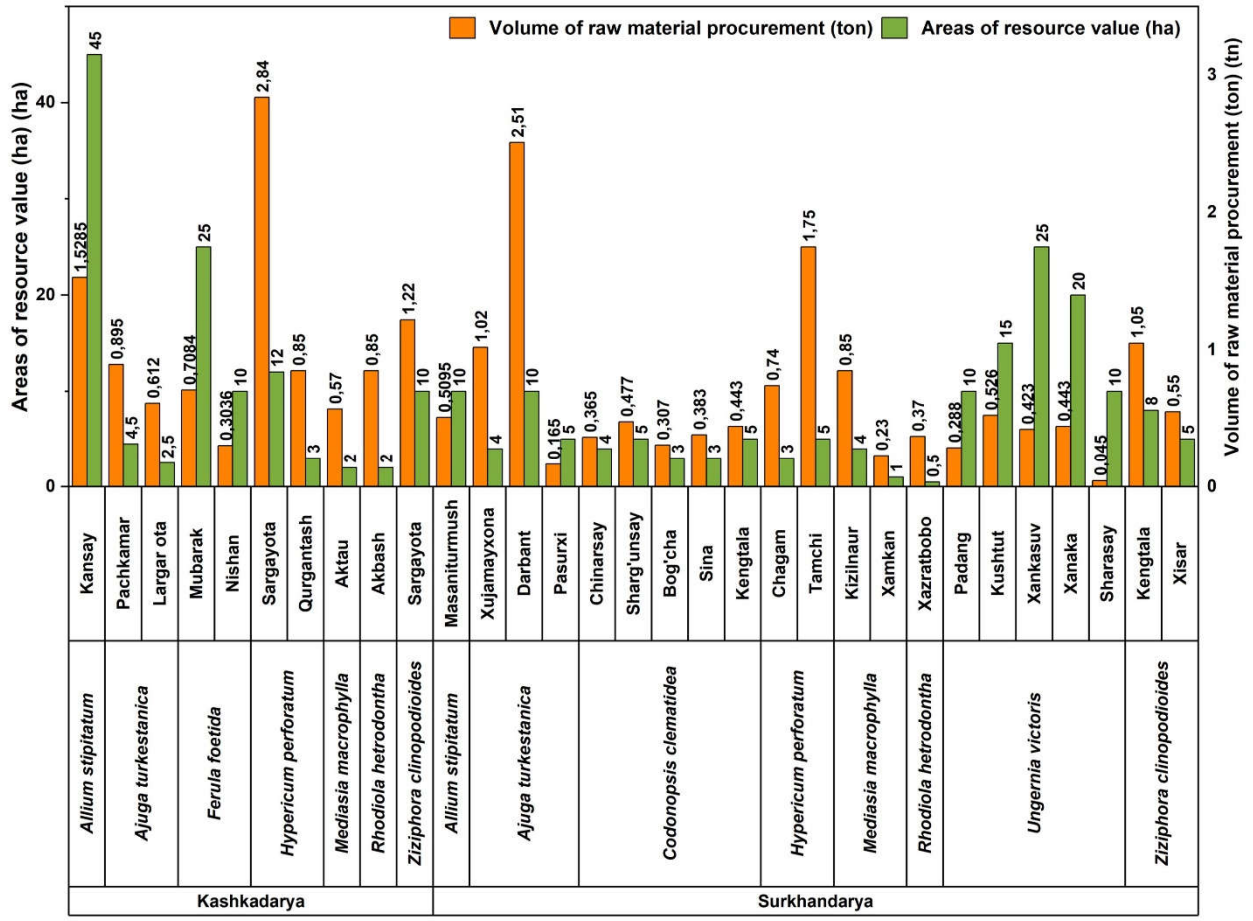


**Figure 2.** Natural resources of medicinal plant raw materials classified in the first category

According to the results of the resource potential assessment of species belonging to the second category, the following values were established: for *Berberis integerrima* in the Surkhandarya region, areas with raw material reserves averaging 75.0 hectares were identified, providing a potential annual harvest volume of 0.215 tons. For *Crataegus turkestanica* in the Kashkadarya region, areas with reserves covering 35.0 hectares and a possible harvest volume of 1.05 tons were recorded. In the Surkhandarya region, this species occupies 58.0 hectares, with a raw material volume of 1.623 tons. For *Hippophae rhamnoides* in the Kashkadarya region, reserves were identified on 15.0 hectares, with a raw material volume of 0.988 tons. The reserves of *Rosa canina* amount to 2.302 tons in the Kashkadarya region and 1.292 tons in the Surkhandarya region. The resource potential of *Rheum maximowiczii* in the Kashkadarya region is estimated at 14.5 tons, while in the Surkhandarya region it is only 0.066 tons (Fig. 3).

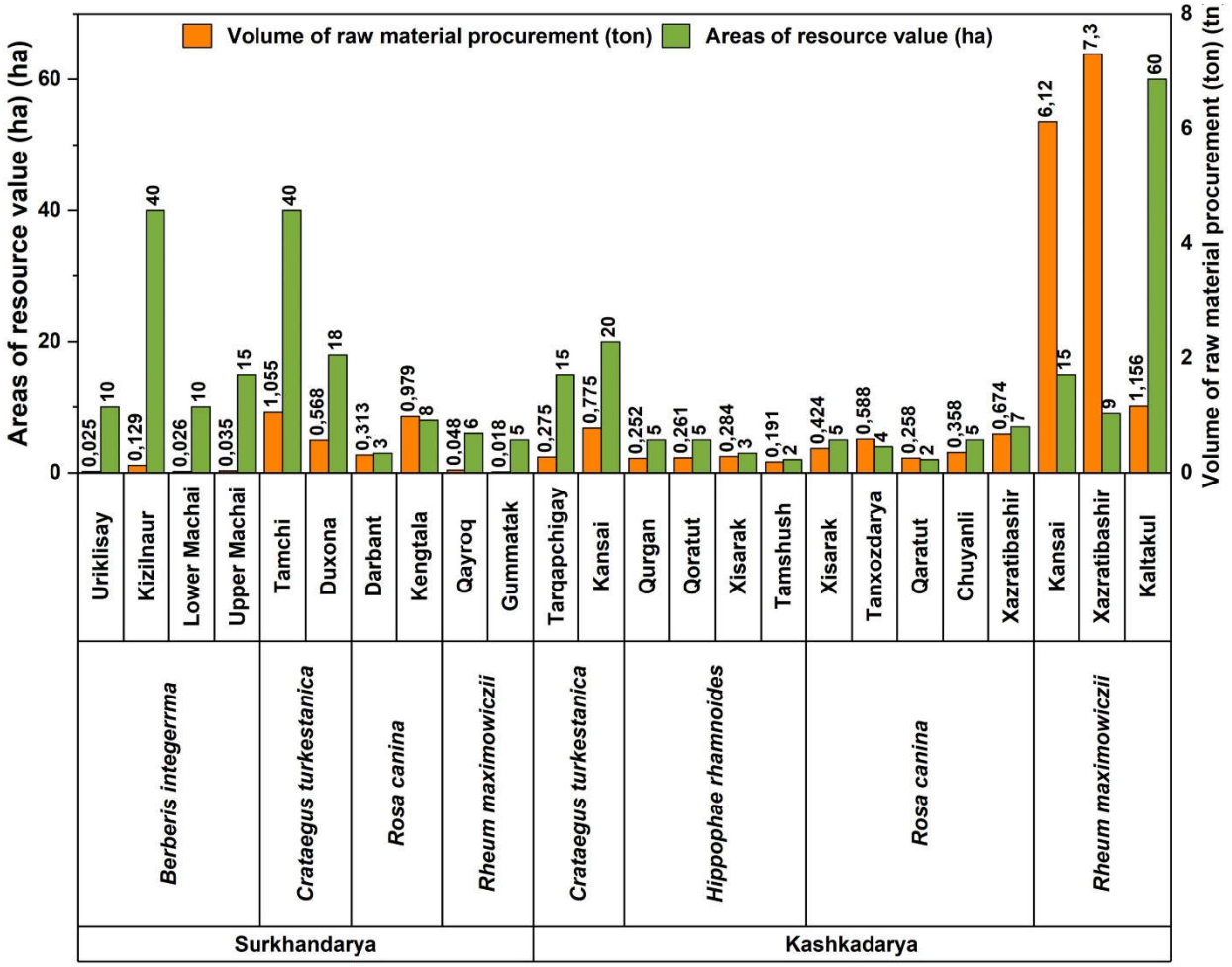


**Figure 3.** Natural resources of medicinal plant raw materials classified in the second category

According to data on the resource potential of species classified in the third category, the following estimates have been identified: in the Surkhandarya region, *Alcea nudiflora* occupies an area of approximately 10.0 hectares, with an estimated annual yield of 0.288 tons of raw material. In the Kashkadarya region, this species is more widely distributed, covering an average area of 57.0 hectares, where the potential annual harvest is estimated at 1.275 tons. For *Pistacia vera* in the Surkhandarya region, natural populations with resource potential were recorded over an area of 73.0 hectares, with a projected raw material yield of approximately 0.832 tons annually (Fig. 4).

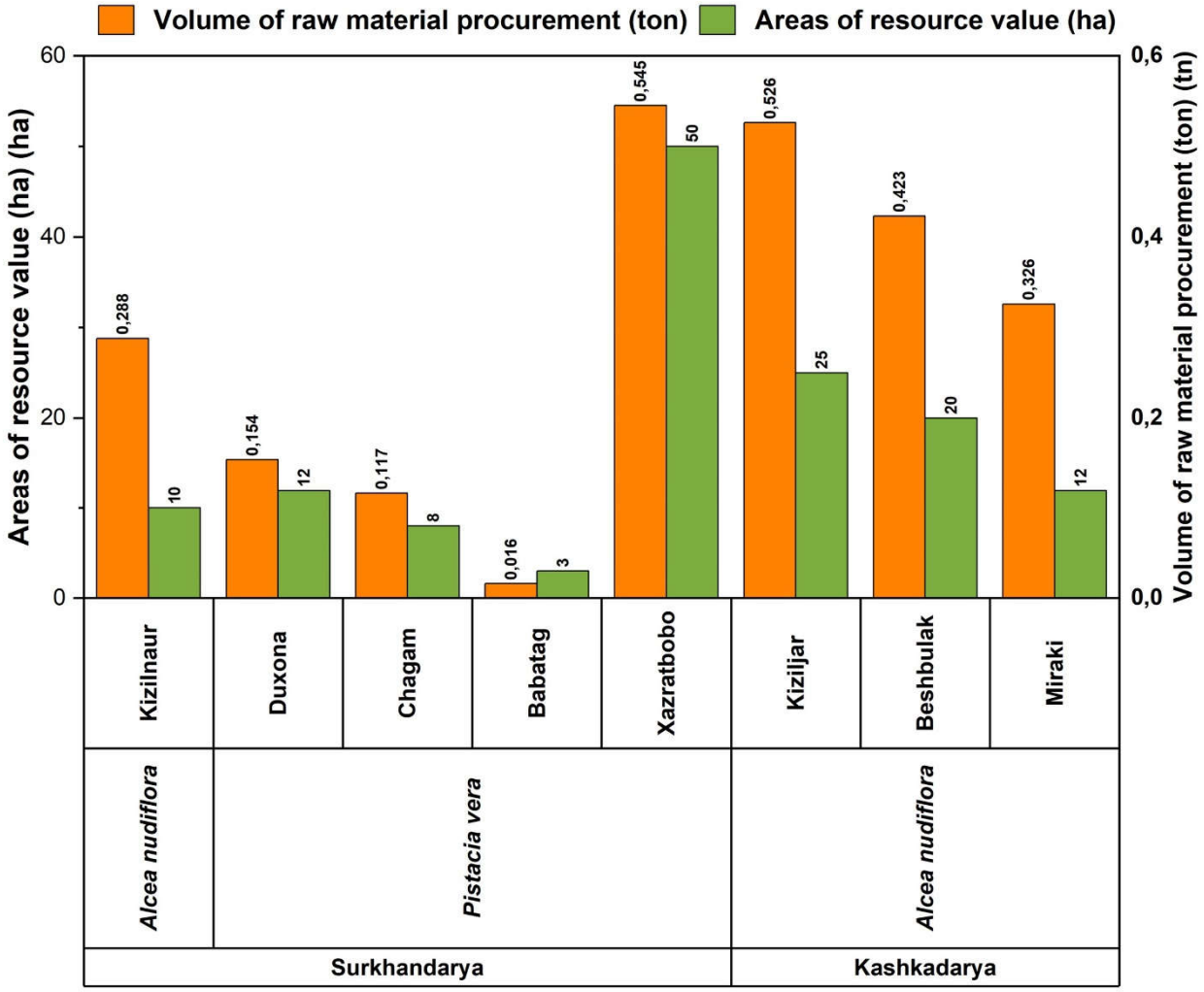


**Figure 4.** Natural resources of medicinal plant raw materials classified in the third category

According to the conducted assessment, species included in the fourth category are characterized by limited distribution and particularly vulnerable status, requiring special approaches for their use and conservation.

The species *Rhus coriaria*, listed in the Red Book of the Republic of Uzbekistan, is found in the Surkhandarya region on areas averaging 12.0 hectares. The population yield is 0.036 tons. These data reflect only the biological resource potential of the species and are not intended for commercial exploitation. Based on its conservation status and low productivity, harvesting of this species is not recommended.

For *Hypericum scabrum*, areas with raw material reserves of 35.0 hectares were identified in the Kashkadarya region, with a possible harvest volume of 0.448 tons. In the Surkhandarya region, this species is distributed over 40.0 hectares, with a harvestable raw material volume of 0.435 tons (Fig. 5).

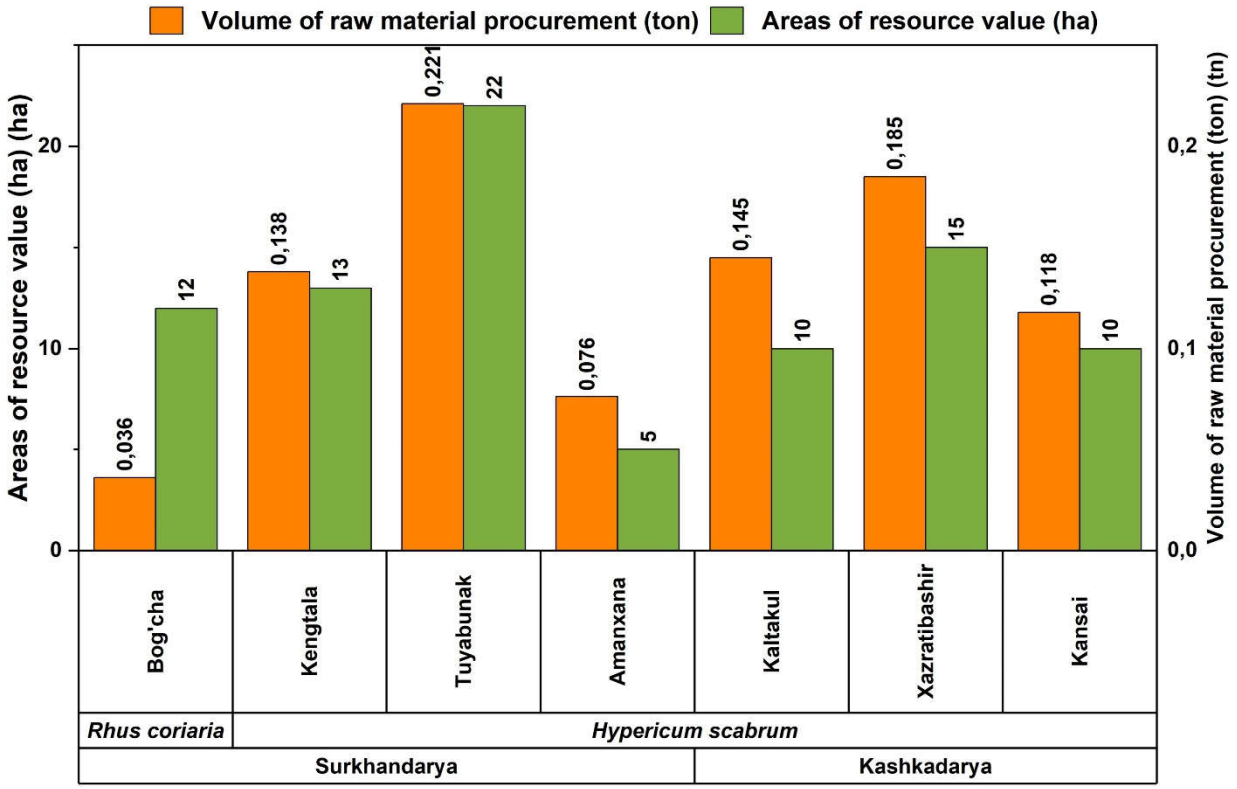


**Figure 5.** Natural resources of medicinal plant raw materials classified in the fourth category

***Soil Analysis of Southern Uzbekistan***

In Kashkadarya Region, seven soil types have been identified: drifting sands (DS), meadow brown soils (Ge), mountain-stony soils (I), brown semi-desert soils (Xk), brown solonetzic and solonchak soils (Yk), brown structureless soils (Yt), and meadow solonchak soils (Z). In contrast, Surkhandarya Region features six soil types: meadow brown soils (Ge), mountain-stony soils (I), alluvial calcareous soils (Jc), pine sands (Qc), brown semi-desert soils (Xk), and meadow solonchak soils (Z).

Based on these findings, a soil type map of Southern Uzbekistan was developed. In Kashkadarya, the dominant soil types are mountain-stony Lithosols (I) and calcareous Calcic Xerosols (Xk), while drifting sands (DS) and meadow brown soils (Ge) are less widespread. In Surkhandarya, drifting sands (DS) are absent; the leading soils are mountain-stony Lithosols (I) and meadow brown soils (Ge) classified as Calcaric Gleysols, with meadow solonchak soils (Z) occurring less frequently.

The soils in the studied areas predominantly belong to the mountain-stony Lithosols (I), which are classified within the Leptosols group—characterized by dense, highly stony soils developed on hard rock. For the analysis of the Lithosols' topsoil composition, four parameters were selected: sand content, water pH, nitrogen content (N), and calcium carbonate content ($CaCO_3$). The average values for Southern Uzbekistan soils are as follows: sand 63.4%, water pH 6.8, nitrogen 0.12%, and $CaCO_3$ 0.125% [4] (Fig. 6).

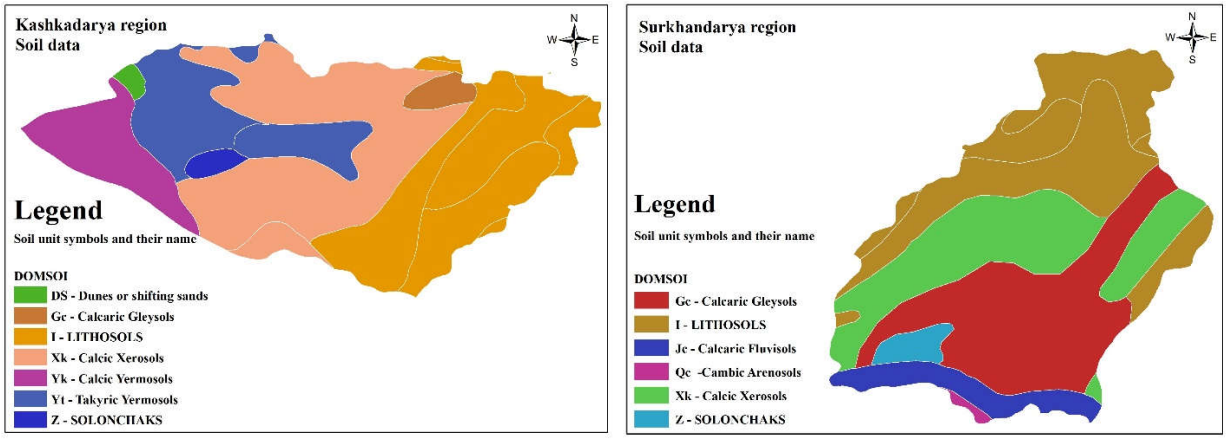


**Figure 6.** Soil Type Map of Southern Uzbekistan

The resource potential of medicinal plants distributed in the Kashkadarya region was recorded primarily on soils corresponding to the edaphic optimum of type I (Lithosols). It was established that the resource potential of only one species from the first category, *Ferula foetida*, is associated with soils of the Calcic Xerosols (Xk) and Calcic Yermosols (Yk) types (Fig. 7).

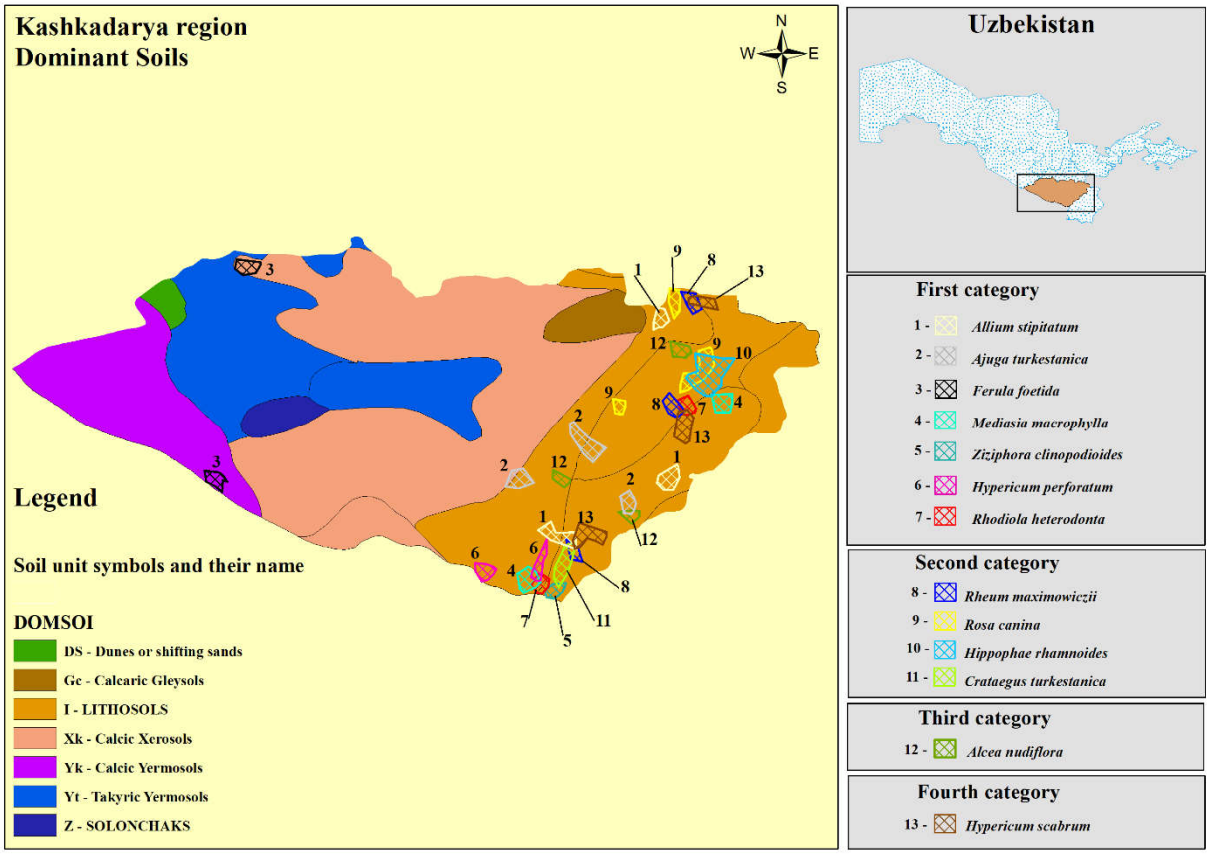


**Figure 7.** Distribution map of the resource potential of medicinal plants by soil types in the Kashkadarya region

Resource potential of 13 medicinal plant species distributed in the Surkhandarya region is predominantly associated with edaphic optimum soils of type I (Lithosols). It was found that the resource potential of *Ajuga turkestanica, Hypericum perforatum*, and *Hypericum scabrum* is localized on Calcic Xerosols

(Xk) soils. Additionally, *Ungenia victoris* and *Ajuga turkestanica* exhibit nearly equal resource potential values on both type I (Lithosols) and type Xk (Calcic Xerosols) soils (Fig. 8).

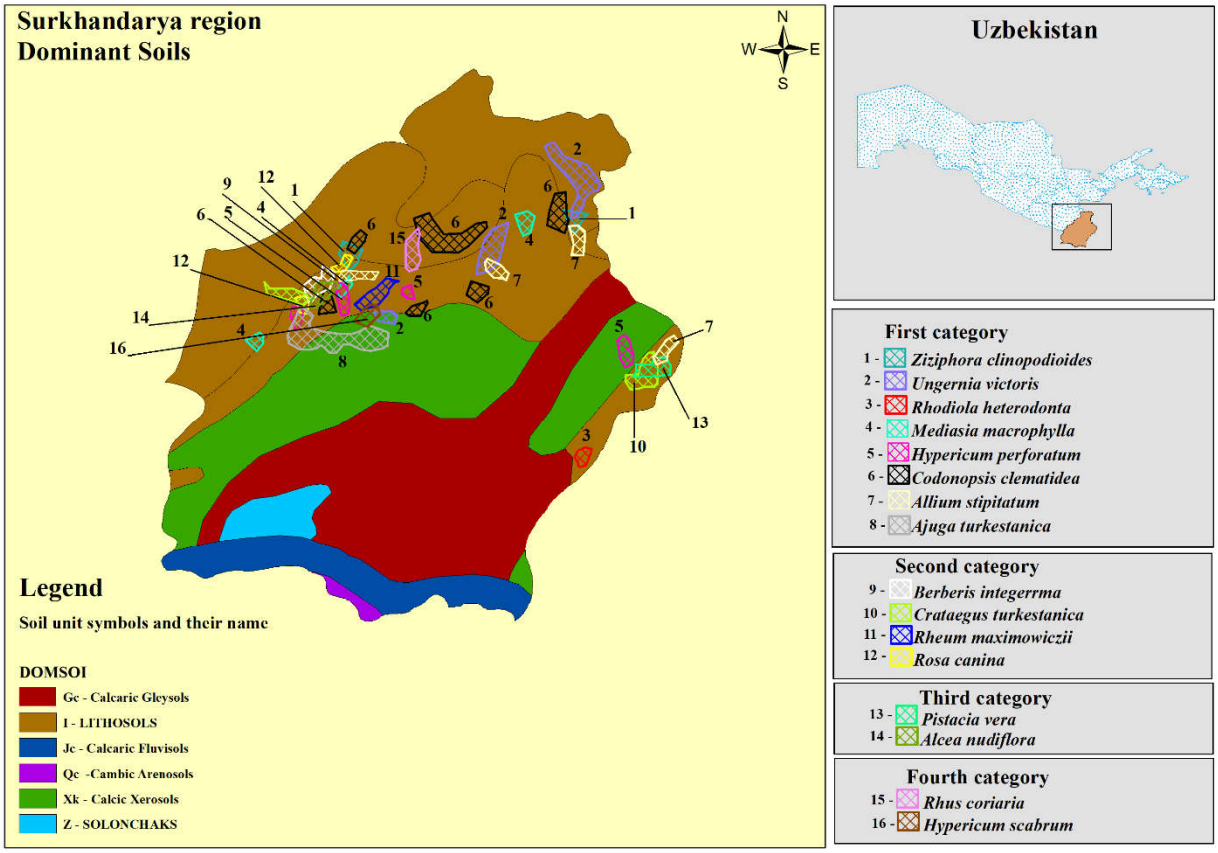


**Figure 8.** Distribution map of the resource potential of medicinal plants by soil types in the Surkhandarya region

## Discussion

The assessment results of the resource potential of medicinal plants, categorized into different groups, revealed significant differences in reserve volumes and area of occurrence between Kashkadarya and Surkhandarya regions.

Among the first-category species, *Allium stipitatum* is of greatest interest, with reserve areas averaging 45.0 ha and a potential harvest volume of 1.5285 tons in Kashkadarya, compared to 10.0 ha and 0.5095 tons in Surkhandarya. *Codonopsis clematidea* and *Ungernia victoris* were recorded exclusively in Surkhandarya, whereas *Ferula foetida* was noted only within Kashkadarya. The remaining species of this category exhibit resource potential across both regions, indicating a broader ecological amplitude and resilience to various edaphic conditions.

For second-category species, the following patterns were identified: in Surkhandarya, *Berberis integerrima* is distributed over 75.0 ha with an estimated annual harvest of 0.215 tons. *Crataegus turkestanica* demonstrates high resource significance in both regions: 35.0 ha and 1.05 tons in Kashkadarya, and 58.0 ha and 1.623 tons in Surkhandarya. Substantial reserves were also noted for *Hippophae rhamnoides* in Kashkadarya (15.0 ha, 0.988 tons), *Rosa canina* (2.302 tons in Kashkadarya and 1.292 tons in Surkhandarya), and *Rheum maximowiczii*, with

reserves of 14.5 tons in Kashkadarya and only 0.066 tons in Surkhandarya. These data indicate favorable conditions for growth and biomass accumulation of these species specifically in Kashkadarya.

Within the third category, *Alcea nudiflora* shows considerable resource value, with reserves covering 10.0 ha and an estimated harvest volume of 0.288 tons in Surkhandarya, compared to 57.0 ha and 1.275 tons in Kashkadarya. Additionally, *Pistacia vera* in Surkhandarya occupies 73.0 ha with an estimated raw material volume of 0.832 tons, highlighting the economic feasibility and potential for its rational use.

The analysis of the fourth category revealed that these species have restricted distribution and high vulnerability. *Rhus coriaria*, listed in the Red Book of the Republic of Uzbekistan, was identified in Surkhandarya on approximately 12.0 ha with a yield of 0.036 tons. This figure reflects only the biological resource potential and does not imply commercial exploitation due to the species' protected status and low productivity.

Simultaneously, *Hypericum scabrum* demonstrated stable distribution in both regions: 35.0 ha (0.448 tons) in Kashkadarya and 40.0 ha (0.435 tons) in Surkhandarya. Despite its conservation status, the biomass volumes suggest the possibility of controlled harvesting under strict adherence to sustainable use principles.

Thus, the results emphasize the importance of a differentiated approach to the assessment and utilization of medicinal plant resources, considering both their biological characteristics and the territorial and edaphoclimatic specificity. Special attention should be given to species categorized as protected, with harvesting activities conducted in strict compliance with environmental and legal regulations.

Analysis of the resource potential distribution relative to soil types revealed specific edaphic preferences among first-category species. In Kashkadarya, the resource potential of medicinal plants is predominantly concentrated on soils of the edaphic optimum type I (Lithosols). The sole exception is *Ferula foetida*, whose resource potential is associated with Calcic Xerosols (Xk) and Calcic Yermosols (Yk) soils, indicating a broader ecological and cenotic amplitude and an ability to thrive under conditions of increased carbonate content and xerophytism.

A similar pattern is observed in Surkhandarya for 13 medicinal plant species, whose reserves are mainly tied to Lithosols soils. However, three species — *Ajuga turkestanica*, *Hypericum perforatum*, and *Hypericum scabrum* — show adaptation to Calcic Xerosols (Xk) soils, evidencing high ecological plasticity and the capacity to form productive coenopopulations under arid and carbonate-rich edaphoclimatic conditions.

Of particular interest are *Ungenia victoris* and *Ajuga turkestanica*, which exhibit nearly identical resource potential on both Lithosols and Calcic Xerosols soils. This edaphic versatility makes these species promising candidates for rational use and potential cultivation across diverse soil types, considering their adaptive traits (Fig. 9).

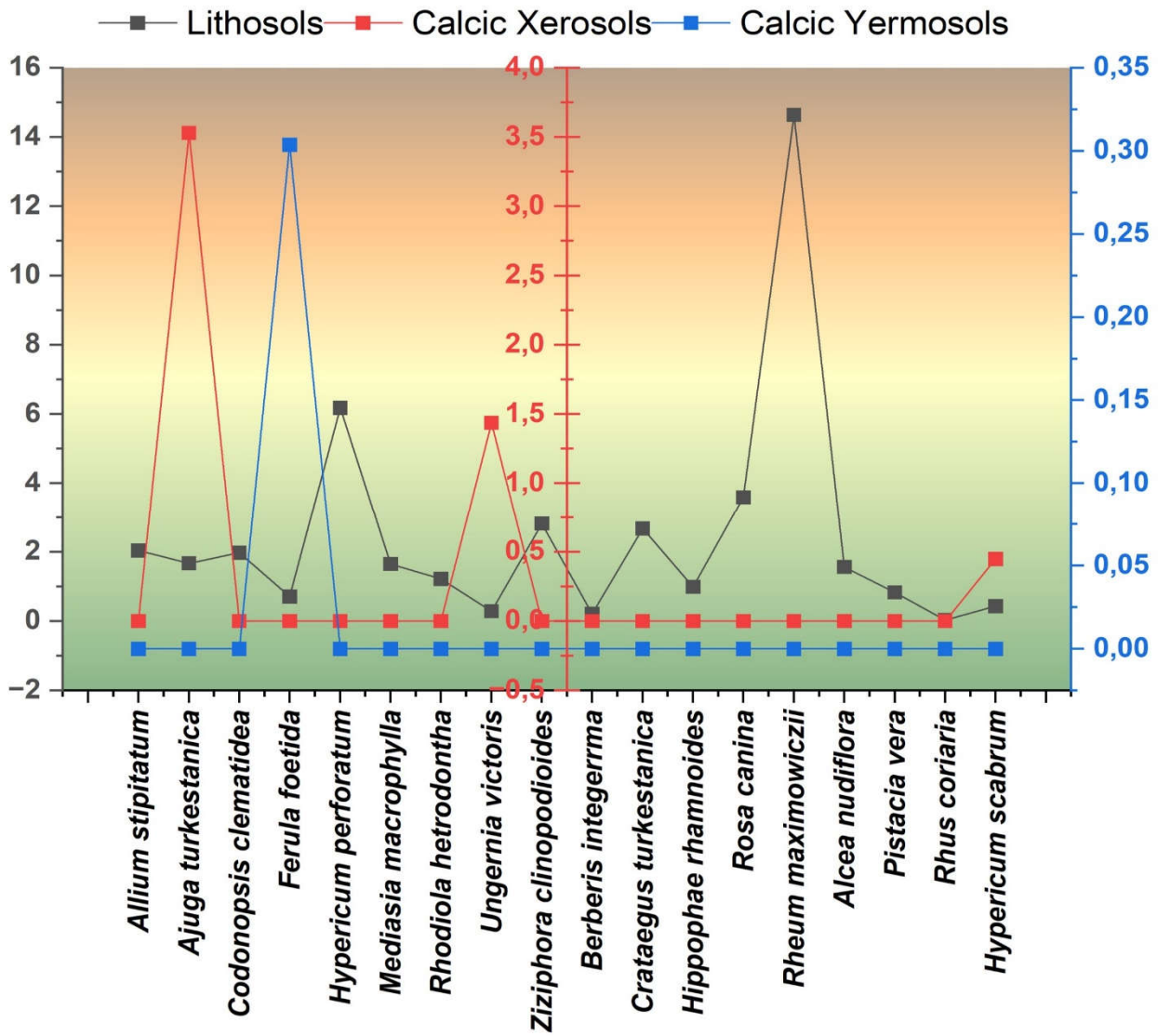


**Figure 9.** Comparative Analysis of the Resource Potential of Medicinal Plants on Different Soil Types

The results confirm the significant role of edaphic factors in the formation and spatial distribution of the resource potential of medicinal plants. Considering these factors is essential for developing sustainable natural resource management strategies, planning harvests, and exploring the potential cultivation of promising wild species.

## Conclusions

The assessment of the resource potential of medicinal plant species in the Kashkadarya and Surkhandarya regions revealed notable interregional differences in both the extent of distribution and the volume of natural reserves. These variations are primarily attributed to species-specific ecological characteristics and the diverse soil-climatic conditions of the respective regions.

Species classified in the first category are predominantly associated with Lithosol soils, characterized by shallow, stony profiles. An exception is *Ferula foetida*, which demonstrates adaptation to carbonate-rich soils, particularly Calcic

Xerosols and Calcic Yermosols—soil types commonly found in arid and semi-arid landscapes with high calcium carbonate content.

In the Surkhandarya region, high edaphic plasticity was recorded in species such as *Ajuga turkestanica*, *Hypericum perforatum*, and *Hypericum scabrum*, all of which demonstrate the ability to establish and develop on Calcic Xerosols, indicating a broad ecological tolerance to soil conditions.

The study highlights the critical role of edaphic factors in determining the distribution and productivity of medicinal plant resources. As such, these factors must be integrated into strategies for sustainable resource management, particularly in determining optimal harvest zones and planning conservation interventions.

Species with a broad ecological amplitude, such as *Ungenia victoris* and *Ajuga turkestanica*, are of particular interest for further phytogeographic studies, domestication potential, and ex-situ cultivation, due to their adaptability across varying edaphic and climatic conditions.

Conversely, species with limited geographic distribution and protected status, including *Rhus coriaria* and *Ungenia victoris*, require strictly regulated harvesting protocols to ensure the preservation of natural populations and prevent genetic erosion, thereby maintaining the regional phytodiversity.

In conclusion, the effective management and conservation of medicinal plant resources in southern Uzbekistan necessitate a comprehensive approach, incorporating biological, ecological, and territorial parameters. Such integration will facilitate the rational use of natural resources and support the long-term conservation of biodiversity in the region.

**Acknowledgments**

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