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Traditional medicinal plant knowledge under anthropogenic pressure: evidence from the Middle Syrdarya botanical-geographical district, Uzbekistan

Z.Z. Kosimov, Rainer W. Bussmann, N.Yu. Beshko, N.M. Naraliyeva, U.E. Khujanazarov, M.A. Mirzoyeva, S.U. Kuzieva

Correspondence

Z.Z. Kosimov[1*], Rainer W. Bussmann[2,3] N.Yu. Beshko[1], N.M. Naraliyeva[4], U.E. Khujanazarov[5], M.A. Mirzoyeva[6], S.U. Kuzieva[7]

[1]Institute of Botany of Uzbek Academy of Sciences, 100125, Durmon Yuli, st. 32, Tashkent, Uzbekistan
[2]Department of Botany, State Museum of Natural History, 76133 Karlsruhe, Germany
[3]Department of Ethnobotany, Institute of Botany, Ilia State University, 0105 Tbilisi, Georgia.
[4]Department of Ecology and Sustainable Development, Andijan State University, 170100, Andijan, Uzbekistan.
[5]Department of Botany, National Pedagogical University of Uzbekistan named after Nizami, Tashkent, Uzbekistan.
[6]Department of Medical biolology, Bukhara State Medical Institute named after Abu Ali ibn Sino, Bukhara, Uzbekistan.
[7]Department Jizzakh State Pedagogical University, 130100, Jizzakh city, Sh. Rashidov street.

*Corresponding Author: zikirmagistr@mail.ru

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Research

Abstract

Background: Strong anthropogenic transformation in semi-arid regions substantially alters native vegetation and threatens traditional medicinal plant knowledge. The Middle Syrdarya botanical-geographical district represents one of the most intensively modified landscapes in Central Asia, where natural ecosystems have largely been replaced by agroecosystems. Integrated assessments are therefore required to evaluate medicinal plant diversity, adventive components, and the persistence of ethnobotanical knowledge under such conditions.

Methods: Field surveys were conducted between 2021 and 2025 across major landscape types of the Middle Syrdarya region. Medicinal plant species were recorded using floristic inventories, herbarium collections, and semi-structured interviews with local informants. Taxonomic composition, functional use categories, and adventive status were analyzed. The proportion of adventive species was applied as an indicator of floristic transformation, and functional traits were evaluated to assess ecosystem-related services of medicinal plants.

Results: A total of 245 medicinal plant species belonging to 158 genera and 47 families were documented. Asteraceae (49 species), Fabaceae (19), and Lamiaceae (17) were the most species-rich families. Fifty-six species (22.9%) were identified as adventive, indicating pronounced anthropogenic influence on regional flora. Adventive representation was highest in Solanaceae (71.4%) and Malvaceae (54.5%), while no adventive medicinal species were recorded in Polygonaceae. Functional analysis revealed dominance of weed and melliferous species, suggesting that medicinal resources are increasingly derived

from secondary and agroecosystems. Traditional knowledge was found to be reorganized around ecologically plastic and widespread species, whereas narrowly adapted aboriginal taxa are gradually disappearing from local practice.

Conclusions: The high proportion of adventive medicinal plants reflects reduced ecosystem stability and ongoing floristic restructuring in the Middle Syrdarya region. Medicinal plants and associated traditional knowledge act as sensitive bioindicators of anthropogenic transformation. These findings provide a scientific basis for monitoring, conservation prioritization, and sustainable management of medicinal plant resources in transformed semi-arid landscapes.

Keywords: Ethnobotany; medicinal plants; anthropogenic transformation; adventive species; traditional knowledge; ecosystem resilience; land-use change; Middle Syrdarya region; Uzbekistan

Background

In recent decades, increasing anthropogenic pressures have caused substantial changes in the structure and functional composition of natural ecosystems (Allan *et al.* 2015). In arid and semi-arid regions, irrigation-driven land reclamation, intensive agriculture, urbanization, and infrastructure expansion have led to landscape fragmentation, transformation of aboriginal floristic components, and an increasing dominance of synanthropic elements (Qosimov 2025). These processes are also evident at the global scale, accompanied by the decline of traditional cultural landscapes and functional simplification of ecosystems (Zerbe 2022). Under such conditions, biodiversity assessment requires an integrated socio-ecological perspective rather than a purely taxonomic approach.

Central Asia, particularly Uzbekistan, represents one of the regions experiencing high levels of anthropogenic pressure (Reyer *et al.* 2017). The Middle Syrdarya botanical–geographical district is a transitional zone within the Turanian province, located between the Western Tien Shan and Pamir-Alay mountain systems and the Kyzylkum Desert (Tojibaev *et al.* 2017). Since the second half of the twentieth century, large-scale irrigation and agricultural development in the Mirzachul area have converted natural desert and semi-desert landscapes into agroecosystems (Tojibaev *et al.* 2017). Consequently, the balance between aboriginal and adventive floristic fractions has shifted, the extent of natural phytocenoses has decreased, and ruderal components have intensified (Mavlonov 2019).

Under such strong transformation, evaluating the status of medicinal plants and the persistence of associated traditional knowledge is of particular scientific importance (Qosimov 2025). In degraded landscapes, biodiversity loss is often accompanied by changes in the spectrum of plant species utilized by local communities (Khojimatov *et al.* 2025). At the same time, certain functionally important species with high ecological plasticity may persist under anthropogenic conditions. These dynamic highlights the need to analyze the complex relationships between ecosystem stability and traditional ethnobotanical knowledge.

Although floristic and taxonomic studies have been conducted in the Middle Syrdarya botanical–geographical district, traditional medicinal plant knowledge and its role under anthropogenic transformation have not yet been comprehensively addressed from a socio-ecological perspective (Qosimov 2025). In particular, structural and functional changes in medicinal plant resources associated with the expansion of adventive fractions require targeted investigation.

Therefore, the present study aims to assess traditional medicinal plant knowledge in the Middle Syrdarya region under strong anthropogenic pressure, quantify the contribution of adventive species within regional flora, and evaluate their relationship to ecosystem stability. The findings provide a scientific basis for monitoring and conservation strategies of medicinal plant resources in transformed semi-arid landscapes.

Materials and Methods

Study area

The Middle Syrdarya botanical-geographical district is a transitional zone within the Turanian floristic province, extending along the middle course of the Syrdarya River (Tojibaev *et al.* 2017). The district is bordered by the Tien Shan Mountains to the north, the Pamir–Alay ranges to the south, the Fergana Valley to the east, and the Kyzylkum Desert together with the Aydar-Arnasay lake system to the west. According to the botanical–geographical regionalization of Uzbekistan, the district comprises the Chinaz and Mirzachul subregions (Fig. 1) (Tojibaev 2010).

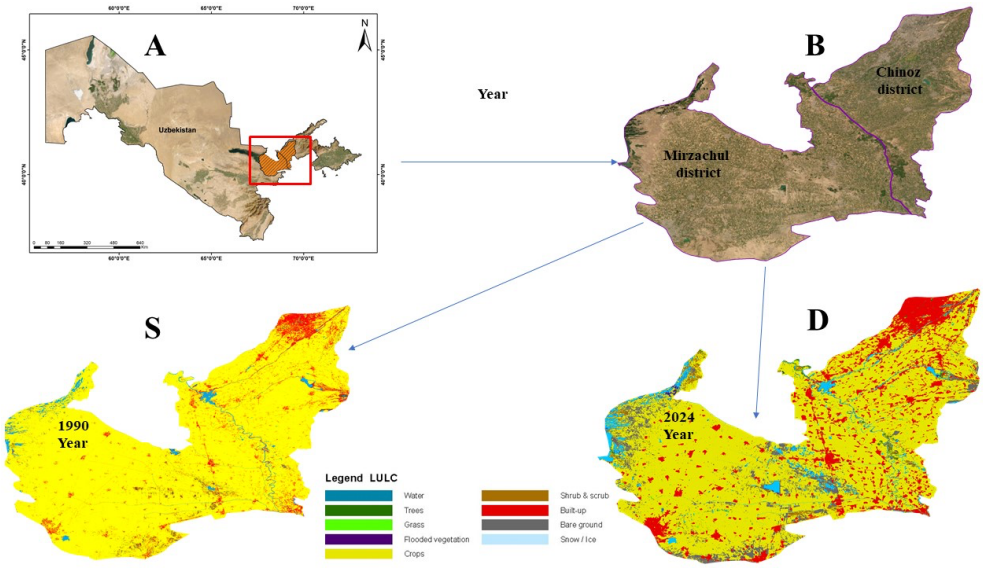

Figure 1. Location of the Middle Syrdarya Botanical–Geographical District within Uzbekistan (A), administrative boundaries of the study area (B), and land use/land cover (LULC) patterns in 1990 (S) and 2024 (D). The comparison illustrates the expansion of built-up areas, croplands, and anthropogenically transformed landscapes over the past three decades.

The region belongs to a continental semi-arid climatic zone, characterized by hot and dry summers and relatively mild winters. Mean January temperatures range from 0 to –1 °C, while July averages reach +24 to +28 °C. Annual precipitation varies between 250 and 300 mm in lowland areas and exceeds 400 mm in the Tashkent oasis (Tojibaev 2010). The soil cover is represented by irrigated light and typical sierozems, sandy desert soils, solonchaks, and alluvial meadow-marsh soils (Tojibaev 2010).

Geomorphologically, the area consists of piedmont proluvial and alluvial plains, river terraces along the Syrdarya valley, sandy and saline desert landscapes, and wet meadow ecosystems (Qosimov 2025). The southern part includes the foothills of the Turkestan, Molguzar, and Nurata ranges, where erosion-denudation piedmont landscapes are developed. Historically, the district was characterized by desert and semi-desert plant communities typical of the Turanian province, including ephemeral-ephemeroid, halophytic, psammophytic, and tugai vegetation.

Since the second half of the twentieth century, large-scale irrigation and agricultural development in the Mirzachul area have transformed most natural landscapes into agroecosystems (Sulaymonov *et al.* 2015). Cotton and wheat fields, orchards, vineyards, and settlements expanded rapidly. As a result, the aboriginal floristic component declined, synanthropic and adventive species increased, and natural vegetation cover became highly fragmented (Qosimov 2025).

Administratively, the Middle Syrdarya district includes the entire Syrdarya Province, the Arnasay, Dostlik, Zafarobod, Zarbdor, Mirzachul, and Pakhtakor districts of Jizzakh Province, as well as the Oqqurgon, Bekobod, Buka, Chinaz, Yangiyol, O‘rta Chirchiq, and Quyi Chirchiq districts of Tashkent Province. In addition, adjacent areas of Turkistan Province in Kazakhstan are also included within the district boundaries (Qosimov 2025).

This region represents one of Central Asia’s oldest agricultural landscapes, shaped by intensive human activity over extended historical periods. Consequently, the Middle Syrdarya botanical-geographical district currently serves as an important model area for investigating medicinal plant resources and associated traditional knowledge within strongly anthropogenically transformed semi-arid landscapes.

Field surveys and floristic sampling

Field investigations were conducted between 2021 and 2025 throughout the Middle Syrdarya botanical-geographical district. Floristic data were collected using route-based and semi-stationary survey methods. All major natural and anthropogenic landscape types were covered, including irrigated agroecosystems, desert and semi-desert areas, river valleys, piedmont plains, and tugai ecosystems.

At each sampling site, vascular plant species were recorded, and more than 2,000 herbarium specimens were collected and deposited in the National Herbarium of Uzbekistan (TASH). Species identification was performed using regional floras and

contemporary taxonomic references. Digital images of selected specimens were uploaded to the Global Biodiversity Information Facility (GBIF).

Collection of ethnobotanical data

Traditional knowledge related to medicinal plants was documented through semi-structured interviews with local inhabitants. Information recorded during interviews included local plant names, utilized organs, application categories, preparation methods, and frequency of use. Interviews were conducted with prior oral informed consent, and informants primarily consisted of rural residents, livestock keepers, and traditional healers (Martin 1995).

Data analysis

The relative importance of medicinal plants was assessed using the Ethnobotanical Value Index (EVI) and associated use indicators. The degree of anthropogenic transformation of regional flora was evaluated based on the proportion of adventive species and the Adventization Index (AI). Comparative analyses were conducted between aboriginal and adventive components to assess differences in taxonomic composition.

In selected cases, floristic similarity among sites was calculated using the Jaccard coefficient (Martin 1995; Khojimatov *et al.* 2025).

Cartographic and statistical processing

Spatial visualization and mapping of the study area were performed using GIS technologies. Statistical analyses were applied to summarize species richness, medicinal plant proportions, and adventive components. Results are presented in tables and graphical formats.

Results

Diversity and taxonomic composition of medicinal plants

A total of 245 medicinal plant species were recorded in the Middle Syrdarya botanical–geographical district, belonging to 158 genera and 47 families. The leading families in terms of species richness and their relative contributions to the medicinal flora are presented in Table 1, with Asteraceae, Fabaceae, and Lamiaceae representing the dominant taxonomic groups.

Table 1. Distribution of medicinal plant species by family (Top–10 families).

Family	Number of species
Asteraceae	49
Fabaceae	19
Lamiaceae	17
Polygonaceae	15
Apiaceae	12
Amaranthaceae	12
Malvaceae	11
Brassicaceae	10
Poaceae	8
Solanaceae	7

The results show that Asteraceae (49 species), Fabaceae (19), and Lamiaceae (17) occupy leading positions within the medicinal flora. Polygonaceae (15 species), Apiaceae and Amaranthaceae (12 species each), and Malvaceae (11 species) also constitute major components of the regional taxonomic core. The dominance of these families confirms general floristic patterns typical of the lowland regions of Central Uzbekistan and reflects the higher persistence of ecologically plastic groups within anthropogenically modified landscapes.

Overall, although the medicinal flora exhibits considerable taxonomic diversity, its core is dominated by families characterized by high ecological plasticity, highlighting the adaptive restructuring of floristic assemblages under anthropogenic pressure.

To visualize the proportion of medicinal and adventive species within dominant families, the taxonomic structure was illustrated graphically (Fig. 2). This approach enables assessment of both quantitative and structural characteristics of the medicinal flora.

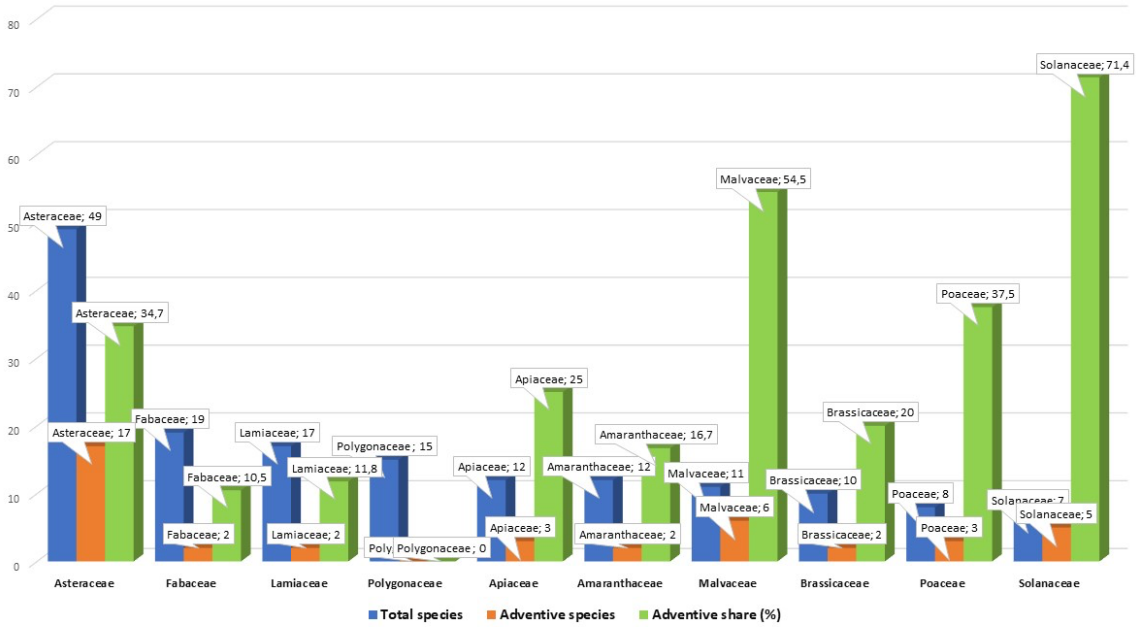

Figure 2. Top ten plant families ranked by medicinal species richness in the Middle Syrdarya Botanical-Geographical District. Blue bars represent the total number of medicinal species, orange bars indicate the number of adventive species, and green bars show the proportion of adventive taxa (%). The figure highlights the taxonomic concentration of medicinal flora and the varying contribution of adventive species across dominant families.

Functional use-group analysis of medicinal species allowed identification of the prevailing ecological–economic categories under anthropogenic transformation (Fig. 3). The high representation of weed and melliferous species indicates strong adaptation of regional flora to disturbed environments. A total of 81 species were recorded as fodder plants, 57 as ornamental, 47 as essential oil–bearing, and 47 as food plants. These findings demonstrate that the medicinal plant fraction is not limited to therapeutic applications but is closely linked to ecosystem services and economic functions.

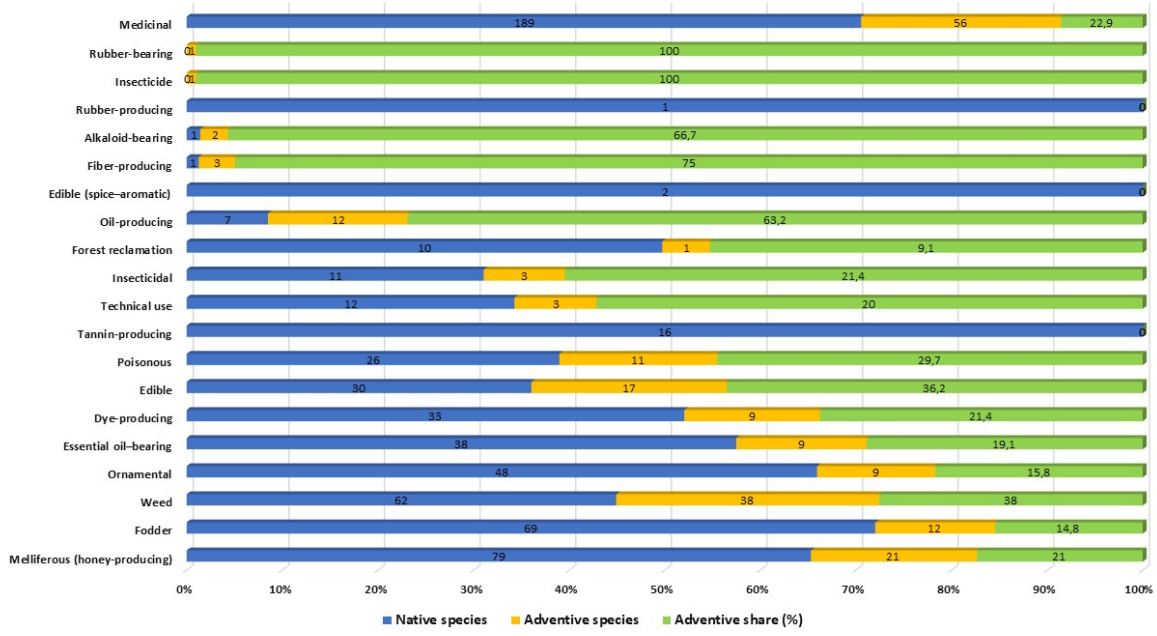

Figure 3. Distribution of functional traits among medicinal plant species, showing the number of native and adventive taxa and the percentage share of adventive species within each functional category. The diagram illustrates the relationship between ethnobotanical use categories (e.g., fodder, melliferous, edible, weed) and the relative contribution of adventive elements under anthropogenic landscape transformation.

Adventive medicinal species and floristic transformation

To evaluate the distribution of the adventive component within dominant families, a comparative analysis was conducted (Table 2). Of the 245 medicinal plant species recorded in the study area, 56 were identified as adventive, representing 22.9% of the total medicinal flora.

Table 2. Distribution and proportion of adventive medicinal species across dominant plant families.

Family	Total medicinal species	Adventive species	Adventive share (%)
Solanaceae	7	5	71.4
Malvaceae	11	6	54.5
Poaceae	8	3	37.5
Asteraceae	49	17	34.7
Apiaceae	12	3	25.0
Polygonaceae	15	0	0

The distribution of adventive species across families was markedly uneven. Solanaceae exhibited the highest proportion of adventive taxa (71.4%), indicating a strong association of this family with anthropogenically disturbed environments. Malvaceae (54.5%) and Asteraceae (34.7%) also showed substantial adventive representation. In contrast, no adventive medicinal species were recorded within Polygonaceae. The absence of adventive taxa in Polygonaceae suggests a relatively high ecological resistance of this group to anthropogenic transformation, allowing it to be interpreted as an important aboriginal indicator family within the region.

Adventive species were predominantly represented by fast-growing, ecologically plastic taxa adapted to agrocenoses and synanthropic habitats. Most exhibited ruderal characteristics, reflecting the increasing dominance of anthropogenic elements within the medicinal flora.

The overall adventive proportion (22.9%) is directly linked to the fragmentation of natural phytocenoses, expansion of irrigated agriculture, and development of secondary landscapes surrounding transport networks and settlements. In this context, the adventive component of the medicinal flora can be interpreted as a sensitive indicator of the degree of anthropogenic transformation.

Collectively, these findings highlight two key aspects of the regional medicinal flora: (1) its considerable taxonomic diversity structured around dominant families, and (2) the ongoing structural reorganization of this assemblage under anthropogenic pressure, as evidenced by the substantial adventive fraction.

Ecosystem stability and adaptation of traditional medicinal knowledge

The results demonstrate that traditional medicinal knowledge is increasingly structured around ecologically plastic and widely distributed species such as *Glycyrrhiza glabra, Plantago major, Taraxacum officinale, Artemisia vulgaris*, and *Mentha arvensis*. Conversely, aboriginal species with narrow ecological amplitudes are gradually disappearing from local ethnomedicinal practice.

The high proportion of adventive species further supports the interpretation of reduced ecosystem stability within the region. As illustrated in Fig. 1, medicinal plant occurrences are concentrated primarily within irrigated agroecosystems, river valleys, and secondary landscapes, indicating a spatial shift of medicinal resources toward anthropogenically modified habitats.

Discussion

Comparative analysis of land-use and land-cover (LULC) maps for 1990 and 2024 reveals pronounced structural changes across landscapes of the Middle Syrdarya botanical-geographical district. Visual interpretation indicates a substantial expansion of irrigated croplands and settlements, accompanied by progressive fragmentation and reduction of natural vegetation cover. In particular, semi-natural phytocenoses that were formerly continuous in the Mirzachul and Chinaz areas have been largely replaced by irrigated agroecosystems and urbanized surfaces.

These transformations reflect decades of land reclamation, irrigation development, and settlement expansion, resulting in the conversion of original desert and steppe ecosystems into highly anthropogenically modified agrolandscapes. The current

spatial configuration is dominated by mosaics of croplands, ruderal vegetation, and artificial surfaces, while remnants of natural habitats persist mainly along waterways and in peripheral zones.

Such landscape dynamics provide an essential ecological context for the floristic patterns observed in this study, particularly the high proportion of adventive medicinal species and the dominance of ecologically plastic taxa. LULC dynamics thus serve as visual evidence of anthropogenic pressure and highlight land-use change as a primary driver of ecosystem simplification and biocultural restructuring within the region.

Our results demonstrate that medicinal plant flora in the Middle Syrdarya district is shaped under intense anthropogenic transformation. Nearly one quarter (22.9%) of the 245 recorded medicinal species are of adventive origin, indicating substantial restructuring of floristic composition. This pattern is closely linked to fragmentation of natural phytocenoses, expansion of irrigated agriculture, and formation of secondary landscapes around settlements and transport corridors.

The dominance of ecologically plastic families such as Asteraceae, Fabaceae, and Lamiaceae reflects floristic trends typical of Central Uzbekistan lowlands. Particularly high adventive representation within Asteraceae (34.7%) underscores the increasing importance of ruderal and agro-adapted taxa. Even more pronounced adventive dominance in Solanaceae and Malvaceae suggests progressive simplification of the floristic core under sustained anthropogenic pressure.

Although traditional medicinal knowledge persists within the region, its composition has undergone substantial transformation. Local communities increasingly rely on resilient, fast-recovering, and widely distributed species. This shift can be interpreted as adaptive reorganization of traditional knowledge in response to degraded landscapes. Conversely, aboriginal medicinal species with narrow ecological amplitudes are gradually disappearing from practical use, increasing the risk of simultaneous biological and cultural erosion.

Compared with previous studies from the Nurata Range and Western Tien Shan, the Middle Syrdarya region exhibits markedly higher proportions of adventive medicinal plants (Kosimov *et al.* 2026). While mountainous areas retain relatively intact natural phytocenoses that support aboriginal floristic dominance, irrigated lowland landscapes of Middle Syrdarya accelerate floristic homogenization.

From this perspective, medicinal plants represent not only biological resources but also sensitive bioindicators of ecosystem condition. Rising adventive proportions signal declining ecosystem stability, whereas structural changes in traditional knowledge reflect adaptive shifts in human–nature interactions under novel ecological realities.

Overall, medicinal plants and associated ethnobotanical knowledge in the Middle Syrdarya botanical-geographical district form a complex social-ecological system undergoing continuous restructuring under anthropogenic transformation. These findings emphasize the urgent need for sustainable resource-use strategies, prioritization of aboriginal taxa, and systematic documentation of local knowledge.

In conclusion, medicinal plant assemblages in the Middle Syrdarya region are tightly linked to land-use dynamics, with increasing adventive components and dominance of ecologically plastic species reflecting ongoing ecosystem simplification. These trends further indicate parallel transformations in traditional knowledge systems.

Conclusion

This study highlights the current status of medicinal plant flora and the adaptive dynamics of associated traditional knowledge under strong anthropogenic transformation in the Middle Syrdarya botanical-geographical district. Although the documentation of 245 medicinal plant species indicates that floristic diversity has not yet been completely eroded, a substantial proportion of these species now consists of synanthropic and agro-adapted taxa characterized by high ecological plasticity.

The adventive component, accounting for 22.9% of the medicinal flora, represents a sensitive bioindicator of declining ecosystem stability and is directly linked to fragmentation of natural phytocenoses and shifts in land-use regimes. Uneven distribution of adventive species among dominant families demonstrates that floristic transformation proceeds differentially across taxonomic groups, while the absence of adventive taxa within Polygonaceae confirms the comparatively high ecological resistance of this family.

Our findings further indicate that traditional medicinal knowledge is increasingly reorganized around species with broad ecological amplitudes that persist within secondary phytocenoses, whereas aboriginal taxa with narrow ecological requirements are gradually disappearing from local practice. This trend amplifies the risk of simultaneous biological and cultural erosion.

Overall, medicinal plants and associated ethnobotanical knowledge can serve as integrated indicators of ecosystem condition in the Middle Syrdarya region. The results provide a scientific foundation for developing regional management strategies focused on monitoring medicinal plant resources, conserving aboriginal species, and safeguarding traditional knowledge in degraded semi-arid landscapes.

Declarations

Ethics approval and consent to participate: Ethnobotanical data collection and processing were conducted in accordance with internationally accepted ethical guidelines for ethnobotanical research (Martin 1995). All interviews were carried out with prior oral informed consent of participants. Information obtained from local communities was anonymized, aggregated, and used exclusively for scientific purposes.

Consent for publication: No additional individual consent is required for publication of the data presented in this manuscript.

Availability of data and materials: The ethnobotanical datasets generated during this study are retained by the authors and are available upon reasonable scientific request.

Competing interests: The authors declare that they have no competing interests.

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Authors’ contributions: All authors equally contributed to study design, field investigations, data analysis, and manuscript preparation. All authors read and approved the final version of the manuscript.

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