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Current State of Natural Resources of *Alhagi pseudalhagi* L. in Navoi Region, Uzbekistan

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Abstract

The efficient use of medicinal plant resources plays a crucial role in ensuring long-term economic development. The sustainable management of these resources directly contributes to creating new jobs in the regions, improving the social well-being of the population, and preserving biodiversity. Medicinal plants are widely used across all cultures in various forms, contexts, and applications to maintain and enhance physical, mental, and spiritual health. In this study, the natural resources, distribution, productivity, and biological and exploitable reserves of the *Alhagi pseudalhagi* species in the Navoi region were evaluated using a comprehensive botanical-resource assessment approach. Field research determined the species' natural growth areas, biological reserves, exploitable reserves, and the volume of raw material that can be harvested annually on a sustainable basis. The results obtained serve as a scientific basis for the rational and sustainable use of *A. pseudalhagi* resources, the determination of optimal harvest yield, and the conservation of natural populations.

Keywords

Alhagi pseudalhagi, Medicinal Plants, Biological Reserve, Exploitable Reserve, Annual Harvestable Yield, Navoi Region, Uzbekistan

1. Introduction

Medicinal plants are a vital natural resource worldwide for the production of various herbal preparations and products. Globally, nearly 80% of the population continues to rely on plant-based remedies or medicinal plants for primary

healthcare [1]. Bioactive compounds contribute to various therapeutic effects including wound healing, anti-inflammatory, antimicrobial, and antioxidant activities [2] [3].

However, many medicinal plant species are declining rapidly due to overharvesting and the destruction of their natural habitats [4]. It is estimated that there are between 50,000 and 80,000 flowering plant species used for medicinal purposes globally, with approximately 15,000 of them at risk of extinction [5].

In rural areas, wild edible plants serve as a source of daily food and home remedies, as well as a vital supplementary resource during times of food scarcity, illness, or economic hardship. Consequently, their significance is not merely ecological but also social, linking biodiversity, community resilience, and systems of local traditional knowledge. This multifaceted importance is increasingly recognized internationally, with wild food plants being identified as key factors in establishing sustainable, resilient food systems and ensuring human well-being [6]-[8].

One such medicinal plant is *Alhagi pseudalhagi*, a perennial shrub belonging to the family Fabaceae. The family Fabaceae is one of the largest families of flowering plants, comprising more than 760 genera and approximately 19,500 species [9] [10]. The genus *Alhagi* Gagnebin (Fabaceae) is widely distributed from North Africa and the eastern Mediterranean through the Middle East to Central Asia [11] [12]. Species of *Alhagi* are predominantly associated with arid and semi-arid environments, particularly desert and semi-desert habitats characterized by saline, rocky and stressful soils and its natural distribution was extended by man [13]-[15].

The genus *Alhagi* Tourn. ex Gagnebin comprises four accepted species: *Alhagi brevispina* Maire, *Alhagi graecorum* Boiss., *Alhagi maurorum* Medik., and *Alhagi pseudalhagi* (M.Bieb.) Desv. ex Wangerin [16].

A key biological characteristic of the plant *Alhagi pseudalhagi* is its deep root system, which enables it to survive even in drought conditions. In desert ecosystems, *A. pseudalhagi* contributes to soil and sand stabilization, thereby helping to reduce wind erosion. Its dense and thorny above-ground structures have also been traditionally used by local communities as protective barriers around cultivated fields against drifting sand and wind [17] [18]. It serves not only to stabilize the soil within the ecosystem but also as an important plant with significant medicinal properties [19].

A. pseudalhagi is used in both clinical and folk medicine to treat disorders of the gastrointestinal tract, genitourinary system, and liver, as well as colds and rheumatism. It serves as a choleretic, diuretic, and body-cleansing agent in the treatment of liver diseases and gastric ulcers. When applied externally, a decoction of the plant aids in wound healing [20] [21].

The medicinal and economic significance of *A. pseudalhagi* further heightens interest in studying its natural resources. In addition to being used for various purposes in folk medicine, this species is also important as a forage plant in live-

stock farming.

There are a number of studies that have assessed the population status and resource potential of *A. pseudalhagi* in other arid regions of Central Asia. For example, Sagyndykova *et al.* (2024) investigated four populations of *A. pseudalhagi* in the Atyrau Region of Western Kazakhstan. The study evaluated botanical characteristics, ontogenetic spectra, morphological traits, productivity, thicket areas, and reserves of above-ground medicinal raw material. The study emphasized the importance of regular monitoring of natural populations and the development of scientifically based harvesting regimes to ensure the sustainable utilization and conservation of *A. pseudalhagi* [22].

Similar resource assessments are particularly important for arid regions, where environmental constraints and increasing anthropogenic pressures may strongly influence the structure, productivity, and regenerative capacity of natural plant populations. A large proportion of Navoi Region is occupied by desert and other arid landscapes, providing suitable ecological conditions for the formation and persistence of natural populations of *A. pseudalhagi*. However, intensive land use, livestock grazing pressure, water scarcity, climate change, and other anthropogenic factors negatively affecting the condition and resource potential of this species. These pressures may result in changes in its spatial distribution, population structure, productivity, and natural reserves across different habitats.

Despite the ecological and medicinal importance of *A. pseudalhagi* and the availability of resource assessments from other parts of its distribution range, region-specific information on its population structure, biological reserves, exploitable reserves, and overall resource potential in the arid ecosystems of Uzbekistan remains limited, particularly in Navoi Region. Therefore, assessing the current state and resource potential of natural populations of *A. pseudalhagi* in Navoi Region is of considerable scientific and practical importance. Such assessments provide a scientific basis for the rational use of natural plant resources, maintenance of their natural regenerative capacity, and development of sustainable harvesting and conservation strategies. This study aimed to assess the biological and exploitable reserves, and resource potential of *A. pseudalhagi* in different habitats of Navoi Region and to develop recommendations for its sustainable utilization and conservation.

2. Research Methods

Research on the natural distribution, raw material resources, biological reserves, and exploitable reserves of *A. pseudalhagi* in Navoi Region was conducted using established resource-science and geobotanical approaches, including methods by Smirnova, Elzinga and etc. [23] [24].

A total of 12 cenopopulations of *A. pseudalhagi* were randomly selected from areas within the species' natural distribution range across five districts of Navoi Region. Within each selected cenopopulation, ten sampling plots measuring 100 m^2 (10 × 10 m) were selected using simple random sampling, resulting in 120

sampling plots across the study area. Data collected from these plots included the total number of plants, the number of plants suitable for raw material harvesting, the fresh and dry mass of model plants, and the productivity of the area. Based on the obtained data, the resource potential of the species' natural populations was assessed.

Productivity (P)

The productivity was calculated using the mean dry biomass per plant and number of plants recorded in each 100 m^2 sampling plot:

$$P = N * W/10$$

where (P) is dry biomass productivity (kg/ha), (N) is the number of plants per 100 m^2, and (W) is the mean dry biomass per plant(gr). The factor 10 converts biomass expressed in grams per 100 m^2 to kilograms per hectare.

Biological reserve (BR)

The biological reserve was calculated by multiplying dry biomass productivity by the reserve-valued field area:

$$\mathrm{BR} = P * A/1000$$

where (BR) is the biological reserve (t), (P) is dry biomass productivity (kg/ha), and (A) is the reserve-valued field area (ha). The factor 1000 converts kilograms to tonnes.

The exploitable reserves were subsequently estimated at 50% of the biological reserves, following the resource-assessment guidelines for herbaceous plants harvested for their above-ground parts by Minarchenko *et al.* (2019) [25]. The annual allowable harvest was estimated by dividing the exploitable reserve by the recovery period. Based on Pupykina *et al.* (2019) two-year recovery period for *A. pseudalhagi*, the annual allowable harvest was also, calculated as half of the exploitable reserve [26].

Spatial visualization and mapping of *A. pseudalhagi* distribution areas were carried out using QGIS 3.44.4 software. The geographic coordinates of locations identified during field research were recorded using MAPS.ME software.

The relationship between the fresh and dry biomass of the plant was evaluated using correlation-regression analysis.

Principal component analysis (PCA) was performed to assess variation among the 12 *Alhagi pseudalhagi* cenopopulations using six variables: species distribution area (SDA, ha), reserve-valued field area (RVF, ha), plant density (number of individuals per 100 m^2), fresh biomass (FB, g), dry biomass (DB, g), and altitude (m a.s.l.). All variables were centered and standardized to unit variance using z-score transformation before PCA.

For hierarchical cluster analysis, also six resource-related variables were used: SDA, RVF, plant density, FB, DB, and biological reserve (BR, t). The variables were rescaled to the range 0 - 1 using min-max normalization. Euclidean distances were calculated, and clusters were formed using Ward's minimum-variance method (Ward.D2). The number of clusters was evaluated using average silhouette widths

for solutions containing two to six clusters. The two-cluster solution had the highest average silhouette width among the evaluated solutions, yielding Cluster I (CP6 - CP11) and Cluster II (CP1 - CP5 and CP12).

Statistical analysis and data visualization were performed in the R Studio environment using R version 4.3.2.

Study Area

The study was conducted in the natural habitats of *A. pseudalhagi* in Navoi Region, Uzbekistan. The study area covered the Tamdy, Uchquduq, Navbahor, Kanimekh, and Nurata districts. Navoi Region is located in the central part of Uzbekistan and is characterized by considerable landscape and ecological diversity.

The territory of Navoi Region is characterized by a sharply continental arid climate, with hot and dry summers and moderately cold winters accompanied by moderate frosts. The mean January temperature ranges from 0˚C in the southern part of the region to −6˚C in the north, while the mean July temperature reaches +28˚C - 30˚C. The annual mean air temperature is approximately +13˚C in the northern part of the region (Uchquduq) and +15.6˚C in the south (Navoi). Annual precipitation varies from approximately 121 mm in Uchquduq and even lower values in the northern desert areas to about 338 mm in the south, particularly in the Zarafshan Valley [27]. From a botanical-geographical perspective, Navoi Region encompasses areas of the Kyzylkum Desert and the Nurata mountain range. Over 60% of Central Asia is defined as arid and semi-arid areas, and they are an important dust source region of the world and contributes about 17% - 20% to global dust emissions [28]-[30]. These dryland areas appear to provide massive mineral dust emissions and significantly influence the ambient atmospheric environment and human activities [31].

Topography in the desert consists mainly of plains, also partly lowlands, hills, a series of enclosed basins and isolated mountains, including Bukantau Mountain, Tamdytau Mountain and Nurata Range [32]. The combination of desert, foothill, and mountainous landscapes contributes to considerable variation in the distribution, abundance, population structure, and ecological characteristics of plant species throughout the region. The study area is characterized by the widespread presence of natural pastures and varying degrees of anthropogenic impact. In particular, the impact of livestock grazing on vegetation cover is evident in certain areas. Such ecological and anthropogenic factors play a significant role in influencing the population structure, regeneration potential, biomass productivity, and both biological and exploitable reserves of wild plants (**Figure 1**).

Central Asia is an important region rich in wild plant resources, where applied research is being conducted to support their assessment, conservation, and sustainable use [33]-[38]. The findings provide a scientific basis for determining the distribution [35] [39]-[42] and natural stocks of economically valuable plant species and developing measures for their conservation and sustainable utilization [43]-[46].

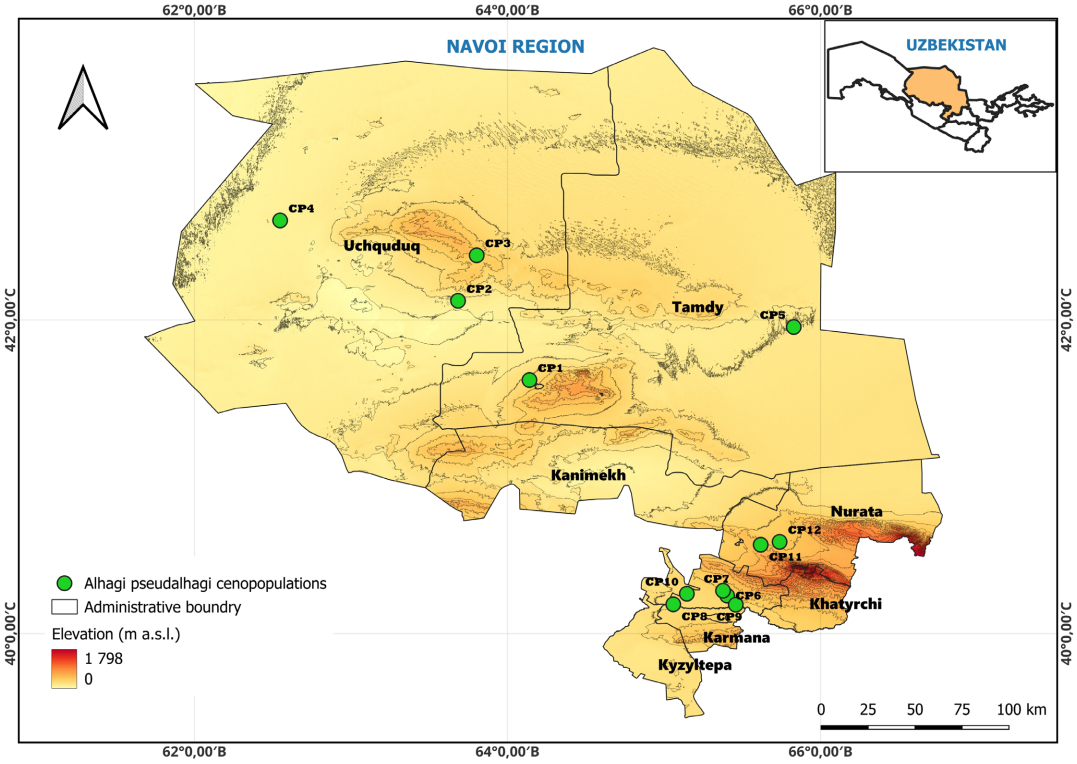


Figure 1. Study area.

3. Results

A total of 12 monitoring sites were selected in five districts of Navoi Region to assess the natural raw material resources of *A. pseudalhagi*. At each site, ten replicate sampling plots, each measuring 100 m^2 (n = 10), were established. The study assessed the total number of plant individuals, the number of harvestable individuals, the harvesting rate per plot, biomass productivity, biological and exploitable reserves, and the annual amount of raw material available for harvesting.

The results showed considerable variation in the natural resource indicators of *A. pseudalhagi* among the studied areas. The total area covered by the surveyed sites was 219 ha, of which 103 ha represented the reserve-valued field. Within the 100 m^2 sampling plots, the total number of plant plants ranged from 14 to 33.

Fresh and dry biomass also varied considerably among the studied cenopopulations. The fresh biomass per plant ranged from 328 to 1845 g, whereas dry biomass per plant ranged from 119 to 506 g. The highest fresh and dry biomass values (per plant) were recorded at CP2, where fresh biomass reached 1845 g and dry biomass 506 g. In contrast, the lowest values were recorded at CP7, with 328 g fresh biomass and 119 g dry biomass. Across all 12 cenopopulations, the total measured fresh biomass was 12,538 g, while the total dry biomass was 3734 g. The mean fresh and dry biomass per monitoring site was 1044 and 311 g, respectively. The proportion of dry biomass relative to fresh biomass ranged from 26.78% to 38.30%, indicating variation in moisture content among the studied cenopopulations.

The highest biological and exploitable reserves were recorded at CP3 along the Kukpatas-Yuzquduq road in Uchquduq District, reaching 12.80 and 6.40 t, respectively. At this site, the reserve-valued field was 31 ha, with a productivity of 413 kg/ha. The second-highest biological reserve was recorded at CP2 in the Kukpatas village area of Uchquduq District, amounting to 10.93 t. At this site, the exploitable reserve was 5,46 t, while productivity reached 910 kg/ha.

The lowest biological and exploitable reserves were recorded at CP10 along the Navoi-Zarafshan road in Kanimekh District, amounting to 1.10 and 0.55 t, respectively. At this site, the reserve-valued field was 2 ha, productivity was 552 kg/ha, and the annual harvestable raw material was estimated at 0.28 t (Table 1).

Table 1. Resource indicators of the *A. pseudalhagi.*

CP	SDA (ha)	RVF (ha)	NF	NP (per 100 m²)	FB (gr.)	DB (gr.)	BR (t.)	ER (t.)	AHY (t.)
1	12	4	10	33	864	266	3.51	1.76	0.88
2	32	12	10	18	1845	506	10.93	5.46	2.73
3	52	31	10	14	812	295	12.80	6.40	3.20
4	27	13	10	24	1167	324	10.11	5.05	2.53
5	35	12	10	25	577	221	6.63	3.32	1.66
6	5	2	10	22	1467	418	1.84	0.92	0.46
7	12	7	10	15	328	119	1.25	0.62	0.31
8	8	3	10	19	1352	362	2.06	1.03	0.52
9	5	2	10	20	1142	310	1.24	0.62	0.31
10	4	2	10	22	781	251	1.10	0.55	0.28
11	7	3	10	17	1237	377	1.92	0.96	0.48
12	20	12	10	30	966	285	10.26	5.13	2.57
Total:	**219**	**103**	**120**		**1044**	**311**	**63.66**	**31.83**	**15.92**

Note: Species distributed area (SDA); Reserve-valued field (RVF); Number of sampling fields (NF); Number of plants (NP); Fresh biomass per plant (FB); Dry biomass per plant (DB); Biological reserve (BR); Exploitable reserve (ER); Annual Harvestable Yield (AHY).

A strong positive relationship was observed between fresh and dry biomass in *A. pseudalhagi* samples. Across 12 cenopopulations, fresh biomass per plant ranged from 328 to 1845 g, while dry biomass per plant ranged from 119 to 506 g. The mean fresh biomass per plant was 1044 g, whereas the mean dry biomass per plant was 311 g.

The Pearson correlation coefficient was r = 0.980, indicating a strong and statistically significant positive relationship ($p < 0.001$). The linear regression model yielded an R^2 value of 0.960. The linear regression equation was:

$$y = 0.2356x + 64.98$$

This equation can be used to estimate the dry biomass of *A. pseudalhagi* from fresh biomass measurements (Figure 2).

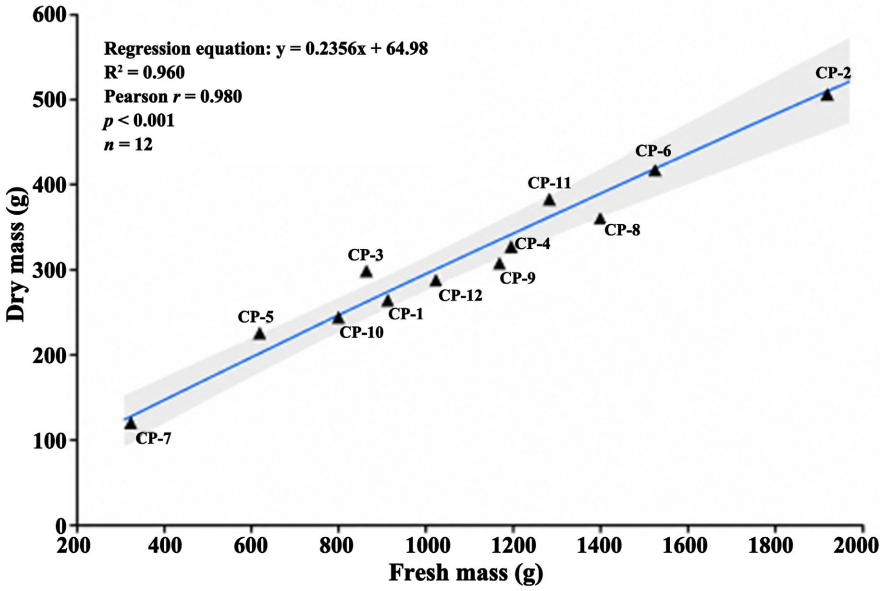


Figure 2. Linear regression relationship between fresh and dry mass.

Hierarchical cluster analysis grouped the 12 *A. pseudalhagi* cenopopulations into two clusters (Figure 3). Cluster I (CP6 - CP11) showed lower mean biological reserves (1.57 t), whereas Cluster II (CP1 - CP5 and CP12) had higher reserves (9.04 t).

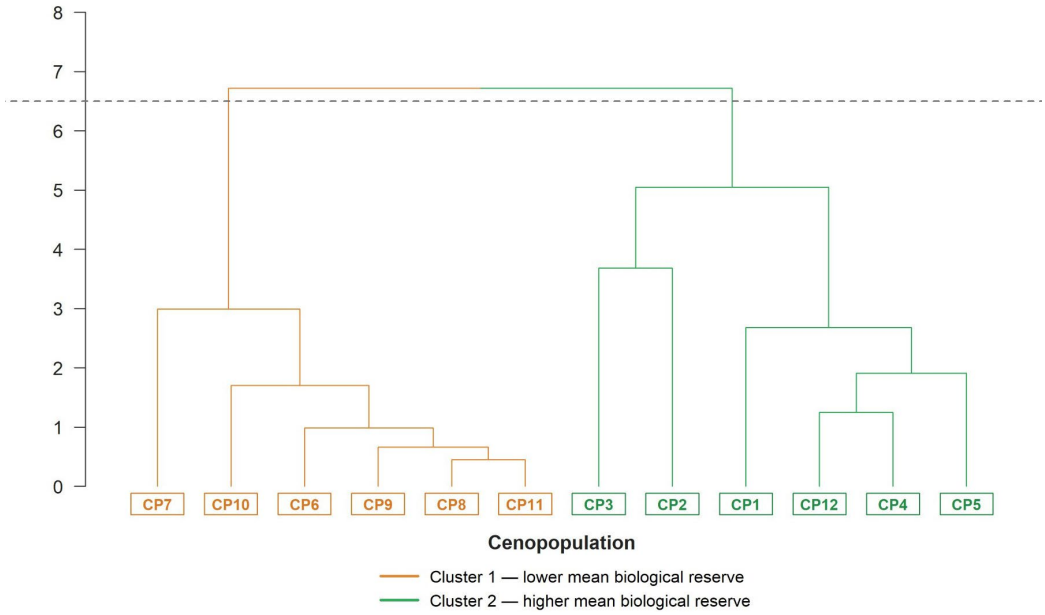


Figure 3. Hierarchical clustering dendrogram of *A. pseudalhagi* cenopopulations.

PCA was used to evaluate resource-related variation among *A. pseudalhagi* cenopopulations based on six indicators. The first two principal components explained 68.90% of the total variance (PC1: 36.59%; PC2: 32.32%). The results revealed variation in the spatial distribution and resource characteristics of the stud-

ied cenopopulations (Figure 4).

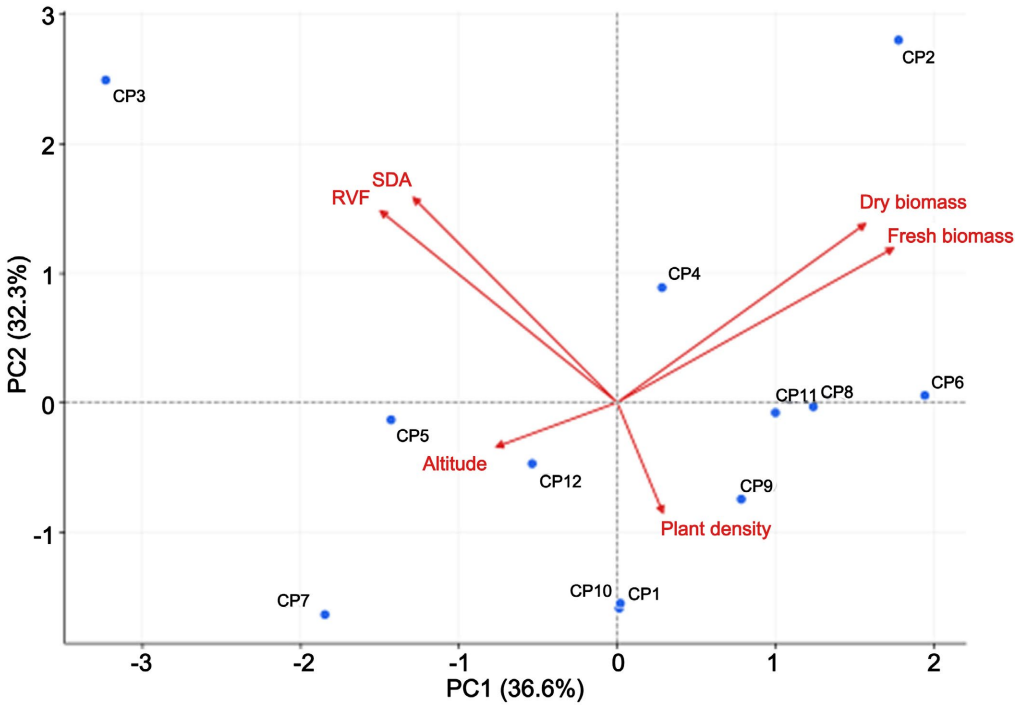


Figure 4. Principal component analysis (PCA) of resource-related indicators of *A. pseudalhagi*.

During the study, regular livestock grazing was observed across most areas where *A. pseudalhagi* is distributed. Unregulated and excessive grazing pressure exerts mechanical stress on individual plants within natural populations, potentially leading to a reduction in their above-ground biomass. Unsystematic cutting and harvesting by local residents were also observed during the plant's growing season. Harvesting the plant before it produces seeds has a negative impact on the species' regeneration process. Thus, given that *A. pseudalhagi* serves as livestock fodder, unregulated pasture use was identified as a significant anthropogenic factor indirectly affecting the vegetative and generative regeneration of its natural populations (Figure 5).



(a) (b)

Figure 5. Natural distribution areas of *A. pseudalhagi* in Navoi Region.

4. Discussion

The study demonstrated considerable spatial variation in the natural resource potential of *Alhagi pseudalhagi* across Navoi Region. Differences in biomass productivity, plant density, distribution area, and resource reserves indicate that the resource status of the species is strongly influenced by local ecological conditions and anthropogenic pressure. Therefore, resource assessment should consider not only biomass productivity but also population distribution and regeneration potential.

The highest biological reserve was recorded at CP3, followed by CP2, whereas the lowest was observed at CP10. These differences reflect the combined influence of population density, reserve-valued field area, and biomass accumulation. Importantly, high plant productivity did not necessarily correspond to a high total resource reserve. This is clearly can be seen on CP2 and CP3. Although CP2 showed substantially higher fresh and dry biomass per plant (1845 and 506 g, respectively) than CP3 (812 and 295 g), its smaller reserve-valued area (12 ha) resulted in a lower biological reserve (10.93 t). In contrast, CP3 occupied a much larger area (31 ha), and despite its lower plant productivity, had a higher biological reserve (12.80 t). Thus, the total resource potential of a cenopopulation depends not only on plant productivity but also on the area occupied by the population.

Fresh biomass per plant ranged from 328 to 1845 g, while dry biomass per plant ranged from 119 to 506 g. The variation in dry-to-fresh biomass ratios suggests differences in plant water content, phenological and environmental conditions. The strong relationship between fresh and dry biomass ($R^2 = 0.960$) indicates that fresh biomass can be used to estimate dry biomass during field surveys. However, further validation under different ecological conditions would improve the applicability of this model.

The total biological reserve across the study sites was at 63.66 t, compared with 31.83 t of exploitable reserve and 15.92 t of annual harvestable raw material. Maintaining this distinction is important for sustainable use because excessive removal of biomass may reduce population regeneration, particularly in areas affected by grazing and repeated harvesting. Rotational harvesting, seasonal restrictions, and retention of sufficient reproductive individuals are therefore important management measures.

5. Conclusions

Overall, the assessment of *A. pseudalhagi* cenopopulations across Navoi Region demonstrated considerable spatial differences in their resource potential, while the species showed a substantial capacity to provide medicinal raw material under appropriate management conditions. The observed variation among populations highlights the importance of considering local resource availability, population characteristics, and regeneration potential when planning the utilization of natural plant resources.

The sustainable use of *A. pseudalhagi* depends on maintaining a balance be-

tween harvesting intensity and natural population recovery. In particular, harvesting during critical reproductive stages and continued grazing pressure may compromise regeneration and reduce the long-term availability of raw materials.

Therefore, the sustainable procurement of *A. pseudalhagi* should be based on regular population monitoring, site-specific assessment of resource availability, appropriate timing and frequency of harvesting, and rotational use of harvesting areas. These measures can support the continued availability of this medicinal plant while contributing to the conservation and long-term stability of its natural populations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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