Postprint: Vegetation Types, Distribution, and Quantitative Characteristics in the Desert Area of the Shiyang River Basin

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Abstract

Vegetation in the desert areas of the Shiyang River Basin plays an extremely important role in curbing the merging of the Badain Jaran Desert and the Tenger Desert and ensuring the ecological security of regional oases. To comprehensively understand the vegetation types, distribution, and current status in the desert areas of the Shiyang River Basin, multi-year field surveys were conducted based on the interpretation of satellite imagery, desert vegetation types were classified, vegetation distribution maps were drawn, and quantitative characteristics of typical desert vegetation communities were analyzed, providing a basis for the conservation and utilization of desert vegetation and its species diversity in the Shiyang River Basin. The results show that: (1) There are many vegetation types in the desert areas of the Shiyang River Basin, including 4 vegetation type groups, 6 vegetation types, 7 vegetation subtypes, and 40 vegetation formations, exhibiting typical characteristics of desert and steppe-desert. The spatial distribution of desert vegetation within the basin varies significantly; the eastern part has extensive drifting sand distribution with relatively simple vegetation types, while the northern part has interlaced distribution of gobi and desert with relatively rich vegetation types and species composition. (2) The species composition of desert vegetation in the Shiyang River Basin is relatively rich, with 486 species belonging to 255 genera and 57 families, dominated by temperate desert plants; perennial herbs, annual herbs, and shrubs account for 49.59%, 25.31%, and 18.93% of the total species number, respectively, while trees, parasitic herbs, and aquatic plants are relatively few in number. The vegetation synusial structure in the desert areas of the Shiyang River Basin is simple, with community constructive species often being shrubs and semi-shrubs. (3) The quantitative characteristics of dominant species in typical plant communities in the Shiyang River Basin vary significantly. In terms of species richness, the species richness of typical plant communities in the desert areas of the Shiyang

River Basin ranges from 2.1 to 16.3, with an average of 7.6 species. The Reaumuria songarica + Nitraria sphaerocarpa community is the most species-rich at 16.3 species; the Caroxylon passerinum + Nitraria sphaerocarpa + Kalidium cuspidatum community follows at 14.5 species; while the Nitraria tangutorum community, Sympegma regelii community, Kalidium foliatum community, and Artemisia ordosica community have the fewest species at 2.7, 2.6, 2.1, and 2.6 species, respectively. In summary, desert vegetation areas in the Shiyang River Basin have diverse types and relatively rich species composition, but community coverage, species richness, and diversity indices are relatively low. Therefore, it is necessary to strengthen the protection and restoration of desert vegetation and its fragile habitats to maintain the diversity, stability, and sustainability of desert ecosystems and fully exert their ecological protective functions.

Full Text

Vegetation Types, Distribution, and Quantitative Characteristics in the Desert Area of the Shiyang River Basin

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Abstract: Desert vegetation in the Shiyang River Basin plays an extremely important role in curbing the convergence of the Badain Jaran and Tengger Deserts and ensuring the ecological security of regional oases. To comprehensively understand the vegetation types, distribution, and current status of desert vegetation in the Shiyang River Basin, we conducted multi-year field surveys based on satellite image interpretation, classified desert vegetation types, mapped vegetation distribution, and analyzed the quantitative characteristics of typical desert plant communities. These efforts provide a basis for the conservation and utilization of desert vegetation and its species diversity in the Shiyang River Basin. The results show that: (1) The desert area of the Shiyang River Basin features diverse vegetation types, including 4 vegetation type groups, 6 vegetation types, 7 vegetation subtypes, and 40 vegetation formations, exhibiting typical desert and steppe-desert characteristics. Spatial distribution of desert vegetation varies significantly across the basin, with extensive drifting sand and relatively homogeneous vegetation types in the east, while the north shows interspersed Gobi and desert distribution with richer vegetation types and species composition. (2) The species composition of desert vegetation is relatively rich, comprising 486 species belonging to 255 genera and 57 families, dominated by temperate desert plants. Perennial herbs, annual herbs, and shrubs account for 49.59%,

25.31%, and 18.93% of the total species, respectively, while trees, parasitic herbs, and aquatic plants are relatively few. The vegetation structure is simple, with shrubs and semi-shrubs commonly serving as community constructive species. (3) Quantitative characteristics of dominant species in typical plant communities vary significantly. Species richness ranges from 2.1 to 16.3 species, with the *Reaumuria songarica* + *Nitraria sphaerocarpa* community being the most species-rich (16.3 species), followed by the *Caroxylon passerinum* + *Nitraria sphaerocarpa* + *Kalidium cuspidatum* community (14.5 species). The *Nitraria tangutorum*, *Sympegma regelii*, *Kalidium foliatum*, and *Artemisia ordosica* communities have the fewest species (2.7, 2.6, 2.1, and 2.6 species, respectively). In summary, the Shiyang River Basin desert vegetation area exhibits diverse types and relatively rich species composition, but community coverage, species richness, and diversity indices are low. Therefore, strengthening the protection and restoration of desert vegetation and its fragile habitats is essential to maintain the diversity, stability, and sustainability of desert ecosystems and to fully realize their ecological protection functions.

Keywords: vegetation type; community distribution; species composition; species diversity; Shiyang River Basin

Introduction

The Shiyang River Basin, one of the three major inland rivers in the Hexi Corridor, is located in the eastern Hexi Corridor and northern Qilian Mountains of Gansu Province, forming an important component of the northern sand prevention belt in China []. The northwestern part of the basin borders the Badain Jaran Desert, while the eastern part adjoins the Tengger Desert, with interspersed Gobi and desert distribution. Salt lakes and alkaline flats are sporadically distributed in low-lying areas []. Due to its location in an arid inland region, the natural environment of the desert area in the middle and lower reaches of the Shiyang River Basin is harsh. The accelerated convergence of the Badain Jaran and Tengger Deserts and frequent aeolian sand activities pose serious threats to oasis production and livelihoods. Desert vegetation serves as a green barrier ensuring ecological security in the Shiyang River Basin. Understanding vegetation types, distribution, and quantitative characteristics is a prerequisite for protecting desert ecosystems and provides important guidance for ecological restoration, reconstruction, and plant diversity conservation in the basin.

The Shiyang River Basin's typical geographic representativeness and prominent ecological degradation issues have made it a hotspot for ecological protection research in China. Against the backdrop of comprehensive biodiversity conservation, China has established nature reserves centered on the Qilian Mountain National Park to protect various ecosystems in the basin. Previous studies have investigated floristic characteristics of the lower Shiyang River [], species diversity in the Minqin Liangucheng Nature Reserve [], and community structure and diversity of typical desert plants such as *Zygophyllum xanthoxylum* []. However,

existing research has been limited to small areas or single vegetation types, lacking systematic investigation and classification of desert vegetation at the basin scale. The main vegetation types, distribution ranges, and species composition of typical communities remain unclear. Based on remote sensing data and field vegetation surveys, this study classified desert vegetation types, mapped vegetation distribution, and examined quantitative characteristics and diversity of typical desert plant communities in the Shiyang River Basin. These findings provide basic data for desert vegetation and diversity conservation, and offer guidance for vegetation selection to mitigate the convergence of the Tengger and Badain Jaran Deserts, protect oasis ecological security, and build ecological security barriers.

Study Area and Methods

Study Area Overview

The desert area of the Shiyang River Basin features a continental temperate arid climate [], characterized by drought, low precipitation, severe wind-sand activity, and large diurnal temperature variations. Annual precipitation ranges from 50–200 mm, annual evaporation from 1,300–2,600 mm, and mean annual temperature from 6–10 °C. The zonal soil is gray-brown desert soil, with aeolian sandy soil being the most extensive soil type in the basin's desert area. Fixed and semi-fixed dunes are mainly distributed at oasis edges, dominated by *Nitraria tangutorum*, *Artemisia ordosica*, and *Zygophyllum xanthoxylum*. Mobile dunes occur outside oases, supporting *Artemisia desertorum*, *Psammochloa villosa*, *Corethrodendron scoparium*, and *Phragmites australis*. Large Gobi areas are dominated by *Potaninia mongolica*, *Reaumuria songarica*, *Caroxylon passerinum*, *Caragana korshinskii*, and *Sympegma regelii*.

Vegetation Classification

Using the vegetation classification system from *Vegetation of China* [] as the standard, and referencing the *1:1,000,000 Manual for the Vegetation Atlas of the People's Republic of China* [], the revised vegetation classification system of China [], and the vegetation classification system and type arrangement for *Vegetation of China* [], as well as *Vegetation of Gansu* [], *Vegetation of Inner Mongolia* [], and *Grassland Vegetation and Grassland Ecosystems in Gansu* [], we classified vegetation in the Shiyang River Basin.

Community Survey

Based on interpreted remote sensing images and the China vegetation map, we conducted vegetation surveys in the desert area of the Shiyang River Basin from May to September 2019–2021. Sample plots (100 m × 100 m) were established in areas with uniform distribution of dominant species. Within each plot, five shrub quadrats (10 m × 10 m) were set at the four corners and center, and herb quadrats (1 m × 1 m) were arranged in a nine-grid pattern. We recorded species

composition and quantities, measured height, crown width, and coverage for 5–10 standard individuals of each plant species, and documented plot coordinates, elevation, soil conditions, site conditions, and landform characteristics []. We analyzed population and community quantitative characteristics for 20 typical communities, including *Nitraria tangutorum*, *Lycium ruthenicum*, *Artemisia xerophytica*, *Nitraria tangutorum* + *Haloxylon ammodendron*, *Reaumuria songarica* + *Convolvulus tragacanthoides* + *Ptilagrostis pelliotii*, *Caroxylon passerinum* + *Reaumuria songarica*, and *Nitraria sphaerocarpa* communities.

Importance value was calculated as the mean of relative height, relative coverage, and relative frequency []. Considering that annual herbs are greatly affected by rainfall and contribute little to community stability, importance values for typical plant communities only included shrubs and perennial herbs. Species diversity was evaluated using species richness (R), Shannon-Wiener diversity index (H), Simpson diversity index (D), Pielou evenness (J), community ecological dominance (C), and interspecific encounter rate (PIE). The formulas are as follows:

$$R = S$$

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

$$J = \frac{H}{\ln S}$$

$$C = \sum_{i=1}^{S} \left(\frac{N_i}{N}\right)^2$$

$$PIE = \sum_{i=1}^{S} \left(\frac{N_i}{N}\right)\left(\frac{N - N_i}{N - 1}\right)$$

where S is the number of species in the quadrat, N is the total number of plant individuals, N_i is the number of individuals of species i, and P_i is the proportion of individuals of species i.

Results

Vegetation Types and Distribution

Desert vegetation in the Shiyang River Basin can be classified into 4 vegetation type groups, 6 vegetation types, 7 vegetation subtypes, and 40 vegetation formations. Desert vegetation comprises 6 vegetation types, 7 subtypes, and 33 formations; swamp and aquatic vegetation includes 1 type and 3 formations;

herbaceous vegetation includes 1 type, 1 subtype, and 4 formations (Table 1). The desert area of the Shiyang River Basin is a typical arid region where the dry climate determines the desert character of vegetation. Spatial distribution varies significantly between the eastern and western parts of the basin. The eastern part is dominated by drifting sand belts, primarily supporting *Artemisia ordosica* and *Artemisia desertorum* communities, with *Artemisia ordosica* being the most extensive, followed by *Artemisia desertorum* and *Nitraria tangutorum* communities. *Kalidium foliatum* communities occur on saline-alkali flats and salinized sandy lands.

The western and northern parts, including the northeastern Gobi-desert interspersed area and the Minqin oasis region, feature more vegetation types, including *Caragana korshinskii*, *Zygophyllum xanthoxylum*, *Nitraria tangutorum*, *Lycium ruthenicum*, *Reaumuria songarica*, *Caroxylon passerinum*, *Haloxylon ammodendron*, *Potaninia mongolica*, *Nitraria sphaerocarpa*, and *Oxytropis aciphylla* communities. *Kalidium foliatum* communities also occur on saline-alkali flats, while *Nitraria tangutorum* communities form rings around these on sandy soils, often creating fixed or semi-fixed shrub sand mounds. Rocky mountainous areas in the northwest support *Reaumuria songarica* and *Sympegma regelii* communities; alluvial fans host *Potaninia mongolica* and *Caroxylon passerinum* communities. *Prunus mongolica* occurs sporadically on rocky slopes as low cushion-shaped plants. Perennial herbs *Phragmites australis* and *Psammochloa villosa* are distributed throughout the basin. In Minqin's Qingtu Lake, reed swamp area is expanding due to artificial water replenishment. In mobile dunes of the eastern basin, communities dominated by *Psammochloa villosa* and *Artemisia desertorum* often form, with *Apocynum pictum* and *Iris lactea* communities occurring sporadically on saline-alkali lands in the northern and northeastern parts of the basin (Figure 2).

Species Composition of Desert Vegetation

Survey statistics show that desert vegetation in the Shiyang River Basin comprises 486 species of native seed plants belonging to 255 genera and 57 families, including 6 gymnosperm species and 480 angiosperm species. Angiosperms dominate, accounting for 98.77% of the flora. Among angiosperms, dicotyledons include 376 species (78.33% of angiosperms), while monocotyledons include 104 species (21.67%), giving dicotyledons absolute numerical superiority.

According to the life form classification system of *Vegetation of China*, desert vegetation plants in the Shiyang River Basin belong to 5 primary life forms and 15 secondary life forms. Herbs dominate absolutely, accounting for 79.63% of total species, with perennial herbs being most prominent at 49.59% of total species. Woody plants account for only 13.17% of total species, with shrubs being the most numerous at 11.71%. Semi-woody plants are relatively few, accounting for 7.20% (Table 2).

Quantitative Characteristics of Typical Plant Communities

Affected by the arid climate and habitat conditions, vegetation in the Shiyang River Basin desert area is dominated by temperate desert plants, with significant differences in quantitative characteristics among typical plant community dominant species (Table 3). Population density is highest for *Allium mongolicum* in the *Allium mongolicum* community, reaching 92,000.0 ± 6,754.3 individuals · hm^{-2}, while *Nitraria tangutorum* density is lowest in the *Nitraria tangutorum* community at 1,666.7 ± 12.7 individuals · hm^{-2}. Community and dominant species coverage are generally low, with the *Asterothamnus centraliasiaticus* community showing the highest coverage at 47.2%, followed by the *Ptilagrostis pelliotii* community (31.6%); all others are below 23.9%. *Reaumuria songarica* in the *Reaumuria songarica* + *Ptilagrostis pelliotii* community shows the highest dominant species coverage at only 21.3%, followed by *Kalidium foliatum*, *Artemisia ordosica*, *Asterothamnus centraliasiaticus*, *Caragana korshinskii*, and *Nitraria tangutorum* in their respective communities, with coverage of 21.6%, 17.4%, 14.6%, 12.0%, and 11.4%, respectively. Other community dominant species have coverage below 10%.

Most typical plant communities in the Shiyang River Basin are co-dominant, with few single-dominant communities. In single-dominant communities, *Kalidium foliatum* has the highest importance value (0.86), followed by *Artemisia ordosica* (0.80). Community layers are typically composed of shrub/semi-shrub layers and perennial/annual herb layers, though some communities consist only of shrub and annual herb layers, resulting in simple layer structures. Annual herbs are greatly affected by seasonal rainfall, while shrubs often serve as community dominants.

Species Diversity Characteristics of Typical Plant Communities

Species richness of typical desert plant communities in the Shiyang River Basin ranges from 2.1 to 16.3 species, with the *Reaumuria songarica* + *Nitraria sphaerocarpa* community being the most species-rich (16.3 species). The *Caroxylon passerinum* + *Nitraria sphaerocarpa* + *Kalidium cuspidatum* community follows with 14.5 species, while *Nitraria tangutorum*, *Sympegma regelii*, *Kalidium foliatum*, and *Artemisia ordosica* communities have the fewest species (2.7, 2.6, 2.1, and 2.6 species, respectively) (Table 4).

The *Reaumuria songarica* + *Nitraria sphaerocarpa* community and the *Caroxylon passerinum* + *Nitraria sphaerocarpa* + *Kalidium cuspidatum* community show high species richness and diversity indices, with less obvious dominant species. Conversely, the *Nitraria tangutorum* + *Haloxylon ammodendron* and *Kalidium foliatum* communities have lower diversity indices and higher community dominance. The *Reaumuria songarica* + *Nitraria sphaerocarpa*, *Caroxylon passerinum* + *Nitraria sphaerocarpa* + *Kalidium cuspidatum*, and *Reaumuria songarica* + *Ptilagrostis pelliotii* communities have higher interspecific encounter rates (0.87, 0.81, and 0.79, respectively), while *Kalidium foliatum*,

Nitraria tangutorum + *Haloxylon ammodendron*, and *Lycium ruthenicum* communities have lower rates.

The eastern basin is dominated by mobile dunes with *Artemisia desertorum* and *Artemisia ordosica* communities showing relatively homogeneous composition. The northern Gobi gravel areas have relatively higher species richness and diversity indices, while community ecological dominance shows the opposite pattern. Interspecific encounter rates and community evenness follow similar patterns, contrasting with community dominance and diversity indices.

Discussion

Survey statistics indicate that desert vegetation in the Shiyang River Basin comprises 486 species, with 33 vegetation formations. In contrast, the Ulan Buh Desert has only 162 species and 18 formations []. The Shiyang River Basin spans a large area with moisture conditions varying from south to north and east to west, creating vegetation distribution differences and complexity []. Clearly, the Shiyang River Basin is one of China's regions richest in desert plants and vegetation types.

Located in the ecological transition zone between the Qilian Mountains, desert, and oasis, and at the intersection of the Tengger and Badain Jaran Deserts, the basin provides an important environmental foundation for rich desert vegetation types. Perennial herbs dominate the vegetation composition, accounting for 49.59% of total species, while annual herbs and perennial herbs together account for 74.9% of total species. Annual herb numbers fluctuate with rainfall changes and contribute little to community stability []. Wang et al. found that species composition around the Badain Jaran Desert consists of shrubs (21.67%), perennial herbs (49.59%), and annual herbs (25.31%) [], indicating that shrubs are the main constructive species in arid regions and key to community stability, representing stable layers. Annual herbs are unstable layers that change with precipitation. Therefore, shrubs play a critical role in community stability in desert areas, with their abundance determining community stability 程度.

Vegetation and diversity distribution are determined by ecological adaptability and influenced by environmental factors such as climate and human disturbance []. Hu et al. showed that species distribution in the Shiyang River Basin is uneven, with the upper Qilian Mountains having the best biodiversity maintenance function, followed by the middle plain area, and the lower desert area having the poorest []. Overall species diversity shows a pattern of high in the west and low in the east, high in the south and low in the north []. Species richness increases sequentially from saline-alkali land to sandy land, gravel land, and low mountains, with site conditions being the dominant factor controlling community species diversity []. Vegetation types are relatively rich and diversity indices are higher on gravel lands in the western basin. Precipitation decreases gradually from the southern Qilian Mountains to the northern basin [], with

increasing temperatures and decreasing groundwater and surface runoff, which are unfavorable for vegetation growth []. This study found obvious spatial differences in desert vegetation and species diversity in the Shiyang River Basin, with higher species richness and diversity indices in the low-precipitation northern and western Gobi areas compared to the east, while community ecological dominance shows the opposite pattern.

Habitat conditions determine that species richness, Shannon-Wiener index, Simpson index, and interspecific encounter rates are higher in the northern and western parts than in the eastern part of the basin, while community ecological dominance is lower. The special geographical environment and climate characteristics have created the vegetation distribution and species composition patterns in the Shiyang River Basin desert area, with simple community structure, relatively homogeneous species composition, and uneven vegetation distribution, fully reflecting desert vegetation characteristics.

Due to long-term overexploitation of water and soil resources, the Shiyang River Basin has become one of China's most degraded regions, seriously threatening the sustainable development of desert vegetation and plant resources []. Under these extreme environmental conditions, strengthening the conservation of desert vegetation and its species diversity, particularly in the northern and eastern parts, and ecological restoration construction is urgent. Future efforts should focus on scientific protection of desert vegetation and its habitats, gradually restoring degraded hydrological environments, enhancing the stability, diversity, and sustainability of desert ecosystems, fundamentally changing the passive management situation of the Shiyang River Basin's ecological environment, and playing a key role in mitigating the convergence of the Tengger and Badain Jaran Deserts and building a western ecological security barrier.

Conclusions

Based on remote sensing data and field vegetation surveys in the Shiyang River Basin, we mapped desert vegetation distribution and analyzed quantitative characteristics and diversity of typical desert plant communities. The main conclusions are:

(1) Desert vegetation in the Shiyang River Basin can be classified into 4 vegetation type groups, 6 vegetation types, 7 vegetation subtypes, and 40 vegetation formations, with typical desert and steppe-desert characteristics. Spatial distribution varies significantly, with extensive drifting sands and homogeneous vegetation types in the east, while the north shows interspersed Gobi and desert distribution with richer vegetation types and species composition.

(2) Desert vegetation comprises 486 species, with perennial herbs being dominant but shrubs commonly serving as community constructive species and representing stable layers, while annual herb numbers fluctuate with precipitation and represent unstable layers.

(3) Typical desert plant communities have simple layer structures, mostly composed of shrub/semi-shrub and herb layers, with low community coverage, species richness, and diversity indices, consistent with the harsh ecological environment of the Shiyang River Basin.

(4) Habitat conditions determine that species richness, Shannon-Wiener index, Simpson index, and interspecific encounter rates are higher in the northern and western parts than in the eastern part, while community ecological dominance shows the opposite pattern. Therefore, strengthening the protection and restoration of desert vegetation in the Shiyang River Basin is essential to maintain ecosystem diversity, stability, and sustainability.

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