HunShanDaKe sand east edge of vegetation ecological niche and interspecific association studies

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Abstract. Plant communities show some kind of interspecific relationship and different niche characteristics through the sharing and competition of resources in the living environment, which is of great significance for interpreting the response mechanism of vegetation to the environment. This study analyzes the niche breadth, niche overlap, and interspecific relationships of plant species in the study area by using ecological statistics. Although there are certain correlations among the species in the Hunshandake Sandy Land, the relationship is relatively loose and the whole is in an unstable stage; the plants with relatively wide niche under three types of site types in the eastern margin of the Hunshandake Sandy Land The species are Quercus mongolica (Betula platyphylla), Malus baccata + Spiraea pubescens, Ribes diacanthum (Ostryopsis davidiana) of the leeward slope; Ulmus pumila + Ribes diacanthum and Siberian apricot (Ribes pulchellum) on the windward slope; Ulmus pumila and Malus baccata + Spiraea trilobata , Rosa davurica (Kochia prostrata) on the hilly land. The combination of the leeward slope niche overlap is Betula platyphylla and Malus baccata + Spiraea pubescens, Ostryopsis davidiana; Ulmus pumila + Ribes pulchellum, Kochia prostrata on the windward slope; the hilly land for Malus baccata, Ulmus pumila + Spiraea trilobata.

1. Introduction
As one of the four major sands in Inner Mongolia, Hunshandake Sandy Land has formed representative sandy vegetation due to its special historical climate and complex external environmental conditions [1]. This unique landscape of sandy land makes it an important part of the biosphere and is important for maintaining the normal operation and development of the entire ecosystem [2]. In recent years, with the increase of human activities and the constant changes of climate, the vegetation of sandy land has been continuously damaged, which has seriously affected the sustainable development of the region [3]. Previous studies have focused on the hinterland and southern end of the Hunshandake sandy land, and there are few studies on the variation of vegetation distribution in the eastern margin [4]. The plant community is composed of multiple interacting and interacting plant individuals and shows some kind of interspecific relationship and different niche characteristics through the sharing and competition for resources in the living environment [5]. The niche theory can now explain the mechanism of community structure establishment [6]. It includes the habitat requirements of a species and the impact of the environment on the growth and survival of the species. The properties of the species can be seen to some extent [7] as an important indicator...
of community, interspecific association reflects the evolution of the community and the structure pattern of the community. At the same time, it can be used as a basis for classifying and understanding the relationship between species, and thus can have a correct understanding of the population community [8].

Based on the field investigation of vegetation in the eastern margin of Hunshandake Sandy Land, this study investigate the niche overlap and niche breadth of each vegetation layer species in the resource dimension, reveals the ability of major plant species to utilize resources, and then explores the plants in the study area. The structural characteristics of the community and the adaptation characteristics of different plants to the environment have theoretical and practical significance for regulating the existing management measures of arbors and shrubs, and provide more basic theoretical and scientific guidance for the protection of Hunshandake sand resources and vegetation restoration.

2. Experiments and methods

2.1. Overview of research sites
Keshiketeng Banner is located in the northwest of Chifeng City, Inner Mongolia Autonomous Region, with geographical coordinates of 42°23′~44°22′ N, 116°21′~118°26′ E. It is adjacent to Linxi County and Wengniute Banner in Chifeng City in the east; Zhenglan Banner, Xilinhot City, Duolun County and Xiwuzhumuqi Banner in the northwest are adjacent to Xilin Gol League [9]. The site is located at the intersection of the Inner Mongolia Plateau and the southern end of the Daxinganling Mountains and the Yanlao Mountains, and the terrain is complex and diverse. It is mainly divided into three geomorphic areas: the western high plain area, the central Zhongshan area, and the eastern lava station area. The terrain of the Keshiketeng Banner is high in the northwest and low in the southeast, with an elevation of 680.90m~2067m [10].

2.2. Research methods

2.2.1. Sample ground setting
A comprehensive survey of the Keshiketengxiang Xiangshui Reservoir was conducted using a typical plot survey method. In the study area, sand dunes with a uniform sand dune were selected, totaling 10 sand dunes. A comprehensive survey of the arbor and shrub indicators under different site types for each dune was conducted by setting up the plot.

Arbor-like square: Set the large sample on the leeward slope, the windward slope and the inter-hill area of each sand dune. The sample area is the slope length × square width (30 m).

Shrub-like formula: Six 5 m×5 m shrub-like squares are set in each of the arbor-like plots of the windward slope, the leeward slope and the inter-hill, respectively, for a total of 180 sample squares.

2.2.2. Sample survey content.
(1) Sample survey: Record the geographical location of the surveyed dunes, the direction of the dune, the height of the dune, the slope direction, and the slope.
(2) Arbor survey: Each wooden ruler is used to record the type and number of trees in the sample, and the height (m), breast diameter (cm), base diameter (cm), and height of the branches (m) of each tree are determined, the east and west crowns (cm), and locate each tree, record the horizontal and vertical coordinates of the arbor species. (3) Shrub survey: The types of shrubs appearing in the sample were measured, and the number of plants, average height (cm), base diameter (cm) and crown width (cm) of each shrub were determined. The aboveground part was obtained according to the percentage of each shrub, and the fresh weight was weighed.

2.2.3. Calculation formula

2.2.3.1. Niche width
The following two indexes were used to calculate the niche breadth [11,12]:

...
Levins Index:  \[ B_1 = \frac{1}{\sum_{j=1}^{r} (P_{ij})^2} \]  (1)
where: \( B_1 \) is the niche breadth of species \( i \); \( P_{ij} = \frac{N_{ij}}{Y_i} \), that is, the number of individuals in species \( j \) in resource position \( j \) accounts for the total number of individuals in the entire resource state.

Shannon-Wiener Index:  \[ B_2 = -\sum_{j=1}^{r} (P_{ij} \ln P_{ij}) \]  (2)
where: \( B_2 \) is the niche breadth of species \( i \); \( r \) is the number of grades of resources; \( P_{ij} \) is the ratio of the utilization of the \( j \)th resource to the utilization of all resources by species \( i \). Considering that important values can better reflect the utilization efficiency of plant species on environmental resources, \( P_{ij} \) is an important value of species when using this index to calculate the niche breadth.

2.2.3.2. Ecolocation overlap
The overlap of niches reflects the degree of similarity between species to a certain extent, and is the similarity between the two species and their living environment factors. Comparing the commonly used calculation formulas with the research needs of this study, the Schoener (1974) index based on the similar percentage is selected to calculate the niche overlap between the plants [13].

\[ O_{ik} = 1 - \frac{1}{2} \sum_{j=1}^{r} \left| P_{ij} - P_{kj} \right| \]  (3)
where: \( O_{ik} \) represents the overlap index of the resource utilization curve of species \( i \) and the resource utilization curve of species \( k \). When the distribution of species \( i \) and species \( k \) is identical in all resource states, \( O_{ik} \) is equal to 1, indicating that the species \( i \) and species \( k \) niches completely overlap; conversely, when the two species do not have a common resource state, their niche do not overlap at all, \( O_{ik} = 0 \).

2.2.3.3. Interspecific association
Usually, the \( \chi^2 \) test is used to judge whether the two species are related or not, but the test has a deviation under the discontinuous sampling, so the continuous correction coefficient of Yates is selected for correction [14]. The Yates coefficient correction formula is:

\[ \chi^2 = N \left[ \frac{ad-bc}{(a+b)(c+d)(a+c)(b+d)} \right] - \frac{1}{2} N \]  (4)
where: \( N \) is the total number of squares; \( a \) is the number of squares in both species, \( b \) and \( c \) are the number of squares in which only one species appears, and \( d \) is the number of squares in which neither species appears.

According to the critical value table, the theoretical values under different levels are: \( \chi^2 \) = 3.841, 6.635. When \( 2 < 3.841 \), the two species are independent of each other; when \( 3.841 \leq 2 < 6.635 \), the two species are significantly correlated; when \( 2 \geq 6.63 \), the correlation is extremely significant. If \( ad = bc \), there is no correlation between species. If \( ad > bc \), the two species are positively related. On the contrary, when \( ad < bc \), it is negative association [15].

3. Results and analysis

3.1. Niche width

3.1.1. Phytoplankton plant species niche breadth
Under the leeward slope, the important value of *Betula platyphylla* is 40.72%, followed by *Malus baccata* and *Quercus mongolica*, and the important value of *Crataegus sanguinea* is 2.78%. Among the B1 values of niche breadth, the arbor species with the largest niche are Q.
mongolica, followed by M. baccata and B. platyphylla, and the smallest plant species is Populus davidiana. Among the B2 values of the niche breadth, B. platyphylla has the largest niche breadth and corresponds to the important value. This is because B. platyphylla, Q. mongolica and M. baccata are more adaptable to the middle-class trees and have a wider distribution range; while Prunus padus and C. sanguinea have limitations due to their habitat requirements and thus the niche breadth is narrow (table 1).

On the windward slope, Ulmus pumila has the largest value and the largest niche under the B1 index. The three arbor niches under the B2 niche are all 0, indicating that they only appear in a sample on the windward slope and are pure forest. In the inter-mountain, U. pumila also occupies the maximum in the B1 niche, and is smaller than the M. baccata in the B2 niche. It shows that U. pumila has the absolute advantage and the adaptability as the only arid plant species in the arbor layer of the study area (table 1).

Table 1. Species composition and niche breadth of arbor layers under different site types.

| Numbering | Arbor species                  | Leeward slope | Windward slope | Hilly land |
|-----------|--------------------------------|---------------|----------------|------------|
|           |                                | Pi  B1  B2    | Pi  B1  B2    | Pi  B1  B2 |
| 1         | Betula platyphylla             | 40.72 2.75   | 2.94           |            |
| 2         | Quercus mongolica              | 18.94 6.13   | 2.43 4.19 1    | 0 3.51 1   |
| 3         | Prunus padus                   | 5.56 2.43    | 0.94           |            |
| 4         | Malus baccata                  | 21.22 3.60   | 2.67 13.81 1   | 0 13.53 1 0.36 |
| 5         | Ulmus pumila                   | 7.56 2.61    | 1.20 82.00 2.63 | 0 82.95 2.72 0.32 |
| 6         | Crataegus sanguinea            | 2.78 1.14    | 0.43           |            |
| 7         | Populus davidiana              | 3.22 1.08    | 0.46           |            |

Note: Pi is an important value.

3.1.2. Shrub layer plant species niche breadth
On the leeward slope, the most important value of shrub species is Spiraea pubescens, which is 35.62%, followed by 32.35% of Ostryopsis davidiana, which is significantly higher than other shrub species. In both calculations, S. pubescens has the largest niche breadth, with B1 and B2 indices of 6.43 and 2.78, respectively. This is because the two are the dominant species of the community, which can form a single dominant community and can form a common community with other plant species, suitable for growing in a damp environment under trees. Other shrub species are more sensitive to environmental factors such as light and moisture, and have a narrow niche breadth (table 2).

On the windward slope, Prunus sibirica and Salix gordejevii are the dominant species in the undergrowth; the main associated species is Riber diacanthum. However, in the B1 and B2 niches, R. diacanthum and P. sibirica have larger widths. Similarly, there is also the same change in the inter-hill zone as the windward slope, and the size of the niche breadth does not correspond to the magnitude of the important value. This phenomenon indicates that the number of preferred species under the comprehensive indicator is not necessarily uniform in each sample (table 2).
Table 2. Species composition and niche breadth of shrub layers under different site types.

| Numbering | Shrub species                          | Leeeward slope | Windward slope | Hilly land |
|-----------|---------------------------------------|----------------|----------------|------------|
|           |                                       | Pi  | B1   | B2   | Pi  | B1   | B2   | Pi  | B1   | B2   |
| 1         | *Ostryopsis davidiana*                | 32.3| 2.38 | 2.13 | 2.00| 1.92 | 0.39 | 1.39| 1    | 0.16 |
| 2         | *Spiraea trilobata*                   | 6.69| 1.88 | 0.98 | -   | 38.67| 2.35 | 0.93|      |      |
| 3         | *Spiraea pubescens*                   | 35.6| 6.43 | 2.78 | 3.76| 1.27 | 0.55 | 0.76| 1    | 0.16 |
| 4         | *Viburnum mongolicum*                 | 3.25| 2.16 | 0.69 |     |      |      |     |      |      |
| 5         | *cotoneaster acutifolius*             | 0.83| 1    | 0.19 |     |      |      |     |      |      |
| 6         | *Kochia prostrata*                    | 1.60| 3.77 | 0.67 | 1.49| 2.42 | 0.72 | 16.32| 3.31 | 0.87 |
| 7         | *Rosa davurica*                       | 4.93| 1.97 | 1.14 |     | 22.47| 1.66 | 0.99|      |      |
| 8         | *Ribes diacanthum*                    | 2.45| 4.19 | 0.58 | 9.07| 4.00 | 1.38 | 2.62| 1    | 0.26 |
| 9         | *Ribes pulchellum*                    | 1.99| 1.83 | 0.45 | 4.36| 2.44 | 1.21 | 6.22| 1.18 | 0.53 |
| 10        | *Prunus sibirica*                     | 1.80| 1.49 | 0.38 | 43.6| 2.34 | 2.19 | 5.83| 1    | 0.33 |
| 11        | *Cotoneaster melanocarpus*            | 1.00| 1    | 0.19 |     |      |      |     |      |      |
| 12        | *Lonicera chrysantha*                 | 2.34| 1.54 | 0.54 |     |      |      |     |      |      |
| 13        | *Rhamnus parvifolia*                  | 0.47| 1    | 0.15 |     |      |      |     |      |      |
| 14        | *Rhamnus parvifolia*                  | 0.46| 1    | 0.17 |     |      |      |     |      |      |
| 15        | *Berberis poiretii*                   | 3.57| 1.99 | 0.57 | 1.05| 1    | 0.19 |     |      |      |
| 16        | *Berber amurensis*                    | 0.65| 1    | 0.18 |     |      |      |     |      |      |
| 17        | *Hedysarum laeve*                     |     |      |      | 4.58| 1.81 | 0.74 | 1.82| 1    | 0.22 |
| 18        | *Salix gordejevii*                    |     |      |      | 29.6| 2.24 | 1.24 | 3.92| 1    | 0.31 |
| 19        | *Salix microstachya*                  |     |      |      | 0.42| 1    | 0.18 |     |      |      |

Note: Pi is an important value.

3.2. Niche overlap

3.2.1. The niche overlap of the arbor layer on the three site resources

When different species share the same resource, the phenomenon of niche overlap occurs. When the niche is completely the same, it means that the natural resources of the species are exactly the same. However, in nature, most species only have partial overlap, and there are no species with the same resources [16].

The overlap value of the arbor layer on the leeward slope, the windward slope and the inter-hill land is between 0 and 0.55. The pair with the higher overlap value of the leeward slope is B. platyphylla×Q. mongolica (0.46), B. platyphylla×P. padus (0.45), B. platyphylla×P. davidiana (0.42), P. padus×M. baccata (0.50), P. padus×U. pumila (0.43), P. padus×C. sanguinea (0.55), M. baccata×U. pumila (0.45) (table 3); the niche of each plant species on the windward slope has no overlap (table 4); M. baccata×U. pumila has a small overlap on the inter-hill land (table 5). Plant species with larger niches are not necessarily overlapping, such as B. Platyphylla×M. baccata (0.19) and M. baccata×U. pumila (0.17), indicating...
resource requirements for species with a wide niche not high. Plant species with narrow niche, such as *C. sanguinea* and *P. davidiana*, *Q. mongolica* and *M. baccata*, have an overlap value of 0, indicating that there is no common resource demand and are distributed in a specific environment; however, the niche is narrow. The overlap values between species are not necessarily 0, and the overlap index between *U. pumila* and *C. sanguinea* reaches 0.32, and the species with similar resource requirements will overlap.

### Table 3. The niche overlap of arbor layer plant species on the leeward slope.

| Species number | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|----------------|-------|-------|-------|-------|-------|-------|-------|
| 1              | 1.00  |       |       |       |       |       |       |
| 2              | 0.46  | 1.00  |       |       |       |       |       |
| 3              | 0.45  | 0.27  | 1.00  |       |       |       |       |
| 4              | 0.19  | 0.30  | 0.50  | 1.00  |       |       |       |
| 5              | 0.10  | 0.16  | 0.43  | 0.45  | 1.00  |       |       |
| 6              | 0.08  | 0.07  | 0.55  | 0.26  | 0.32  | 1.00  |       |
| 7              | 0.42  | 0.10  | 0.00  | 0.07  | 0.00  | 0.00  | 1.00  |

### Table 4. The niche overlap of arbor layer plant species on the windward slope.

| Species number | 2     | 4     | 5     |
|----------------|-------|-------|-------|
| 2              | 1.00  |       |       |
| 4              | 0.00  | 1.00  |       |
| 5              | 0.00  | 0.00  | 1.00  |

### Table 5. The niche overlap of arbor layer plant species on the hilly land.

| Species number | 2     | 4     | 5     |
|----------------|-------|-------|-------|
| 2              | 1.00  |       |       |
| 4              | 0.00  | 1.00  |       |
| 5              | 0.00  | 0.17  | 1.00  |

#### 3.2.2. The niche overlap of shrub layers on three site resources

According to the analysis, the proportion of shrub species in the leeward slope between 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 and 0.8-1.0 is 64.17%, 22.50%, 7.5%, 5 respectively, 0.83% (table 6); the proportion of the windward slope is 68.89%, 6.67%, 17.78%, 4.44% and 2.22% (table 7); the inter-mountain land is 68.89%, 13.33%, 2.22%, 2.22% and 13.33% (table 8). The overall level of interspecific shrub overlap in the study area is small, concentrated in the range of 0-0.2, indicating that these species differ in the way they use resources. Among them, there are a total of 7 pairs of *Rhamnus parvifolia × Rhamnus parvifolia*, *R. diacanthum*, *P. sibirica*, *Hedysarum laeve*, and *S. gordejevii*, indicating that the same genus has more environmental requirements in the leeward slope environment. Similar, the overlap value is higher; in the windward slope, due to the ecological characteristics of the four plants and the demand for light, temperature, moisture and other factors, they completely overlap each other. However, *Berberis poiretii* and *Berberis amurensis*, *Spiraea trilobata* and *S. pubescens*, *S. gordejevii* and *Salix microstachya*, *Cotoneaster acutifolius* and *Cotoneaster melanocarpus*, *Ribes pulchellum* and *R. diacanthum* are also plants of the same genus, with niche overlap values of 0.46, 0.49 (0.50), (0.01), 0.56 (0.41) (in parentheses, the inter-ecological niche overlap value of plants on the windward slope or inter-hillland). It shows that the same genus plants do not...
necessarily have a high overlap, and the same ecological characteristics will also result in the differentiation of resource needs.

### Table 6. The niche overlap of shrub species on the leeward slope.

| Species number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1              | 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 2              |     | 0.08| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3              |     | 0.22| 0.49| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |
| 4              |     | 0.30| 0.08| 0.29| 1.00|     |     |     |     |     |     |     |     |     |     |     |
| 5              |     | 0.06| 0.07| 0.19| 0.63| 1.00|     |     |     |     |     |     |     |     |     |     |
| 6              |     | 0.31| 0.49| 0.56| 0.27| 0.14| 1.00|     |     |     |     |     |     |     |     |     |
| 7              |     | 0.12| 0.27| 0.37| 0.06| 0.00| 0.26| 1.00|     |     |     |     |     |     |     |     |
| 8              |     | 0.45| 0.25| 0.30| 0.33| 0.00| 0.32| 0.42| 1.00|     |     |     |     |     |     |     |
| 9              |     | 0.11| 0.28| 0.22| 0.23| 0.00| 0.07| 0.32| 0.56| 1.00|     |     |     |     |     |     |
| 10             |     | 0.18| 0.24| 0.21| 0.08| 0.00| 0.08| 0.79| 0.43| 0.29| 1.00|     |     |     |     |     |
| 11             |     | 0.63| 0.00| 0.03| 0.10| 0.00| 0.21| 0.06| 0.24| 0.00| 0.08| 1.00|     |     |     |     |
| 12             |     | 0.06| 0.00| 0.19| 0.00| 0.00| 0.17| 0.17| 0.08| 0.00| 0.00| 0.00| 1.00|     |     |     |
| 13             |     | 0.06| 0.00| 0.08| 0.00| 0.00| 0.00| 0.01| 0.00| 0.00| 0.00| 0.00| 0.77| 1.00|     |     |
| 14             |     | 0.06| 0.00| 0.08| 0.00| 0.00| 0.00| 0.01| 0.00| 0.00| 0.00| 0.00| 0.77| 1.00| 1.00|     |
| 15             |     | 0.01| 0.24| 0.28| 0.00| 0.00| 0.17| 0.70| 0.32| 0.29| 0.54| 0.00| 0.23| 0.00| 0.00| 1.00|
| 16             |     | 0.01| 0.00| 0.11| 0.00| 0.00| 0.17| 0.16| 0.08| 0.00| 0.00| 0.23| 0.00| 0.00| 0.46| 1.00|

### Table 7. The niche overlap of shrub species on the windward slope.

| Species number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1              | 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3              |     | 0.52| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 6              |     | 0.00| 0.00| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |
| 8              |     | 0.41| 0.41| 0.17| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |
| 9              |     | 0.48| 0.50| 0.02| 0.41| 1.00|     |     |     |     |     |     |     |     |     |     |     |
| 10             |     | 0.10| 0.10| 0.17| 0.54| 0.15| 1.00|     |     |     |     |     |     |     |     |     |     |
| 15             |     | 0.40| 0.88| 0.00| 0.33| 0.42| 0.02| 1.00|     |     |     |     |     |     |     |     |     |
| 17             |     | 0.19| 0.12| 0.00| 0.11| 0.18| 0.14| 0.00| 1.00|     |     |     |     |     |     |     |     |
| 18             |     | 0.06| 0.06| 0.40| 0.60| 0.06| 0.63| 0.00| 0.06| 1.00|     |     |     |     |     |     |     |
| 19             |     | 0.00| 0.00| 0.00| 0.09| 0.00| 0.03| 0.00| 0.00| 0.01| 1.00|     |     |     |     |     |     |

### Table 8. The niche overlap of shrub species on the hilly land.

| Species number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1              | 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 2              |     | 0.02| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3              |     | 0.00| 0.50| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 6              |     | 0.26| 0.11| 0.04| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |     |
| 7              |     | 0.74| 0.04| 0.01| 0.27| 1.00|     |     |     |     |     |     |     |     |     |     |     |     |
| 8              |     | 0.00| 0.00| 0.00| 0.00| 0.24| 1.00|     |     |     |     |     |     |     |     |     |     |
| 9              |     | 0.00| 0.07| 0.00| 0.05| 0.08| 0.08| 1.00|     |     |     |     |     |     |     |     |     |     |
| 10             |     | 0.00| 0.00| 0.00| 0.00| 0.24| 1.00| 0.08| 1.00| 1.00|     |     |     |     |     |     |     |     |
| 17             |     | 0.00| 0.00| 0.00| 0.00| 0.24| 1.00| 0.08| 1.00| 1.00| 1.00|     |     |     |     |     |     |     |
| 18             |     | 0.00| 0.00| 0.00| 0.00| 0.24| 1.00| 0.08| 1.00| 1.00| 1.00| 1.00|     |     |     |     |     |     |

3.3. Interspecies association

3.3.1. Inter-species association of arbor layer plants
\( \chi^2 \) test can determine the correlation between two species and measure the degree of association. It can be seen that the correlation among the species in the arbor layer is not significant. The leeward slope consists of 21 species consisting of 7 species, 8 pairs of positive linkages, 7 pairs of negative linkages, and 6 pairs of no correlations, accounting for 38.10% and 33.33% of the total logarithm, respectively. 28.57%. Among them, \( B. platyphylla \) is not associated with other plant species. This is because \( B. platyphylla \) appears in all the survey samples, so the test results are uncertain and do not represent the actual connection with other species (figure 1). The three plants in the windward slope are negatively connected, indicating that the arbor species are mutually exclusive in this habitat, and the demand for habitats is inconsistent. The side reflects that there is no overlap of the three niches (figure 2). \( Q. mongolica \) is negatively associated with \( M. baccata \) and \( U. pumila \), and positively connected between \( M. baccata \) and \( U. pumila \) on the hilly land, reflecting the greater interspecific competition between the stalk and the eucalyptus (figure 3).

**Figure 1.** Corrected \( \chi^2 \) test half matrix of arbor layer on the leeward slope.

|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----|---|---|---|---|---|---|---|
| 1  |   |   |   |   |   |   |   |
| 2  |   |   |   |   |   |   |   |
| 3  |   |   |   |   |   |   |   |
| 4  |   |   |   |   |   |   |   |
| 5  |   |   |   |   |   |   |   |
| 6  |   |   |   |   |   |   |   |
| 7  |   |   |   |   |   |   |   |

(Figure 2. Corrected \( \chi^2 \) test half matrix of arbor layer on the windward slope.

(Figure 3. Corrected \( \chi^2 \) test half matrix of arbor layer on the hilly land.

(legend: + \( p \geq 0.05 \); - \( p \geq 0.05 \); blank is no association.)

3.3.2. Shrub layer plant interspecific

The interspecific association of shrub communities under three site types is different. Under the leeward slope, there are 120 species of 16 species of shrubs, 46 pairs of positive associations, accounting for 38.33% of the total; 53 pairs of negative associations, accounting for 44.17% of the total; 21 pairs of unrelated species occupying 17.50%. The number of negative connections on the whole is greater than the positive connection, indicating that most of the leeward shrubs are repulsive. Among them, \( V. mongolicum \) and \( R. davurica \) have a significant negative correlation, the existence of one plant is not conducive to the growth of another plant, and the ecology is the embodiment of separation; while \( S. pubescens \) is present in all the samples and other plants. The correlation degree in this test is 0 (figure 4). The logarithm of plant species that are positively connected to the windward slope and the inter-hill zone account for more than 50% of the total, slightly higher than the logarithm of the negative linkage species. In the windward slope, \( O. davidiana \times S. pubescens, R. diacanthum \times S. gordejevii \) is a significant positive linkage, indicating that the
two plant species have similar ecological characteristics to each other, have a convergent reflection on the ecological environment, and have a high niche overlap (figure 5); the species of plants that have no connection relationship between the mounds are *Kochia prostrata* × *Rosa davurica*, *K.prostrata* × *R. pulchellum*, the relationship between the two species is neutral or irrelevant on the hilly land; *R. davurica* (except *K. prostrata*) and the species All are positively related and have strong adaptability due to their wide niche (figure 6).

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | +  | +  | +  | -  | -  | +  | -  | +  | +  | +  | -  | -  | -  | +  | +  | +  |

**Figure 4.** Corrected \( \chi^2 \) test half matrix of shrub layer on the leeward slope.

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|   | ▲  | -  | -  | +  | -  | -  | +  | -  | -  | +  | -  | +  | -  | +  | -  | +  |

**Figure 5.** Corrected \( \chi^2 \) test half matrix of shrub layer on the windward slope.  
(Note: + \( p \geq 0.05 \); -\( p \geq 0.05 \); blank is uncorrelated; ▲ significant positive
4. Discussion

The niche is the use of resources by species [17]. It is generally believed that the wider the niche, the stronger the ability of the species to adapt to the environment, and the species is often accompanied by a higher niche overlap [18]. On the contrary, species with smaller niche width have weaker ability to utilize resources and lower niche overlap. In a mature community, there should be a strong positive correlation between species, multiple species can coexist stably, and the niche similarity proportion value and overlap value between species with larger niche width are larger, which is easier to produce competition. The research shows that the average overlap of the arbor layer in the three subterranean niches are 0.25, 0.00, 0.06, that is, the overall level of inter-species overlap of the leeward slope > inter-mountain land > windward slope. B. platyphylla has a high niche breadth and a wide distribution range, so it has a higher niche overlap with other species.; the niche breadth of P. padus is narrow, but there is also a high degree of overlap with many plant species, indicating that P. padus had a high similarity with other plant species in the living environment and was easy to compete with other species. In the shrub layer, the niche-niche species show less overlap; except for the windward slope, the niche-wide species overlaps less. However, it is not completely absolute; Q. mongolica and M. baccata are positively associated with more arbor species in the arbor layer, indicating that the habitat requirements of Q. mongolica and M. baccata are similar to those of other plant species, to a certain extent, it reflects that the species has a wide niche breadth and a wide distribution range.. The K. prostrata in the shrub layer is negatively associated with all plant species and competes with other species, the niche overlap is small. The determination of the degree of spatial association of different individuals is meaningful for studying the interaction of the two species and the composition and dynamics of the community. Positive associations may indicate that the existence of interactions between populations is beneficial to one or both parties. Negative linkages indicate interaction mechanisms between populations that are not conducive to one or both species. In heterogeneous environments, negative linkages may reflect different population pairs. In heterogeneous environments, negative linkages can reflect the adaptation and response of different populations to different parts of the environmental conditions. Therefore, in an environment where uncertain factors occur, a large amount of monitoring and analysis is still needed in the future, and further information is obtained to further study the interspecies relationship of community species, and to explore the interdependence and mutual restriction of ecological relationships among different plant species. It will further lay the foundation for the vegetation protection and long-term development of Hulunbeier Sandy Land.
5. Conclusion

There is a certain degree of correlation between niche breadth and important value, but not one-to-one correspondence. There is no linear correlation between plant species niche breadth and niche overlap. Although there are certain correlations among the species in the Hunshandake Sandy Land, the relationship is relatively loose and the whole is in an unstable stage.

The plant species with relatively wide niche in the three types of site types in the eastern margin of Hunshandake Sandland are: *Q. mongolica* (*B. platyphylla*), *M. baccata* + *S. pubescens*, *R. diacanthum* (*O. davidiana*) of the leeward slope; *U. pumila* + *R. diacanthum* and *S. apricot* (*R. pulchellum*) on the windward slope; *U. pumila* and *M. baccata* + *S. trilobata*, *R. davurica* (*K. prostrata*) on the hilly land.

The niche overlap of trees and shrub layers on different site resources is different. The combination of the leeward slope niche overlap is *B. platyphylla* and *M. baccata* + *S. pubescens*, *O. davidiana*; *U. pumila* + *R. pulchellum*, *K. prostrata* on the windward slope; the hilly land for *M. baccata*, *U. pumila* + *S. trilobata*.

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