Post-Print on Differences in Rainfall Redistribution between Pure Shrub Forest and Willow Bay Forest under Simulated Rainfall Conditions

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Abstract

The natural shrub mixed forest in the Mu Us Sandy Land, also known as Liuwan Forest, constitutes a unique shrub community type in sandy regions. Currently, research on rainfall redistribution in Liuwan Forest communities versus pure stands remains scarce, hindering elucidation of differential water competition between these community types. This study examined pure stands of Salix psammophila and Hippophae rhamnoides, along with Liuwan Forest, employing artificial rainfall simulation to simultaneously monitor rainfall redistribution processes across different stands and quantitatively analyze relationships between rainfall characteristics and redistribution patterns. Results indicated that effective rainfall in Salix psammophila pure stands, Hippophae rhamnoides pure stands, and Liuwan Forest was 18.58 mm, 21.14 mm, and 20.25 mm, respectively, accounting for approximately 85.46%, 97.24%, and 93.15% of total rainfall. Canopy interception loss was 3.15 mm, 0.60 mm, and 1.49 mm, respectively, representing approximately 15.69%, 3.60%, and 7.31% of total rainfall. The spatial distribution characteristics of throughfall differed significantly among the three stand types; Liuwan Forest exhibited uniformly demarcated zones of "rain poles,""dry poles,"and "intermediate poles"in its throughfall spatial pattern, whereas pure stands of Salix psammophila and Hippophae rhamnoides displayed relatively homogeneous throughfall distribution. Rainfall redistribution processes in all three stands increased with rainfall amount, but tended to stabilize as canopy interception capacity approached saturation. By integrating the morphological and structural characteristics of both Salix psammophila and Hippophae rhamnoides, Liuwan Forest demonstrates enhanced stability maintenance under complex and variable environmental conditions, thereby ensuring ecological balance and stability within Liuwan Forest communities.

Differences in Rainfall Redistribution Between Pure Shrub Forests and Willow Bay Based on Artificial Rainfall Simulation

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Abstract

The natural mixed shrub forest in the Mu Us Sandy Land, also known as Willow Bay, is a unique shrub community type in sandy regions. Currently, research on precipitation dynamics in Willow Bay communities compared with pure forest stands remains relatively scarce, making it difficult to reveal differences in water competition between these community types. This study focused on *Salix psammophila*, *Hippophae rhamnoides* pure forests, and Willow Bay. Using artificial rainfall simulation, we simultaneously monitored rainfall redistribution processes across different forest stands and quantitatively analyzed the relationships between rainfall characteristics and redistribution patterns. The results showed that effective rainfall for *S. psammophila*, *H. rhamnoides*, and Willow Bay was 18.58 mm, 21.14 mm, and 20.25 mm, accounting for approximately 85.46%, 97.24%, and 93.15% of total rainfall, respectively. Canopy interception losses were 3.15 mm, 0.60 mm, and 1.49 mm, accounting for approximately 15.69%, 3.60%, and 7.31% of total rainfall, respectively. Significant differences were observed in the spatial distribution of throughfall among the three forest types. In Willow Bay, the spatial distribution of throughfall was more evenly divided into "rain extreme," "drought extreme," and "intermediate" zones, whereas the distributions in *S. psammophila* and *H. rhamnoides* pure forests were more uniform. The rainfall redistribution processes in all three forest types increased with greater rainfall amounts, but these changes tended to stabilize as canopy interception capacity approached saturation. By combining the morphological and structural characteristics of *S. psammophila* and *H. rhamnoides*, Willow Bay demonstrated better stability under complex and variable environmental conditions, thereby ensuring ecological balance and stability within the Willow Bay community.

Keywords: Willow Bay; pure shrub forest; rainfall redistribution; simulated rainfall; Mu Us Sandy Land

Introduction

Rainfall redistribution by vegetation constitutes a crucial component of water cycling in atmospheric systems, directly influencing material and energy exchange in forest hydrological processes and consequently affecting biodiversity and ecosystem functionality. The vegetation canopy partitions rainfall into three components: throughfall, stemflow, and canopy interception. Throughfall refers to rainfall that passes through the vegetation canopy and reaches the ground surface, including free throughfall that drops through gaps between branches and leaves and non-free throughfall that drips after being intercepted by foliage. Throughfall accounts for approximately 70%-80% of total rainfall and directly influences soil moisture distribution beneath vegetation. Stemflow is rainfall that flows down along leaves and stems, converges at the base of vegetation, and ultimately reaches deep soil layers. Although small in quantity, it affects the vertical distribution of soil moisture around plant roots. Throughfall and stemflow together constitute effective rainfall, which represents the amount of rainfall available for vegetation use after a rainfall event. Canopy interception represents the portion of rainfall intercepted and stored by the canopy, with a small fraction retained as leaf water and the majority lost to evaporation after rainfall, representing a net water loss during rainfall events. Canopy interception extends the time for precipitation to reach the ground surface or causes partial evaporation from the canopy, thereby reducing soil erosion. Therefore, studying rainfall redistribution processes in shrubs is essential for understanding shrub water utilization and the ecohydrological processes in desert steppe regions.

Shrubs are the main vegetation type in sandy areas. Shrub forests composed of a single species are called pure shrub forests, while those composed of two or more species are called mixed shrub forests. The natural mixed shrub forest in the Mu Us Sandy Land is also known as Willow Bay. Willow Bay is a highly stable ecosystem formed through long-term comprehensive effects of multiple factors, with *Salix psammophila* and *Hippophae rhamnoides* as the dominant species distributed in clusters and patches covering areas of 200–5000 m^2. Natural Willow Bay maintains the fragile compound ecological balance in the Mu Us region with its tenacious character and plays an important ecological role in curbing land desertification. *S. psammophila* prefers warmth and cold tolerance, is sand and alkali resistant, reproduces easily, and has strong sprouting ability. Due to its underdeveloped taproot and interwoven lateral roots, it often climbs sand dunes, forming a vast surface root network that provides excellent sand fixation. *H. rhamnoides* has dense thickets and well-developed root systems, forming "an umbrella above ground, a blanket on the surface, and a net underground." Its roots sprout and sucker vigorously, with strong nitrogen fixation ability that can improve soil structure and provide nutrients for other plants. According to Chinese forestry industry standards, shrubs need to be rejuvenated by cutting after reaching a certain age. Therefore, even in pure shrub forests, canopy structure, leaf area index, basal diameter, branch quantity, and branch angle differ, resulting in varying precipitation interception capacities, which complicates accurate estimation of water regulation and comprehensive water source conservation functions at the stand level.

Rainfall redistribution in shrub thickets is a dynamic and complex process influenced by multiple factors including rainfall characteristics, vegetation structure, and meteorological conditions. Rainfall characteristics mainly include rainfall amount, intensity, and duration. Many studies have shown that throughfall, stemflow, and canopy interception all increase with rainfall amount. However, due to canopy structure and other factors, the relationship between rainfall redistribution characteristics and rainfall amount is not constant. In terms of vegetation structure, plant basal diameter, branch quantity, and branch angle affect the amount of throughfall and stemflow. Canopy thickness, closure, and leaf area index influence canopy interception. Meteorological conditions mainly include wind speed, temperature, and humidity. Most previous research has focused on individual shrubs. The clustered "above-ground aggregation" characteristic of Willow Bay communities inevitably leads to interwoven branches among shrubs, with leaf area index, canopy closure, and canopy saturated water capacity necessarily greater than those of scattered shrubs. Therefore, the coupling effect of Willow Bay shrub communities on precipitation redistribution cannot be ignored. To better understand the role of Willow Bay in rainfall redistribution, this study examined *S. psammophila* and *H. rhamnoides* to explore the regulation and impact of different forest types on precipitation.

This study selected *S. psammophila* and *H. rhamnoides* as research subjects, establishing three observation groups: *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay. Using artificial rainfall simulation, we observed shrub morphological structure, rainfall characteristics, and rainfall redistribution processes, and analyzed rainfall redistribution patterns and their proportions in different forest stands, as well as their relationships with rainfall characteristics. This research aims to reveal rainfall redistribution patterns in different forest types, provide basic data support for further study of the ecohydrological effects of Willow Bay, and promote vegetation restoration and ecological construction in Willow Bay.

1.1 Study Area Overview

The study area is located in Uxin Banner, Ordos City, Inner Mongolia Autonomous Region, in the hinterland of the Mu Us Sandy Land (38°36 N, 108°49 E). Uxin Banner lies on the edge of the southern monsoon region in the north temperate zone, with an extreme continental climate strongly influenced by the Mongolian high-pressure system and controlled by northwest cold air for extended periods. Precipitation is scarce, with a multi-year average of 353 mm, concentrated in July-September (70%-80% of annual precipitation). The area is windy with strong evaporation, with an average annual wind speed of 3.4 m ·

s^{-1} and average annual evaporation of 2322 mm. Sunshine is abundant, with annual sunshine hours of 2800 h and an average daily temperature difference of 13.3°C. The vegetation consists mainly of typical steppe and desert steppe, with soils dominated by chestnut soils accompanied by small areas of brown calcic soils. The main natural shrub species include *Salix psammophila*, *Salix cheilophila*, *Hippophae rhamnoides*, *Caragana korshinskii*, *Artemisia desertorum*, and *Corethrodendron fruticosum.* Willow Bay communities are mainly distributed in inter-dune lowlands, with *S. psammophila* and *H. rhamnoides* as the dominant species.

1.2 Sample Selection

Considering the need to simulate rainfall redistribution in *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay under artificial rainfall conditions, sample trees of the same species were selected with the same age and similar height, crown width, crown projection area, and basal diameter. The basic information of sample trees is shown in Table 1 .

1.3 Experimental Design

This study conducted artificial rainfall experiments on *S. psammophila*, *H. rhamnoides* pure forests, and Willow Bay using a rainfall simulation device manufactured by Nanjing Nanlin Electronic Technology Co., Ltd. The effective area of the rainfall device was approximately 3 m × 3 m, with a uniformity coefficient greater than 0.8, raindrop diameter of 1.5-3.0 mm, rainfall adjustment precision of 6-300 $\text{mm} \cdot \text{h}^{-1}$, and rainfall intensity range of 10-90 $\text{mm} \cdot \text{h}^{-1}$. A total of 9 artificial rainfall events were conducted. Before each experiment, yellow collection buckets were placed around sample trees to collect understory throughfall, small bottles were installed at tree bases to collect stemflow, and 3 blue rain gauges were used to collect external rainfall. After rainfall began, throughfall in yellow collection buckets and stemflow in bottles were measured at 30 min, 60 min, and 90 min. After each experiment, canopy interception was estimated using the water balance principle. Figure 1 [Figure 1: see original paper] shows the layout of sample trees and collection buckets. All measurement tools, including rain gauges and rulers, were of uniform specifications.

1.4 Throughfall Measurement and Calculation

Before the experiment, yellow collection buckets were evenly distributed within the forest stand. After rainfall, the rainfall volume in each bucket was measured using a graduated cylinder. The throughfall for each rainfall event was obtained by calculating the weighted average of rainfall collected in each bucket using the following formula:

$$TF = \frac{\sum_{i=1}^{m}(V_i \times 10)}{m \times FA}$$

where TF is throughfall (mm), V_i is the rainfall volume in the i-th collection bucket (mL), m is the number of collection buckets under the sample tree, and FA is the cross-sectional area of the collection bucket (cm^2).

1.5 Stemflow Measurement and Calculation

Small stemflow collection bottles were evenly fitted at the base of sample tree trunks, ensuring the trunk was centered in the bottle. Hot melt adhesive was used to seal the junction between the tree and bottle to prevent leakage, and the sealing was checked regularly. After each rainfall event, the stemflow volume in the bottle (mL) was measured immediately using a graduated cylinder. The stemflow volume for the entire shrub was estimated by multiplying the stemflow from a standard branch by the total number of branches on the shrub. The stemflow calculation formula was:

$$SF = \frac{VS \times 1000}{SP}$$

where SF is stemflow (mm), VS is the total stemflow volume of the shrub (mL), and SP is the canopy projection area of the shrub (m^2).

1.6 Canopy Interception Measurement and Calculation

Since canopy interception is difficult to measure directly, it is generally estimated using the water balance principle as the difference between rainfall above the canopy and effective rainfall below the canopy. Effective rainfall is the sum of throughfall (TF) and stemflow (SF). Therefore, canopy interception (IL) and canopy interception rate (I) were calculated as:

$$IL = P_g - N$$

$$I = \frac{IL}{P_g} \times 100\%$$

where IL is canopy interception (mm), P_g is rainfall outside the forest (mm), and N is effective rainfall (mm).

2.1.1 Differences in Throughfall Among Forest Types and Relationship with Rainfall

Through regression analysis and curve fitting (Figure 2 [Figure 2: see original paper]), the relationship between throughfall and rainfall in different forest stands was analyzed. Results showed that throughfall in each forest stand had a linear relationship with rainfall, with high goodness-of-fit (large R^2 values), indicating that throughfall increased with rainfall amount. Under the same rainfall conditions, throughfall differed among forest types as follows: *H. rhamnoides* pure forest > Willow Bay > *S. psammophila* pure forest. *H. rhamnoides* branches consist mainly of needle-shaped leaves and thorns, with smaller leaf area index and canopy closure, resulting in weaker interception capacity and thus greater throughfall. *S. psammophila* has a higher leaf area index, resulting in relatively lower throughfall. Willow Bay, influenced by both *S. psammophila* and *H. rhamnoides*, had throughfall intermediate between the two pure forests.

2.1.2 Throughfall Rate and Relationship with Rainfall

During the artificial rainfall simulation period, throughfall rates in the three forest stands ranged from 76.61%-83.64% for *S. psammophila* pure forest, 82.80%-91.07% for *H. rhamnoides* pure forest, and 78.57%-85.56% for Willow Bay. Under the same rainfall conditions, throughfall rates followed the pattern: *H. rhamnoides* pure forest > Willow Bay > *S. psammophila* pure forest. The relationship between throughfall rate and rainfall was basically logarithmic, indicating that throughfall rate increased with rainfall amount but the rate of increase gradually leveled off, likely due to the canopy' s water-holding capacity gradually approaching saturation. Willow Bay did not show this obvious trend, possibly because its more complex canopy structure could maintain a relatively stable throughfall rate even as rainfall increased. Meanwhile, because throughfall rate is subject to interference from external conditions such as wind speed and direction, the fitted R^2 values were not particularly high.

2.1.3 Spatial Distribution Characteristics of Throughfall

Research shows that the spatial distribution of throughfall among different forest stands exhibits significant spatial heterogeneity. Based on field studies, areas with throughfall rates below 76% were designated as "drought extreme" zones, areas above 92% as "rain extreme" zones, and areas between 76%-92% as "intermediate" zones. Throughfall rates in all three forest stands showed a gradual increase from shrub base to periphery. Among them, Willow Bay had more evenly divided boundaries between "rain extreme," "drought extreme," and "intermediate" zones, while *S. psammophila* and *H. rhamnoides* pure forests had more uniform spatial distributions. In comparison, *S. psammophila* pure forest showed stronger rainfall interception capacity than *H. rhamnoides* pure forest.

2.2.1 Differences in Stemflow Among Forest Types and Relationship with Rainfall

Through regression analysis and curve fitting (Figure 5 [Figure 5: see original paper]), results showed that stemflow in each forest stand had a linear relationship with rainfall, with good goodness-of-fit (large R^2 values), indicating that stemflow increased with rainfall amount. Under the same rainfall conditions, stemflow followed the pattern: Willow Bay > *H. rhamnoides* pure forest > *S. psammophila* pure forest. Willow Bay showed obvious advantages in stemflow, likely related to its mixed forest canopy structure. The irregular overlapping of branches and leaves from different tree species may promote rainwater convergence and flow, thereby supplementing root water. In contrast, *H. rhamnoides* pure forest, with smoother branches and weaker rainfall interception by foliage, had greater stemflow than *S. psammophila* pure forest.

2.2.2 Stemflow Rate and Relationship with Rainfall

Stemflow rates in *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay ranged from 0%-8.33%, 5.26%-10.89%, and 6.14%-8.08%, respectively. Under the same rainfall duration conditions, Willow Bay had the highest stemflow rate. The relationship between stemflow rate and rainfall showed a logarithmic function, with stemflow rate first increasing and then stabilizing as rainfall increased. *S. psammophila* pure forest showed good fitting, while Willow Bay and *H. rhamnoides* pure forest showed poorer fitting. This trend may be due to the gradual enhancement of water convergence capacity of branches and leaves as rainfall increased, while the water-holding capacity of foliage gradually saturated, causing water convergence to stabilize. Due to canopy interception effects, *S. psammophila* pure forest produced almost no stemflow in the early stages of rainfall, with initial stemflow rate approaching 0, while *H. rhamnoides* pure forest showed small increases in stemflow rate with rainfall, and Willow Bay had significantly higher stemflow rates than pure forests, indicating that stemflow rate is significantly affected by forest composition, with different forest types producing varying degrees of stemflow.

Additionally, during the initial rainfall stage (within 5 min), *S. psammophila* pure forest did not produce obvious stemflow, while *H. rhamnoides* pure forest and Willow Bay produced some stemflow, indicating that *S. psammophila* pure forest has a higher rainfall threshold for stemflow generation, likely influenced by canopy closure, canopy structure, and species differences.

2.3.1 Differences in Canopy Interception Among Forest Types and Relationship with Rainfall

Through regression analysis and curve fitting (Figure 7 [Figure 7: see original paper]), canopy interception showed a linear relationship with rainfall, with good fitting (high R^2 values), indicating that canopy interception increased with rainfall amount. However, *H. rhamnoides* pure forest had lower R^2 values, possibly because its finer leaves are less stable and more susceptible to external factors like wind speed. Under the same rainfall conditions, canopy interception generally followed the pattern: *S. psammophila* pure forest > Willow Bay > *H. rhamnoides* pure forest, indicating that *S. psammophila* canopy structure more easily intercepts rainfall, while *H. rhamnoides*, with its needle-shaped leaf structure, is less prone to canopy interception. Willow Bay plays a balancing role, with a canopy structure that maintains certain leaf water-holding capacity while avoiding excessive rainfall interception and reducing water loss.

2.3.2 Canopy Interception Rate and Relationship with Rainfall

Canopy interception rates in *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay ranged from 13.09%-23.39%, 5.74%-11.59%, and 1.32%-7.74%, respectively. Under the same rainfall conditions, *S. psammophila* pure forest had the highest canopy interception rate and *H. rhamnoides* pure forest the lowest, likely due to comprehensive effects of leaf area index, canopy structure, and canopy closure. The relationship between canopy interception rate and rainfall showed a logarithmic function, with good fitting (high R^2), indicating that canopy interception rate gradually decreased and stabilized as rainfall increased. Meanwhile, vegetation canopy water-holding capacity is limited, and as rainfall increases, interception capacity gradually saturates, causing canopy interception rates in different forest stands to eventually stabilize at a constant value.

3.1 Rainfall Redistribution Characteristics of Different Stands

Throughfall directly affects soil moisture spatial distribution beneath shrub thickets. Analysis of the relationship between throughfall and rainfall in different forest stands showed linear relationships with high goodness-of-fit. Under the same rainfall conditions, *H. rhamnoides* pure forest had the largest throughfall, consistent with results from Zhao Hongliang et al. [22], indicating that greater throughfall in *H. rhamnoides* pure forest ensures more water reaches the soil, maintaining stable soil moisture. *S. psammophila* pure forest had smaller throughfall, which can further avoid surface runoff and soil erosion. Willow Bay, combining characteristics of both, maintained throughfall at an appropriate level. Therefore, different planting methods using pure or mixed shrub forests have varying effects on water conservation and windbreak sand fixation.

Stemflow directly affects the vertical distribution of soil moisture around shrub roots. In this study, stemflow under different forest stands showed linear relationships with rainfall, and under the same rainfall conditions, Willow Bay > *H. rhamnoides* pure forest > *S. psammophila* pure forest, consistent with results from Han Qingchi et al. [31]. Willow Bay demonstrated unique advantages in stemflow generation capacity, likely because the combined effects of *S. psammophila* and *H. rhamnoides* create more complex internal canopy conditions with interwoven branches that further converge rainwater to generate stemflow. *H. rhamnoides* branches are smoother than *S. psammophila*, which is more conducive to stemflow generation, thus its stemflow is greater than *S. psammophila* pure forest. Therefore, different forest stands have different capacities for converging water via stemflow, affecting surface soil and even root zone water distribution.

Rainfall intercepted by the canopy produces throughfall and stemflow collectively called effective rainfall. Among the three forest types, Willow Bay had the lowest proportion of throughfall in effective rainfall but the highest proportion of stemflow (Table 2). Overall, its effective rainfall accounted for a moderate proportion of external rainfall, indicating that Willow Bay shows a balance in rainfall redistribution. Its complex canopy structure increases the possibility of rainwater retention and redistribution, allowing more rainwater to reach the ground as stemflow rather than directly penetrating the canopy, thereby improving water use efficiency. This is significant for concentrated soil water replenishment and provides theoretical support for optimizing ecological management and water resource allocation in Willow Bay.

Canopy interception losses in *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay were 3.15 mm, 0.60 mm, and 1.49 mm, respectively, accounting for approximately 15.69%, 3.60%, and 7.31% of external rainfall. Some rainfall is intercepted by the canopy, with a small portion retained as leaf water and most lost to evaporation after rainfall. Larger canopy loss is unfavorable for maintaining soil moisture stability and groundwater recharge, while smaller canopy loss may lead to runoff and even soil erosion. Willow Bay' s moderate canopy interception loss can better regulate regional water balance. In areas requiring vegetation restoration like the Mu Us Sandy Land, mixed planting of multiple shrub species can ensure regional hydrological stability.

3.2 Spatial Distribution of Rainfall in Different Stands

Research on spatial distribution of throughfall in different stands shows significant spatial heterogeneity, consistent with conclusions from Li et al. [7] and Yang Xinguo et al. [28]. Throughfall spatial distribution in all three stands generally showed a gradual increase from shrub base to periphery, indicating gradually weakening rainfall interception capacity, consistent with Han Qingchi et al. [31]. Willow Bay showed evenly divided boundaries between "drought extreme," "rain extreme," and "intermediate" zones. Due to Willow Bay' s combination of *S. psammophila*' s "luxuriant branches and leaves" and *H. rhamnoides*' s "many thorns," its overall canopy structure is not uniform, resulting in significant spatial heterogeneity in throughfall distribution. *S. psammophila* pure forest, with wider leaves and luxuriant branches, has a relatively uniform canopy structure and more obvious rainfall interception effects, with less uniform boundaries between "drought extreme," "rain extreme," and "intermediate" zones, showing a more unified condition. *H. rhamnoides* pure forest, with narrower leaves compared to *S. psammophila*, has greater throughfall rates but a more uniform canopy structure than Willow Bay, thus not showing the distinct boundaries seen in Willow Bay. In summary, throughfall spatial distribution varies with stand composition, while stand age, rainfall characteristics, and other factors also affect it. Therefore, stand and rainfall characteristics should be considered comprehensively to evaluate regional throughfall spatial distribution.

3.3 Comparison of Effective Precipitation and Canopy Interception Loss Among Different Stands

ANOVA analysis of differences in effective rainfall and canopy interception loss among different stands showed no significant differences in effective rainfall among the three forest types (all $P > 0.05$), while canopy interception loss showed significant differences, with Willow Bay significantly higher than *S. psammophila* pure forest and *H. rhamnoides* pure forest ($P < 0.05$). This indicates that different forest types significantly affect water availability and interception loss during rainfall redistribution, providing a basis for optimizing stand structure and improving water resource use efficiency. Results further show that stand structure optimization has potential regulatory effects on rainfall use efficiency and water resource management. Although Willow Bay' s higher canopy interception reduces effective rainfall directly entering the soil, it may have ecological advantages in mitigating heavy rainfall erosion, improving water distribution, and preventing soil erosion. *S. psammophila* and *H. rhamnoides* pure forests, with lower interception capacity, are more suitable for promotion in areas requiring improved soil water infiltration and utilization. For different ecological objectives, stand type configuration and management strategies should be considered comprehensively to achieve rational regulation and utilization of regional water resources.

4 Conclusion

The rainfall redistribution process by vegetation has important impacts on regional hydrology and ecology. Through artificial rainfall simulation of rainfall redistribution processes in *S. psammophila* pure forest, *H. rhamnoides* pure forest, and Willow Bay, differences were found among different forest types. Willow Bay, by combining the morphological and structural characteristics of *S. psammophila* and *H. rhamnoides* pure forests, demonstrates remarkable effectiveness in maintaining soil moisture, replenishing groundwater, reducing surface runoff, and decreasing soil erosion. Therefore, during vegetation restoration and planting in the Mu Us Desert region, single shrub species should not be planted exclusively. Instead, mixed planting of multiple shrub species should be emphasized to maximize effects on windbreak sand fixation, soil and water conservation, and biodiversity maintenance.

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