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Sand-fixing effects of Caragana microphylla shrub in Horqin sandy land, North China

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Abstract In the semi-arid Horqin sandy land of north China, Caragana microphylla, a leguminous shrub, is the dominant plant species and is widely used in vegetation reestablishment programs to stabilize shifting sand. The sand-fixing effects of 6- and 11-year-old C. microphylla plantations were studied. The results showed that: 1) the wind velocity and sand transport rate in the plantation were less than those in dunes; 2) the air temperature in the plantation was lower than those in dunes. Relative humidity was higher and the soil temperature was lower, which benefits plant growth; 3) the physical and chemical characteristics of soil were improved to some extent over age. The porosity and percentage of tiny sand (diameter 0.05–0.1 mm) and clay particle (diameter < 0.05 mm) increased, bulk density in surface soil decreased, and saturated water-holding capacity improved. Organic C, total N, available N and available K content increased gradually, and soil fertility was enhanced.

Keywords Horqin sandy land, Caragana microphylla, sand-fixing effects, sand transport rate, microclimate

1 Introduction

Horqin region, located in the northern part of China, has been one of the most severe desertification areas in the agro-pastoral ecotone due to fragile eco-environments and improper management of land (Wu et al., 2002; Jiang and Liu, 2003). Restoring degraded ecosystems, maintaining the stability of environments and sustainable development are important issues of modern ecology (Ma, 2002). Many measures such as planting indigenous trees, shrubs and grasses adaptive to sandy land had been implemented in restoring degraded or fragile ecosystems in China since the 1980s, and some theoretical and practical results have been achieved preliminarily. Compared with trees, shrubs have some obvious advantages: needing less water, being more suitable for poor soil moisture and nutrient conditions, and having evident sand-fixing effects. Due to its advantages of cold-tolerance, drought-tolerance, poor-soil-tolerance and heat-tolerance, Caragana microphylla, a leguminous shrub with thorns, is widely distributed in the Horqin sandy land and has been a favored plant in vegetation reestablishment programs. Large areas of artificial C. microphylla shrubs were established to stabilize drifting sand in this region in recent decades. In this paper, C. microphylla shrubs, cultivated on shifting sand dunes in 1995 and 2000, were selected to investigate their sand-fixing effects, and also changes of wind velocity, sand transporting rate, microclimate, physical and chemical characteristics of soil. It is expected that the results will be useful in providing theoretical basis and practical guidance for restoring vegetation in arid and semi-arid regions.

2 Study area

The study site is located at Wulan’ao du village (43°02’N, 119°39’E), Wengniute County, west of the Horqin sandy land, Inner Mongolia, China. The climate of this region is semi-arid. The average annual temperature is 6.2 °C, and the non-frost period is 130 days. Annual precipitation is 340.5 mm with 70%–80% occurring during the growing season of May–September, and evaporation is 2200 mm. Average annual wind velocity is 4.5 m/s, with the frequent occurrence of gales (wind speeds ≥ 20 m/s)
in winter and spring. The landscape is characterized by gently undulating, shifting and half-shifting sand dunes with interdune depression. There are three types of soil: sandy soil, meadow soil, and saline-alkali soil. The original vegetation was the transitional type from forest to grass. However, the original vegetation has been greatly destroyed in the past several decades, and most has evolved into psammophyte and meadow vegetation (Liu and Zhao, 1996). The flora of Mongolia has the widest distribution and most species in this region.

3 Materials and methods

3.1 Materials

*C. microphylla* has been gradually planted on desertified lands in the experimental plots of the Wulan’aoitu Experimental Station of Desertification since the early 1980s. Planting was arranged in belts (row spacing 1 m × 1 m), and the orientation of the belts was perpendicular to the prevailing wind direction. Until 2006, an age series of 6- and 11-year-old *C. microphylla* plantations were distributed on sandy land surrounding the station. The descriptions of plots are shown in Table 1.

3.2 Methods

The research items and their methods mainly included: measuring wind velocity with an AVM-03 anemometer at different heights (30, 80 and 200 cm); measuring sand transport rate at the height of 0–40 cm from the surface; analyzing the changes in physical and chemical characteristics of soil at different depths (soil samples were collected from three random locations within each plot in April 2006) (ISSCAS, 1978). To find the relationship between microclimate and reestablishment of degraded vegetation, microclimate characteristics within each plot were investigated in June 2006, including air temperature and relative humidity (using a wet-and-dry bulb thermometer, which has been corrected by an Assmann psychrometer) at different heights (0 and 30 cm), and soil temperature at three depths (0, 5, and 10 cm). All statistical analyses were performed using the Microsoft Excel and SPSS11.5 software packages.

### Table 1 The habitats of plots

<table>
<thead>
<tr>
<th>plot</th>
<th>total coverage of vegetation</th>
<th>density of <em>C. microphylla</em>/trees·hm⁻²</th>
<th>mean height and crown size of *C. microphylla/cm</th>
<th>main plant species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shifting dunes</td>
<td>&lt; 5%</td>
<td>0</td>
<td>0</td>
<td>Artemisia austrocerata, Agriophyllum arenarium</td>
</tr>
<tr>
<td>6-year-old <em>C. microphylla</em></td>
<td>50%</td>
<td>6438</td>
<td>81</td>
<td>Artemisia halodendron, Corispermum candelabrum, Setaria viridis, Cynanchum sibiricum</td>
</tr>
<tr>
<td>11-year-old <em>C. microphylla</em></td>
<td>70%</td>
<td>7625</td>
<td>106 × 96</td>
<td>A. halodendron, C. candelabrum, S. viridis, C. sibiricum, Salsola ruhenica</td>
</tr>
</tbody>
</table>

4 Results and analysis

4.1 Wind-breaking and sand-fixing effects of *C. microphylla* shrubs

4.1.1 Wind-breaking effects

The wind velocity at each height of shifting dunes was set as 100% (Fig. 1). With the height decreasing, the wind-breaking effects of *C. microphylla* shrubs became more and more significant. Compared with shifting dunes, wind velocity passing through the 6- and 11-year-old *C. microphylla* shrubs at the height of 200, 80 and 30 cm decreased by 17.94%, 31.59%, 71.86% and 27.94%, 39.72%, 75.96%, respectively. These results indicated that vegetation cover had an obvious blocking effect on wind velocity near ground surface, and the effect was better for the 11-year-old shrubs.

4.1.2 Characteristics of wind-sand current structure

Fig. 2 shows the characteristics of wind-sand current structure at the height of 0–40 cm within different plots. Under the same wind velocity conditions, there was a significant difference in total and individual layer sand transport rates within different plots. The rates in the shifting dunes were faster than those in the 6- and 11-year-old *C. microphylla* shrubs; the 6-year-old shrubs had faster rates than 11-year-old shrubs. In the shifting dunes, the total sand transport rate in 6- and 11-year-old *C. microphylla* shrubs were 132.04, 2.22 and 1.15 g/(cm·h), respectively. The results showed that vegetation cover was an effective measure in controlling wind erosion.

The individual layer sand transport rate in the shifting sand dunes, 6- and 11-year-old *C. microphylla* shrubs were reduced sharply with an increase in vertical height. The relationship between sand transport rate (y, g/(cm·h)) and vertical height (x, cm) could be described by a negative exponential distribution \(y = ae^{-bx}\), where \(a\) and \(b\) are regression coefficients, and the correlation coefficients were 0.9932, 0.9331 and 0.9767, respectively.

4.2 Microclimate effects of *C. microphylla* shrubs

The development of shrubs can change soil and air temperature and the moisture condition of surface soil,