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Habitat Change and Plants Invasion in Great Engineering Protective System in Gurbantunggut Desert, China (2000-2009)

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Abstract: The great lined engineering in the hinterland of Gurbantunggut Desert, such as construction of highways and water channels etc. always make strong disturbance to the ground surface. In order to protect ecosystems and control blown-sand disease, the disturbed sand surface on both sides of the engineering project was stabilized by 1 m × 1 m straw checkerboard barriers. Then shrubs were planted at 2 m × 2 m spacing inside the barriers. Based field measurements of plant species and density and analysis of soil characteristics in the protective system, as well as on the natural dune surface, habitat change and plants invasion from 2000 to 2009 were observed. The disturbed sand surface can be stabilized by straw checker-board barrier. Organic matter and fine sand began to accumulate on the surface with time. Water content of soil in the prevention system was greater during the first two-years compared to water content on the natural ground (control), but it exhibited a gradual decreasing trend with time. A total of 48 plant species were identified in the natural dune surface, including 1 dwarf tree, 4 shrubs, 13 perennial and annual herbages and 30 ephemeral plants. Herbages, especially ephemerals, can enter the protective system naturally. 8 species and 1.4 plants/m^2 were measured in the prevention system in 2001, while they reached 33 species and 14 plants/m^2 in 2009. Out of the total number of all invasion plants, ephemeral plants accounted for over 85% while the dwarf arbor and shrubs were scarcely observed. With decline of soil water and encroachment of herbage plants and biological crusts, the development of artificial vegetation needs additional investigation to refine techniques in the future.

Key Words: Ephemeral plants, Plant invasion, Protective system, Soil property

1. Introduction

Gurbantunggut Desert, located in the Junggar Basin in the north Xinjiang Autonomous Region, is the largest fixed and semi-fixed desert in China. Under natural conditions the desert plants grow well and biotic crusts develop extensively, and therefore the sand surface is stable (Wang *et al*., 2005). In recent years extensive construction has created intensive destruction to the ground surface. In order to protect the desert ecosystem and control blown-sand disease, the prevention system made up of straw checker-board barriers and artificial vegetation was set up in areas degraded by the recent construction following the destruction of ground surface. However the comprehensive protective system was faced with many problems to be answered. Especially a detailed study on habitat change and sustainability of artificial vegetation is required. In this paper, the field measurements of plant species and their densities were made on the natural dune surface and in the protective system from 2001 to 2009. Soil properties, such as soil water, soil grain size and organic matter etc., were analyzed as well. Habitat change and plants invasion in the protective system from 2001 to 2009 were observed. The aim of this study was to provide a theoretical basis for rational establishment of a protective forest system in the desert.

2. Study Area and Methods

Gurbantunggut Desert is located between 44°11'-46°20'N and 84°31'-90°00'E, with an area of 4.88×10^4 km^2. It is mainly covered by fixed and semi-fixed longitudinal dunes, ranging from a hundred meters to more than 10 km long, 10-50 m high, and north-south oriented. The interdunes and the middle to lower parts of the dune are stabilized but their crests are mobile. The annual average temperature is 7.2°C and the 10°C accumulative temperature is about 3500°C. Mean annual precipitation is 129 mm, of which 50% is received from April to July. Annual evaporation exceeds 2000 mm. Gurbantunggut Desert has a 20 cm thick snow cover during winter and it melts in early spring. Moisture affected by snow melting and spring rainfall is limited to a depth of 30-50 cm and lasted about 60 days, and that is the key factor responsible for the widespread distribution of ephemeral plants (Zhang and Chen, 2002). *Haloxylon persicum* is the dominant species, mainly appearing at the middle to upper parts of dunes.

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Interdune and middle to lower slopes are covered by *Ephedra distachya* communities and beneath them are ephemeral plants and biological crusts. Soil is dominated by blown sand with fine grain size and loose structure. Controlled by westerly air current and Mongolian high pressure, the main wind directions are NW and NE. Spring and summer are the windy seasons.

The study site is located in the southern part of Gurbantunggut Desert (44°32'30"N, 88°6'42"E). A great water channel with WNW-SSE orientation was constructed in 2000 and formed a disturbed belt about 240 m wide. The disturbed sand surface on both sides of the channel was stabilized by 1 m × 1 m straw checkerboard barriers in 2001. Then two shrub species, *Haloxylon persicum* and *Calligonum leucocladum*, were planted at 2 m × 2 m spacing inside the barriers. A typical section perpendicular to the engineering trend was selected as the survey sample belt, which was 240 m long. Steel pins were inserted along the section in order to observe the sand surface change of protective system, while a parallel bare sand section was selected for the survey as well. During the 2011 windy season the heights of steel pins along the two sections were measured respectively after two sand-moving wind events. Negative values indicated wind erosion and positive values indicated wind deposition. The total surface activity value was calculated by Giles method (Giles *et al*., 1995). In 2001, 2002, 2006 and 2009 the plant species and density inside each straw grid in the transect were surveyed. In the meantime some quadrants were arranged on the natural dune surface and the plants survey was synchronously made. The soil water of 100 cm layer in the protection system and natural dunes were observed as well. Every two years soil samples of 0-5 cm and 5-10 cm layers were collected to measure organic matter content and grain size component.

3. Results and Discussion

3.1. Habitat change

3.1.1. Sand surface stability

After the first sand-moving windy event in 2001 the change of bare sand surface ranged from -60-87 mm, while measurements of the change in bare sand surface within the protective system was -19-20 mm. After the second windy event the control area (bare) measurements indicated -220-311 mm change in bare sand surface while the protective system measured -17-20 mm. During the period from Apr. to May in 2001 the total surface activity value at bare sand ground was 2.4 mm day^{-1}, while inside the protective system it was 0.48 mm day^{-1}. We observed that wind erosion and deposition occurred alternately in bare sand sections. This is because the grains on free sand surface are picked up and transported by wind and dropped quickly due to gravity and, therefore, the initial flat bed surface changes into an undulate surface with a certain distance (Song and Wang, 2001). Slight erosion widely occurred within the protective system because sand grains in the center of each straw grid are transported to the straw stems and therefore form into a stable concave surface.

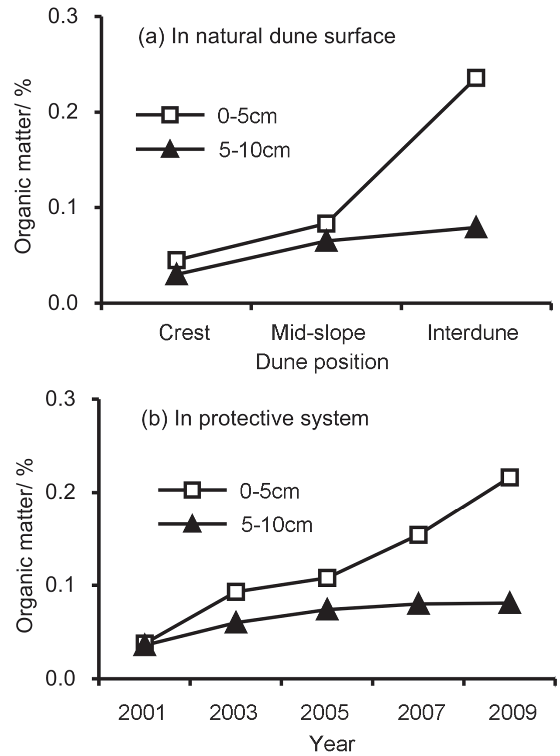

Fig. 1. Various changes of organic matter in 0-5 cm and 5-10 cm soil layers.

3.1.2. Soil grain size and organic matter

In 2001 the soil grain size component in the 0-5 cm and 5-10 cm layers showed no obvious differentiation in the protective system. The percentage of medium, fine, extra-fine and silt materials of the 0-5 cm layer accounted for 17.16%, 56.12%, 24.90% and 1.82% respectively in 2002, and in 2009 they reached 6.98%, 59.13%, 26.18% and 7.72%, respectively. By 2009 biological crusts extensively occurred inside the protective system, which may be a result of the accumulation of silt materials on the soil surface (Wu *et al*., 2003). For the natural dune sand surface, organic matter content in the 0-5 cm soil layer had a significant change at different positions (**Fig. 1(a)**). The interdune had an organic matter content of 0.236% or more, while in the crests of the dune it was only about 0.045%. In 2001, the organic matter content in the 0-5 cm layer within the protective system was 0.038%, which was no more than that of dune crests. Six years later it was 0.154% and 9 years later it reached 0.216 which is close to that in the interdune. In 2001, the difference of organic matter content between 0-5 cm layer and 5-10 cm layer was not obvious. However in 2009 that of the 5-10 cm

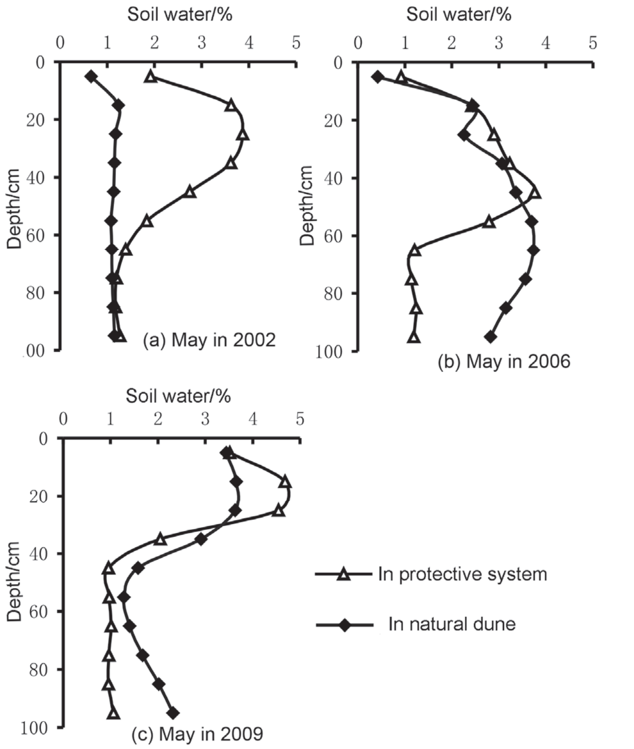

Fig. 2. Comparison of soil moisture between natural dune and protective system.

layer changed little but that of the 0-5 cm layer increased significantly (Fig. 1**(b)**).

3.1.3. Soil water

In 2001 soil water in the protective system was far greater than that in natural dune surface, especially in the 20-40 cm soil layer. The protective system provides a better water condition for plant growth. In 2006, soil moisture in the 0-50 cm soil layer was close to that of natural dune surface, but below 50 cm depth it was significantly lower than that in natural dune. This may be related to such a fact that the root system of vegetation inside the protective system had reached 60-80 cm depth and a large amount of water was consumed. In 2009, soil moisture below the 30 cm layer inside the protective system was lower than that of natural dunes and exhibited a widespread aridity trend. The soil moisture in the 20-30 cm soil layer was relatively higher because a rainfall event occurred in the previous day of observation (**Fig. 2**).

3.2. Plant invasion in the protective system

3.2.1. Number of invasion plant species

A total of 48 plant species were identified in the natural dune surface plot, including 6 life forms, namely dwarf trees, shrubs, sub-shrubs, perennial herbs, annuals and ephemeral plants. Among these, 30 species are ephemeral plants and belong to 15 families. In interdunes and the lower part of the slope the coverage of shrubs dominated by *Ephedra distachya* was 8.9-10.0% and ephemeral coverage reached 51.8% in mid-May. In the upper parts of slopes the coverage of dwarf trees and shrubs dominated by *Haloxylon persicum* ranged 12.2-21.4% and that of ephemerals in mid-May reached 38.2%. The crest was the strongest mobile zone, where the coverage of plants was less than 10%. The ephemerals demonstrated remarkable seasonal change, and they sprouted from the end of March, and died away by early July.

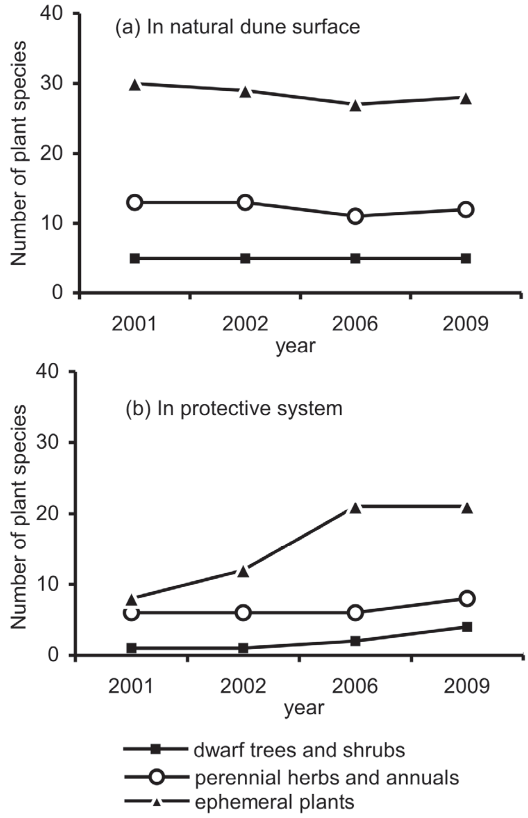

Fig. 3. Number of plant species on natural dune surface and in protective system from 2001 to 2009.

From 2001 to 2009, the number of tree and shrub species on the natural dune surface was 5 species, remaining unchanged, while the number of perennial herb, annual and ephemeral plant species changed slightly (**Fig. 3(a)**). During the same period the number of invasive tree and shrub species inside the protective system did not exceed 3 species. The number of perennial and annual herbs did not exceed 9 species. However the number of ephemeral plant species changed significantly (Fig. 3**(b)**). There were 8 species in 2001, and in 2002, 2006 and 2009 they reached 12, 21 and 21 species, respectively. In 2001 the number of ephemeral plant species occupied 27% of that of natural dune surface, 5 years later it reached 80% and gradually approximated to the natural ground surface.

3.2.2. Variations of invasive plant density

Mean values of 1.4 plants/m^2 were measured in the protective system in 2001, and in 2006 and 2009 they reached 6.5 plants/m^2 and 14 plants/m^2, respectively. Of the total number of invasive plants, ephemerals occupied 65% in 2001, and 85% in 2009. In 2001, the most abundant individuals

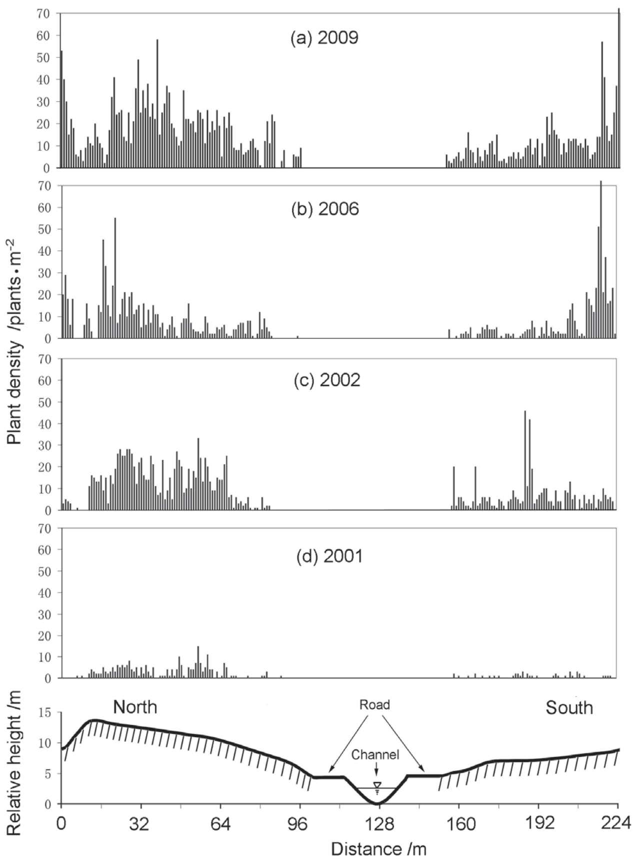

Fig. 4. Plant density along the section in protective system from 2001 to 2009.

inside the protective system were *Erodium oxyrrhynchum*, which accounted for 59% of the total number of invasive plants. In 2002, the invasive plants were dominated by *Erodium oxyrrhynchum* as well. *Trigonella tenella* also occurred and it accounted for 25% of the total number. By 2006 the main invasive ephemeral plants included *Erodium oxyrrhynchum*, *Lactuca tatarica*, *Trigonella tenella* and *Chrozophora sabulosa*, and they accounted for 11.4%, 10.2%, 9.5% and 8% of the total number, respectively. From 2001 to 2009 the number of trees and shrubs in the section was no more than 4 plants. In the first two years following the establishment of the protective system the plant abundance was far larger on the northern side than on the southern side of the channel. Such distribution may be a result of NW and NE winds that prevail in the region and therefore the wind-dispersed seeds dominated by *Erodium oxyrrhynchum* etc. were first blown to the northern side. The plant abundance outside the protective system was higher than inside the protective system. This reflects the invasion processes of plant entrance from the outer edge to the interior (**Fig. 4**).

4. Conclusion

In the Gurbantunggut Desert, straw checkerboard barriers and vegetation could effectively stabilize the disturbed sand surface. Organic matter and extra-fine and silt materials began to accumulate with time in the protective system. In the initial stage following the protective system establishment, the soil water condition was better than that on natural dune surface. However, 10 years later they inevitably exhibited a decrease trend with extensive occurrence of crusts and herbage invasion.

In 2001, of 15 invasive plant species ephemeral plants constituted 8 species; 10 years later, of 33 invasive plant species ephemeral plants constituted 21 species in protective system. Invasive plant density in 2001 was 1.4 plants/m^2. Nine years later this increased to 14 plants/m^2, of which ephemerals accounted for 85% of the total number of invasive plants. *Erodium oxyrrhychun* was the main invasive species. Trees and shrubs were seldom found, which showed that their natural restoration is far more difficult than herbages.

The protective system played a great role in engineering safety in the Gurbantunggut Desert. However soil moisture content in the artificial vegetation zone gradually decreased with time. The plants that adapted to the local environment could reproduce and maintain populations. With invasion of biological crusts and shallow-rooted herbages, the simple pioneering vegetation gradually evolved towards a complex artificial-natural ecosystem. The development of artificial vegetation needs additional investigation to refine techniques in the future.

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