Chapter

Ecological Effects of Oasis Shelterbelts in Ulan Buh Desert

Fengmin Luo, Zhiming Xin, Junliang Gao, Yuan Ma, Xing Li and Huaiyuan Liu

Abstract

In arid region, shelterbelt is the ecological barrier for oasis. Understanding its ecological effects can provide theoretical supports for its long-term management and sustainable development. Two standard meteorological stations were used to monitor climatic factors continuously for 7 years, and two 50 m dust monitoring towers were used to continuously monitor sandstorm for 10 times, which were located inside and outside oasis shelterbelts in the northeastern edge of Ulan Buh Desert. The microclimate differences were analyzed, as well as the ecological effects of oasis shelterbelts was clarified inside and outside oasis. In the present study, under the influence of a large-scale shelterbelts, air temperature, land ground temperature and evaporation respectively decreased 5.13% ~ 24.74%, 2.38% ~ 20.09% and 7.06% ~ 17.68%, whereas the relative humidity and precipitation respectively increased 6.93% ~ 25.53% and 4.30% ~ 50.15%. During the occurrence of sandstorms, the wind speed inside and outside shelterbelt showed an increasing trend with the increase in height. The relationship between wind speed and height was expressed as a power function. The wind direction was mainly W, WNW and NE, but the proportion of each direction was different inside and outside shelterbelt. When the sandstorm passed through oasis shelterbelts, the wind speed was significantly weakened, with an average reduction of 30.68%. The horizontal aeolian sediment flux decreased 414.44 $g{\cdot}m^{-2}$ and the aeolian deposition flux decreased 0.81 $g{\cdot}m^{-2}$. The results revealed that the microclimate was improved by oasis shelterbelts, especially in the growing season. Therefore, oasis shelterbelts help to maintain the sustainable development of oasis.

Keywords: meteorological factor, sandstorm, oasis shelterbelts, Ulan Buh Desert

1. Introduction

Oasis is a unique geographical landscape in arid and semi-arid regions, which plays an extremely role in the development of human society [1, 2]. In arid region, oasis is irreplaceable in landscape, environment and function. Climate change is an important driving factor affecting ecosystem services. Rising temperature, precipitation change, and extreme climate events will have a great impact on the ecosystem [3]. Climate resources are the most important renewable resources for the development of oasis. Meanwhile, oasis will have a significant impact on climate change [4]. Sandstorm will cause long-term climate effects [5]. Wind is an indispensable dynamic condition for the occurrence of sandstorm, and it is also the main indicator for determining sandstorm intensity [6]. Dust monitoring is a necessary means to provide early warning of sandstorm, to study prevention and control measures, and to reduce the damage caused by sand-dust disasters [7]. The near-surface layer (0 ~ 50 m) not only provides the source of dust, but also the main space for people's life, industrial and agricultural production. Therefore, strengthening the monitoring of near-surface dust and making early warning has important practical significance in disaster prevention.

Ulan Buh Desert is one of important sand sources in China, which has serious wind and sand disasters. It is located at 106°09′–106°57′ E and 39°16′–40°57′ N, the arid region of northwest China, covering nearly 11,000 km^2 [8]. The desert lies at an elevation from 1028 to 1054 m [9], where the southwest area is topographically higher than the northeast [10]. Geomorphologically, the types of sand dunes in the area include moving, fixed, and semi-fixed dunes, the proportions of which are almost equal [11]. The desert is expanding to east and south, which affect the normal functions of the transportation network and water conservancy facilities in its territory, threaten the ecological security of the oasis, the development of agriculture and animal husbandry, and the health of residents [12, 13]. As an important part of the "Three-North Shelter Forest Program", Oasis in Ulan Buh Desert plays an important role in promoting the economic development of the Hetao region and reducing wind and sand disasters. Many studies have been carried out in windbreak structure and configuration of shelterbelts, even effectiveness of shelterbelt [14, 15], dust reduction mechanism and effect of sand reduction [16–18]. In recent years, the impact of meteorological elements (wind speed, precipitation and temperature, etc.) and underlying surface elements (vegetation coverage, soil moisture, degree of surface consolidation or looseness and sediment size) on sandstorms were studied worldwide, including Mojave Desert, Junggar Basin, North and Northwest China [19–22]. However, there were relatively few systematic studies on the ecological effects of oasis shelterbelt systems [23].

In arid region, oasis is a necessary condition for economic development, while the climatic factors play a vital role in maintaining the sustainable development of oasis [24]. Therefore, it is particularly important to explore the ecological effects of oasis shelterbelt system in the Ulan Buh Desert. Therefore, the annual dynamic of climate was studied by meteorological data from 2012 to 2018, which came from two meteorological stations inside and outside oasis shelterbelts in Ulan Buh Desert. Meanwhile, sandstorm was analyzed by the wind speed, wind direction and dust flux data from 10 sandstorms of 50 m dust monitoring tower. Therefore, the differences and causes of microclimates are discussed inside and outside the oasis shelterbelts. And effectiveness of shelterbelts is explained. The results can help to predict the trend of microclimate changes precisely in the future, reveal the characteristics of low-altitude sandstorm on the northeastern edge of Ulan Buh Desert, and give theoretical foundation for the management and sustainable development of the oasis shelterbelts.

2. Materials and methods

2.1 Study area

The study area is located in the northeast edge of Ulan Buh Desert. It belongs to Dengkou County, Inner Mongolia. The region has a temperate continental monsoonal climate, which are affected by the southeast monsoon in summer and autumn, and are controlled by the Siberian-Mongolian cold anticyclone in winter and spring. The mean annual air temperature was 7.8°C [9], with highest air

DOI: http://dx.doi.org/10.5772/intechopen.98679

temperature of 25.6°C in July and lowest air temperature of −11.5°C in January. The mean annual precipitation was 140.0 mm, primarily distributed in the summer. However, mean annual potential evaporation was 2372 mm. The mean annual wind speed was 3.7 m/s with the mean annual windy days of 10–32 d. The frost free days were 168d. The annual sunshine time was 3229.9 h [25]. The soil types are mainly eolian soil and sandy loam soil. The natural vegetation is dominated by *Nitraria tangutorum*, *Artemisia ordosica*, *Calligonum alaschanicum* and *Haloxylon ammodendron* [26]. The dominant tree of shelterbelt is *Populus alba var. pyramidalis* in oasis. The distance between two observation sites is 2.85 km. There are fixed and semi-fixed dunes outside shelterbelt, which dominated by *Nitraria tangutorum* with the height of 1.2 ~ 3.6 m. The area of the shelterbelt system is 1487.3 ha. The width of a belt is 32 m, which is composed of 8 rows of trees, with the auxiliary forest belt spacing of 98 m, and the miniature forest belt spacing of 398 m. The characteristics and locations of vegetation inside and outside shelterbelt are shown in **Figure 1**.

2.2 Data sources and research methods

2.2.1 Meteorological factors

The parallel comparative experimental observation of meteorological elements inside and outside oasis shelterbelt were conducted by Windsonic two-dimensional ultrasonic wind speed and direction sensors (1590-PK-020, Campbell, USA) and temperature and humidity sensors (1590- PK-020, Campbell, USA). The data was collected from January 1, 2012 to December 31, 2018. The start wind speed of wind speed and direction sensor is 0.01 $m \cdot s^{-1}$, with the accuracy of ±2% and wind direction of ±3°, which range from 0 ~ 60 $m \cdot s^{-1}$ and 0 ~ 359°, with the resolution of 0.01 $m \cdot s^{-1}$ and 1°, respectively. The precipitation and evaporation were collected in accordance with the relevant regulations of the "Ground Meteorological Observation Regulations" issued by the China Meteorological Administration [27]. The observation time was 8:00, 14:00, and 20:00 (Beijing time) every day. The data at Site 1 and Site 2 were observed simultaneously and recorded instantly inside and outside shelterbelt, respectively. Refer to the definition of high temperature defined by the China Meteorological Administration, the temperature ≥ 35°C is a high temperature weather, and the number of high temperature days is the number

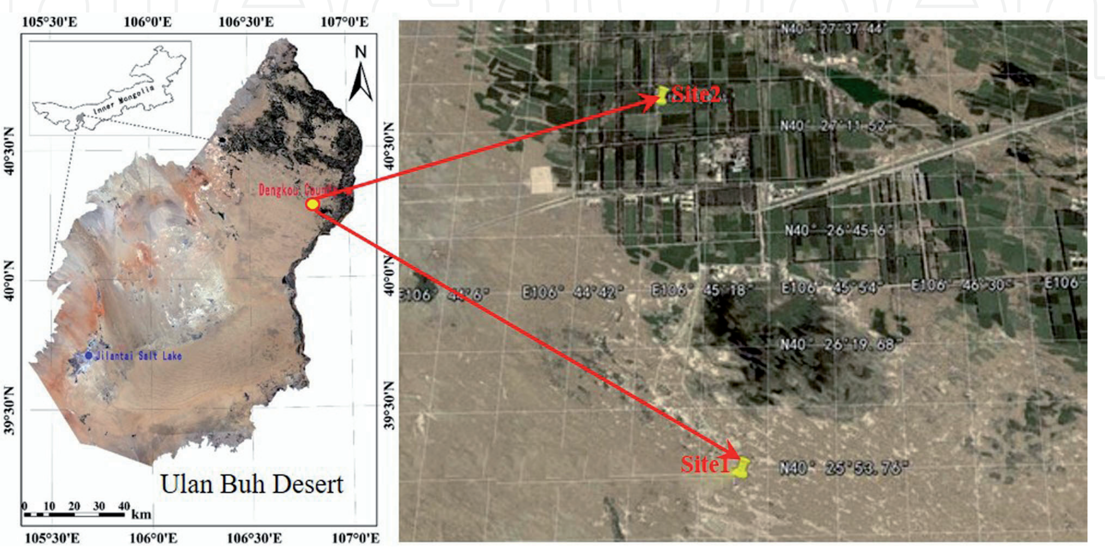

Figure 1.
The location map of the observation plot.

of days with the highest temperature ≥ 35°C. The high temperature data was the daily maximum temperature from 2012 to 2018, and the statistical period was 08:00–08:00 (Beijing time).

Temperature and relative humidity were obtained at a height of 1 m. Wind speed and direction was obtained at a height of 12 m. And precipitation and water surface evaporation were obtained at a height of 10 m. The quality of data was controlled by the simultaneous calibration of two observation points, the logical extreme value check, and the non-conformance time consistency check. According to the dividing method of four seasons in Chinese meteorology [28], spring was defined from March to May, summer was defined from June to August, autumn was defined from September to November, and winter was defined from December to February. The average value of each season's environmental factors was analyzed by Excel 2016. The variation trend graph of each meteorological factor was drawn by Origin 2017.

2.2.2 Dust collection device

The height of dust monitoring tower is 50 m, with horizontal eolian dust samplers and dust deposition traps respectively mounted at 18 heights of 0.50, 1.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 16.0, 20.0, 24.0, 28.0, 32.0, 36.0, 40.0, 44.0, 48.0 and 50.0 m above the ground (**Figure 2**). The horizontal eolian dust sampler and dust deposition traps were developed by the Key Laboratory of Desert and Desertification, Chinese Academy of Sciences [29]. The horizontal eolian dust sampler was used to track the variation of wind direction and collect sand and dust from a dust inlet with the size of 20 mm × 50 mm. A dust deposition trap was designed to collect eolian sediment at different heights. This trap is a transparent glass container with an Inner diameter of 15 cm and a depth of 30 cm. There are a wind speed and direction sensor mounted at each height of 1.0, 2.0, 4.0, 8.0, 12.0, 16.0, 24.0, 36.0 and 48.0 m above the ground.

The monitor of eolian sediment flux was completed within 1 day after the end of the sandstorm. In order to ensure that the collected samples are natural air-drying, precipitation should be avoided during the sampling process. The collected samples were weighed by an electronic balance with the accuracy of 0.001 g. The 10 times sandstorms were monitored from January 2017 to June 2020. The wind speed and direction were automatically recorded during this period, and the data collection frequency was 10 min.

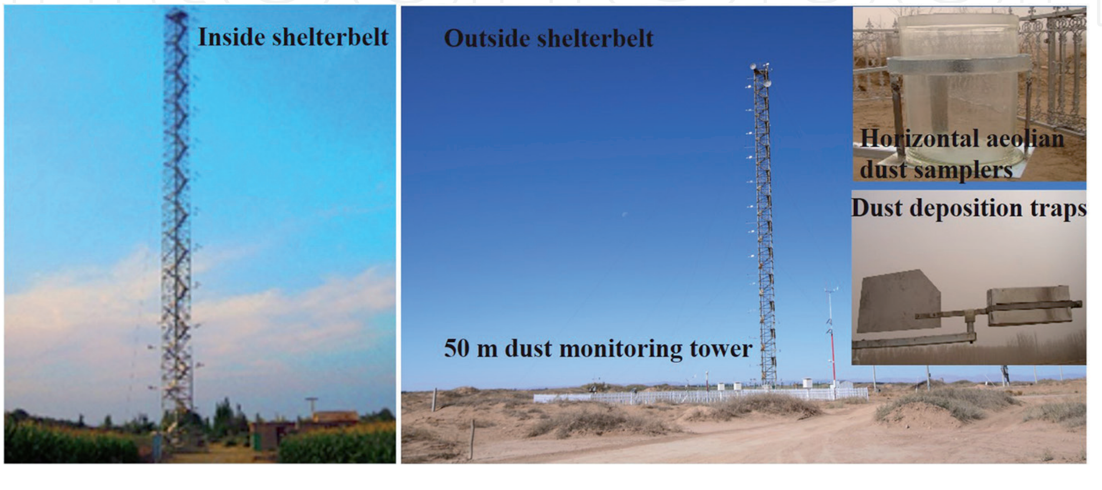

Figure 2.
The 50 m dust monitoring towers inside and outside shelterbelt, the 18 horizontal eolian dust samplers and 18 dust deposition traps.

2.2.3 Data calculation method

The horizontal aeolian sediment was calculated by formulas (1):

$$M_H = W_H / ab \tag{1}$$

Where M_{H} is the horizontal aeolian sediment flux (g·m^{-2}); W_{H} is the net weight of dust collected in the horizontal aeolian sediment samplers (g); a is the width of the horizontal aeolian sediment samplers opening (mm); b is the height of the horizontal aeolian sediment samplers opening (mm).

The aeolian deposition flux was calculated by formulas (2):

$$M_V = W_V / \pi r^2 \tag{2}$$

Where M_V is the amount of aeolian deposition fluxes (g·m^{-2}); W_V is the net weight of dust received in the aeolian deposition traps (g); r is the radius of the aeolian deposition traps opening (cm).

3. Results and analysis

3.1 Interannual variation of microclimate inside and outside shelterbelt

Generally, air temperature, ground temperature, evaporation, and wind speed inside shelterbelt were lower than those outside shelterbelt, while the relative humidity and precipitation were higher than those outside shelterbelt (**Table 1**). The interannual temperature outside shelterbelt varies more than inside shelterbelt, the interannual temperature outside shelterbelt fluctuates between 1.14 ~ 3.21°C, and the interannual temperature inside shelterbelt fluctuates between 0.40 ~ 0.67°C. The evaporation showed a downward trend inside shelterbelt, and it showed an increasing trend outside shelterbelt, but the changes were relatively gentle. The land ground temperature showed an overall upward trend inside and outside the shelterbelt. The precipitation showed a decreasing trend inside and outside shelterbelt, and the changes were relatively gentle. The evaporation showed a downward trend inside and outside shelterbelt. The changes of wind speed were relatively gentle inside and outside shelterbelt. Under the influence of a large-scale oasis shelterbelts, air temperature, land ground temperature and evaporation decreased 5.13% ~ 24.74%, 2.38% ~ 20.09% and 7.06% ~ 17.68%, respectively, whereas relative humidity and precipitation increased 6.93% ~ 25.53% and 4.30% ~ 50.15%, respectively.

3.2 Interannual variation of high temperature days inside and outside shelterbelt

The number of high temperature days (maximum temperature ≥ 35°C) inside and outside shelterbelt from 2012 to 2018 showed a fluctuating upward trend, and the number of high temperature days outside shelterbelt was significantly higher than that inside shelterbelt (**Figure 3**). The annual average high temperature days was 22 days outside shelterbelt, and it was 6 days inside shelterbelt. The number of high temperature days was the most, with 34 days and 17 days inside and outside shelterbelt in 2017, and the fewest high temperature days in 2012 and 2015, with 11 days and 1 days inside and outside shelterbelt, respectively. It can be seen from **Figure 4** that the high temperature days were 43 days and 154 days, the average

	Air temperature (°C)		Evaporation (mm)		Ground temperature (°C)		Precipitation (mm)		Atmospheric humidity (%)		Wind speed ($m{\cdot}s^{-1}$)	
Years	**Outside shelterbelt**	**Inside shelterbelt**	**Outside shelterbelt**	**Inside shelterbelt**	**Outside shelterbelt**	**Inside shelterbelt**	**Outside shelterbelt**	**Inside shelterbelt**	**Outside shelterbelt**	**Inside shelterbelt**	**Outside shelterbelt**	**Inside shelterbelt**
2012	10.8	9.1	2343.9	1987.2	25.7	21.4	193.7	229.5	49.5	62.1	3.1	1.2
2013	11.4	9.2	2333.4	2168.7	26.5	23.0	55.0	59.1	43.6	43.6	3.7	2.9
2014	12.3	9.2	2465.0	2081.7	27.5	23.9	75.	95.2	49.1	52.5	3.4	2.6
2015	10.8	9.0	2287.1	2000.6	26.6	24.2	97.9	147.0	53.6	56.5	3.3	2.7
2016	10.6	9.1	2352.8	2052.8	26.0	23.9	170.1	189.2	44.1	48.9	3.5	2.2
2017	10.2	9.3	2317.0	1925.9	27.7	26.3	86.0	89.7	34.4	38.6	3.5	2.3
2018	9.1	8.6	2403.9	1978.8	27.2	26.6	112.9	119.8	36.3	41.3	3.9	2.6

Table 1.
Annual mean of meteorological factors inside and outside shelterbelt.

maximum temperature were 36.30°C and 36.54°C, whereas the highest temperature fluctuated between 35 ~ 39.5°C and 35 ~ 43.3°C respectively inside and outside shelterbelt from 2012 to 2018. The average maximum temperature outside shelterbelt was 0.66% higher than that inside shelterbelt, but the highest temperature outside shelterbelt was 9.62% higher than that inside shelterbelt. The high temperature days were concentrated from June to August inside and outside shelterbelt, which was also the growing season of plants. The research results showed that oasis shelterbelt

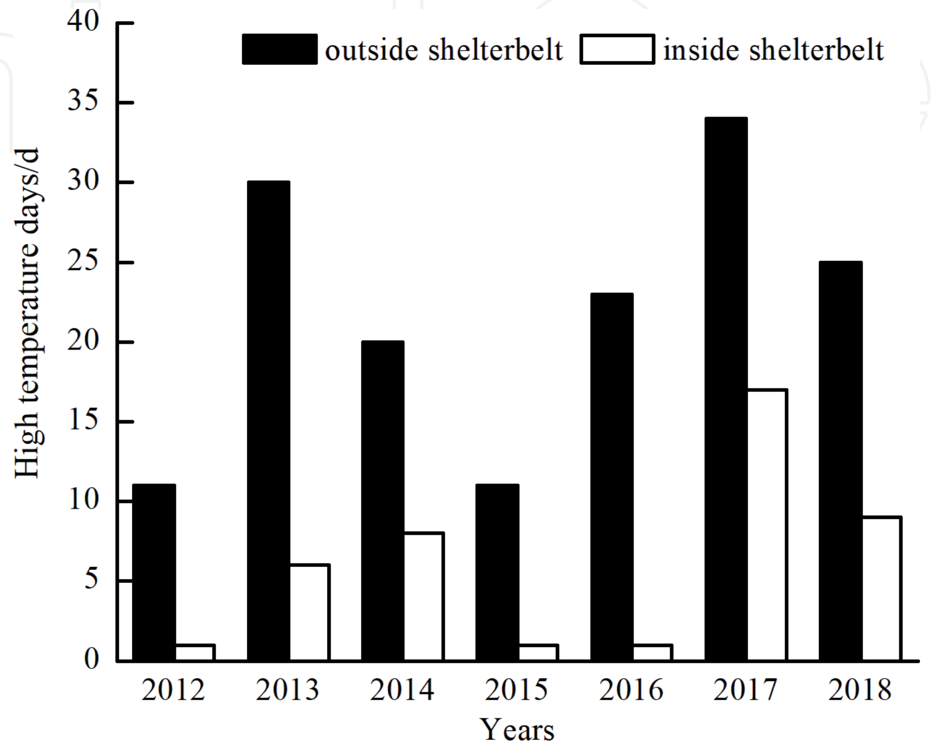

Figure 3.
Annual high temperature days inside and outside shelterbelt.

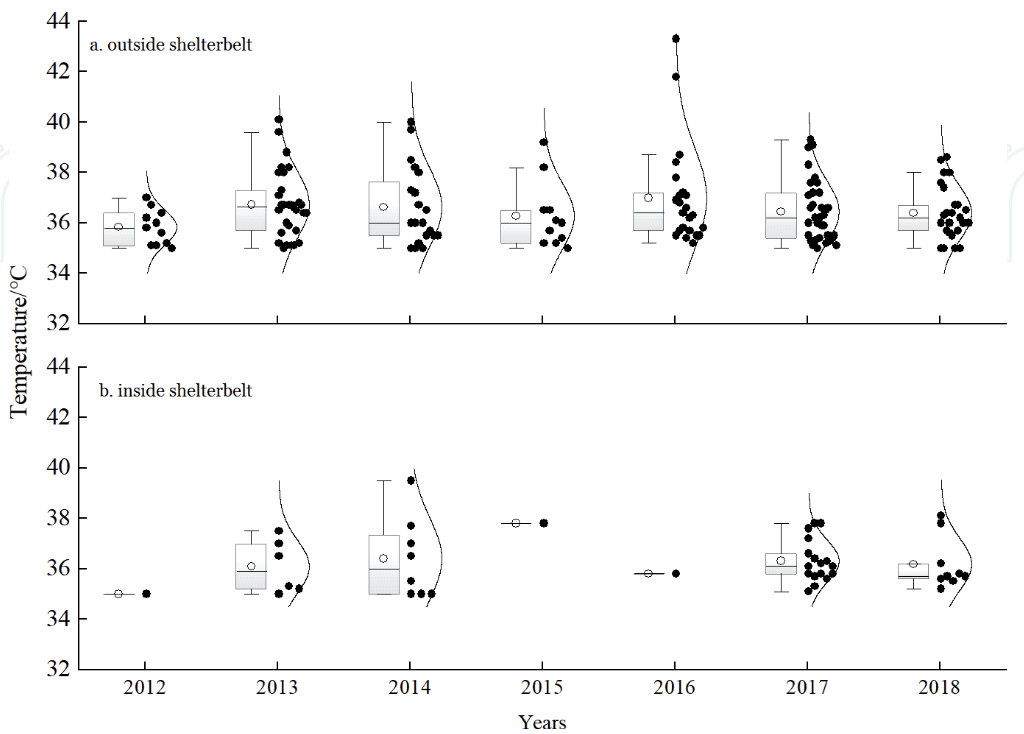

Figure 4.
The distribution characteristics of high temperature inside and outside shelterbelt.

has a good protection effect against extreme weather, it also can protect crops from high temperature damage inside shelterbelts and play a vital role in plant growth and increase crop yields.

3.3 Aeolian sediment flux

3.3.1 Wind rose diagram inside and outside shelterbelt

During the occurrence of sandstorms, the main wind directions were W, WNW, and NE, but their proportions were different inside and outside shelterbelt (**Figure 5**). Three directions inside shelterbelt accounted for 21.77%, 20.20%, and 18.00%, respectively. However, three directions outside shelterbelt accounted for 40.11%, 22.81%, and 11.69%, respectively. The wind direction inside and outside shelterbelt was similar, but the wind flow near surface ground was changed by shelterbelt. The proportion of sand driving wind in W direction outside shelterbelt was relatively high, while the proportions of other three wind directions inside shelterbelt were relatively even. Moreover, wind speed was decreased significantly by shelterbelt. The frequencies of sand driving wind exceeding 11 $m{\cdot}s^{-1}$ were 40.06% and 6.10% outside and inside shelterbelt, respectively, which was reduced by 84.77%. The frequencies of sand driving wind between 9 $m{\cdot}s^{-1}$ and 11 $m{\cdot}s^{-1}$ were 16.72% and 16.60% outside and inside shelterbelt, respectively. However, the wind speeds of sand driving wind between 5 $m{\cdot}s^{-1}$ and 7 $m{\cdot}s^{-1}$ together with those between 7 $m{\cdot}s^{-1}$ and 9 $m{\cdot}s^{-1}$ inside shelterbelt were both higher than outside shelterbelt.

3.3.2 Horizontal aeolian sediment flux

The horizontal sediment flux outside shelterbelt decreased significantly with the increase of height (**Figure 6**), and the relationship was expressed as $M_H = 1224.8\,h^{-0.343}$ ($R^2 = 0.93$, $P < 0.01$). The horizontal sediment flux inside shelterbelt increased slowly with the increase of height, which ranged from 99.62 $g{\cdot}m^{-2}$ to 280.90 $g{\cdot}m^{-2}$. The relationship between horizontal sediment flux and height was expressed as $M_H = 130.08e^{0.023h}$ ($R^2 = 0.85$, $P < 0.01$).

The horizontal sediment flux decreased when sandstorm passed through shelterbelt. The average horizontal sediment flux within 0 ~ 50 m was 592.87 $g{\cdot}m^{-2}$ outside shelterbelt during one sandstorm, whereas the average horizontal sediment flux was only 178.43 $g{\cdot}m^{-2}$ inside shelterbelt. The concentration of horizontal

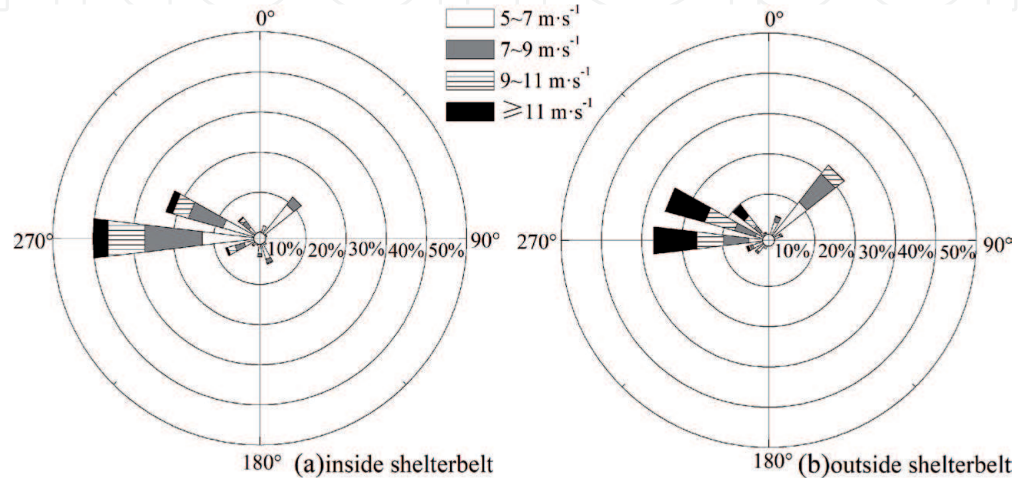

Figure 5.
Sand driving wind rose inside and outside shelterbelt during occurrence of dust storms.

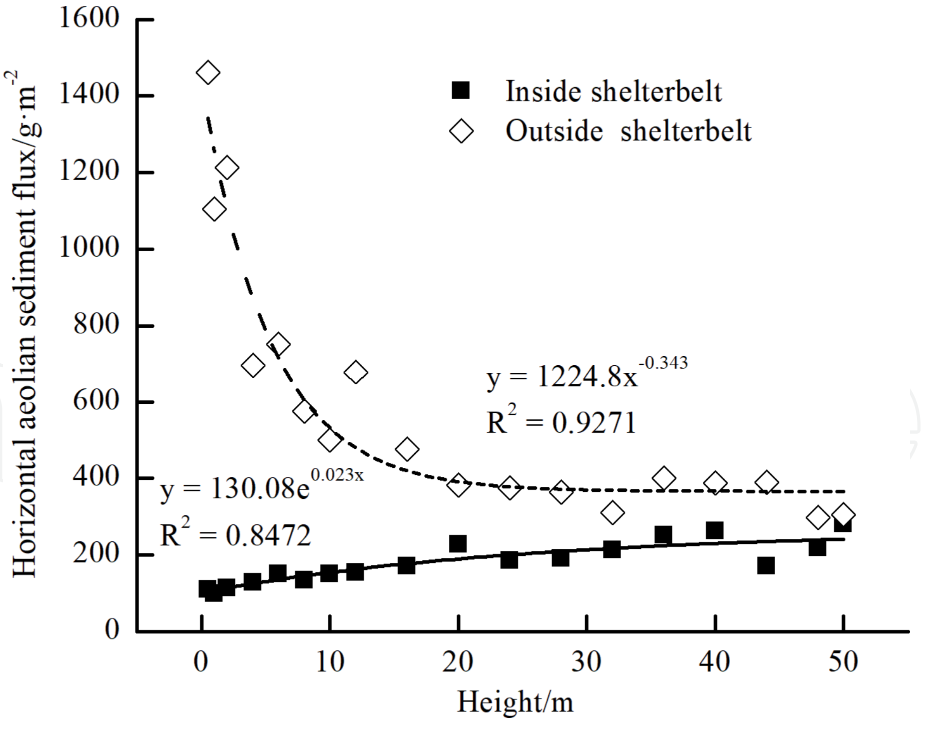

Figure 6.
Horizontal aeolian sediment flux profile inside and outside shelterbelt.

sediment flux was reduced by 69.90%. As the height increased, the difference between two sites gradually decreased with a trend of gradual overlap.

3.3.3 Aeolian deposition flux

The aeolian deposition flux decreased significantly with the increase of height inside and outside shelterbelt (**Figure 7**). Their relationship was expressed as $M_V = 6.64\ h^{-0.42}$ ($R^2 = 0.96$, $P < 0.01$) outside shelterbelt and $M_V = 4.42\ h^{-0.40}$

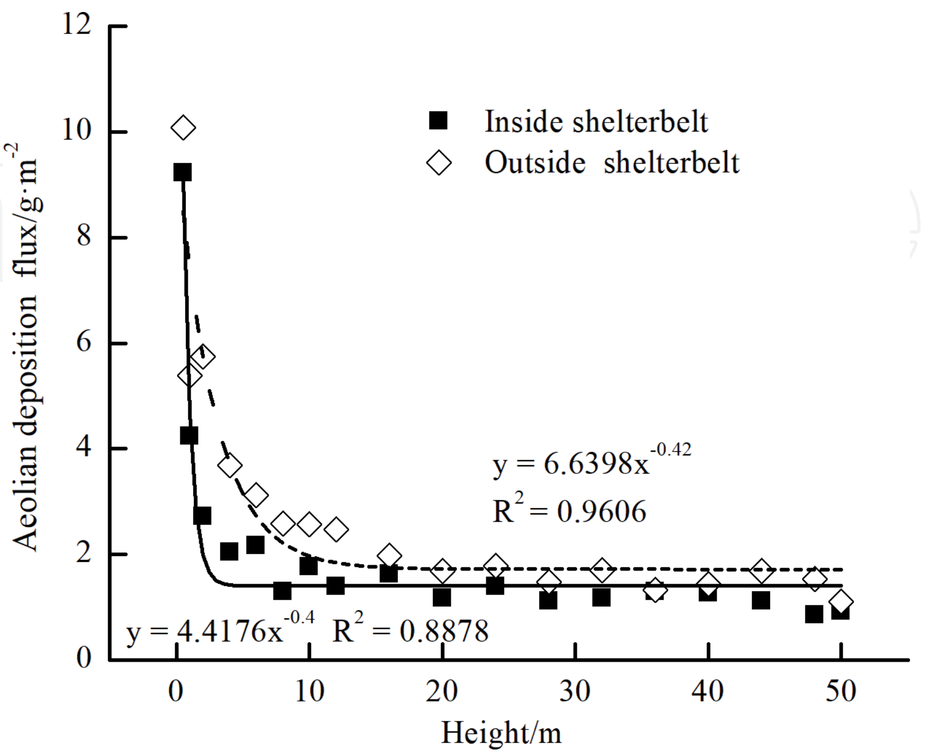

Figure 7.
Aeolian deposition flux velocity profile.

(R^2 = 0.89, P < 0.01) inside shelterbelt. The aeolian deposition flux below 24 m decreased gradually with height inside and outside shelterbelt. The aeolian deposition flux above 24 m continued to decrease gradually outside shelterbelt. However, the aeolian deposition flux gradually increased above 24 m inside shelterbelt. The average aeolian deposition flux during one sandstorm within 50 m was 2.85 $g \cdot m^{-2}$ outside shelterbelt, while it was only 2.04 $g \cdot m^{-2}$ inside shelterbelt. Moreover, the difference between the aeolian deposition flux inside and outside shelterbelt also gradually decreased as the increase of height with a trend of gradual overlap.

4. Discussion

Oasis is an important area that guarantees the normal life and production of residents in arid region. Its climate effects are vital important to the sustainable development of the oasis shelterbelts [30]. The stability of the microclimate was maintained and natural disasters were reduced by oasis shelterbelts [31]. Our results showed that under the influence of a large-scale oasis shelterbelts, air temperature, ground temperature and evaporation decreased 5.13% ~ 24.74%, 2.38% ~ 20.09% and 7.06% ~ 17.68%, respectively. However, relative humidity and precipitation increased 6.93% ~ 25.53% and 4.30% ~ 50.15%, respectively. The cold-humid effect of the atmosphere inside shelterbelt formed a cold-humid column. The warm-dry effect of the desert atmosphere outside shelterbelt caused a warm-dry air current. The interaction of the cold-humid effect and the warm-dry effect formed a local circulation. The warm air outside shelterbelt was transported to the sky above the shelterbelt, thus formed a stable thermal inversion layer. Therefore, the cold and humid air inside shelterbelt was maintained, which was beneficial to crop growth in oasis [32].

The microclimate of oasis shelterbelts was conducive to the overwintering of plants and kept them from the damage of high temperature in summer. Therefore, it played a vital role in plant growth, nutrient accumulation and quality improvement [33]. The relative humidity was increased 0.5% ~ 18.6%, whereas the evaporation was decreased 18.4 ~ 1282.8 mm by oasis shelterbelts in the northeastern edge of Ulan Buh Desert. This played a positive role in increasing soil moisture and inhibiting crop transpiration, thereby increasing crop yields and improving the soil quality in long time [33]. The oasis shelterbelts in the northeastern edge of Ulan Buh Desert also had the effect of cooling in summer and heat preservation in winter. It decreased air temperature in spring, summer and autumn, whereas increased air temperature in winter inside shelterbelt. This was similar to the microclimate effect of the shelterbelt in Heihe River Basin [34]. The air heat transfer was affected by the barrier of shelterbelt, caused the temperature dynamic lag between inside and outside shelterbelt [33]. The attraction and reflection of plants inside shelterbelt to the solar radiation energy reduced the solar radiation energy absorbed by the air. Meanwhile, the growth and transpiration of plants consumed a lot of heat energy. In addition, the shading effect of the shelterbelt also resulted in the cooling effect especially in spring, summer and autumn. On the other side, it had a heat preservation effect in winter [35]. During the growing season of crop, the blocking effect on airflow was enhanced by the shelterbelt in the leafy season. The wind speed was reduced by the weakening of turbulence exchange, whereas the wind speed was increased inside shelterbelt in the leafless season [35]. Saturated water vapor was formed when the temperature inside shelterbelt was lower than that outside shelterbelt. The canopy blocked the exchange of airflow between inside and outside shelterbelt. In addition, the water vapor diffusion from inside to outside shelterbelt was reduced by the decrease of wind speed, which resulted in a higher relative humidity inside than outside shelterbelt [36].

Wind speed increased gradually with the increase of height inside and outside shelterbelt with the significant relationship of a power function. There were obvious differences in wind speed, wind direction, and eolian sediment flux inside and outside shelterbelt in the northeastern edge of Ulan Buh Desert. The results were consistent with the wind speed distribution characteristics of Minqin Oasis and Badain Jaran Desert on the oasis and desert-oasis region, which increased with the height from 0 to 50 m [37]. During the occurrence of sandstorms, wind speed profile and the migration process of sand and dust particles were affected by the type of underlying surface, thereby affecting the distribution of aeolian sediment flux [38–40]. For example, the relationships between the near-surface aeolian sediment flux and height were expressed as an exponential function in Tengger Desert [40–42], a power function in Minqin Oasis [38], whereas both functions in Taklimakan Desert [43]. Wind speed and the aeolian sediment flux through the shelterbelt were reduced significantly by oasis shelterbelts. The microclimate was improved by oasis shelterbelts, together with weakening turbulent exchange inside shelterbelt, and inhibiting vertical transportation of aeolian sediment. Therefore, the quality of aeolian sediment was less inside than outside shelterbelt. The dust is transported under the action of wind, and the sediment flux varies with height during the transport process.

The difference of sand driving wind speed inside and outside shelterbelt was different in wind speed. The frequency of strong sand driving wind exceeding 11 $m \cdot s^{-1}$ was decreased significantly inside than that outside shelterbelt in the northeastern edge of Ulan Buh Desert. However, the frequency of sand driving wind between with 5 $m \cdot s^{-1}$ - 7 $m \cdot s^{-1}$ and between 7 $m \cdot s^{-1}$ and 9 $m \cdot s^{-1}$ increased inside than outside shelterbelt. When sandstorm passed through the oasis shelterbelts, which acted as a tall rough element, and part of the airflow was lifted up, a relatively high speed free-stream was formed above the shelterbelt canopy. After crossing the shelterbelt, it formed a sinking airflow, which spread in all directions at a certain distance in the leeward zone. Another part of the airflow entered into the shelterbelt. Due to the block and friction of the trees, the airflow consumed a large amount of energy during dispersion, thus a low speed bound-stream was formed under the shelterbelt canopy. Therefore, the frequency of sand driving wind with high speed was decreased, whereas the frequency of sand driving wind with low wind speed was relatively increased inside oasis shelterbelts [34]. Because there was spatial and temporal heterogeneity in the shelterbelt distribution in a specific space with the form of grids [38], our methods on the shelterbelt scale cannot be applied to the regional scale [44]. Therefore, the comprehensive evaluation index system of the environmental benefits of shelterbelts needs to be studied urgently on regional scale. Moreover, it was suggested to focus on deducing the results from shelterbelt scale to multiple shelterbelts or even landscape scales in the future, using interpolation methods to establish models on the time scale [45], and integrating vegetation, soil, climate and other factors, in order to obtain simple and effective results.

5. Conclusion

1. Microclimate of oasis was improved by oasis shelterbelts in the northeastern edge of Ulan Buh Desert, including increasing relative humidity and precipitation, reducing air temperature, surface temperature, evaporation and wind speed inside shelterbelt.

2. During the occurrence of sandstorm, wind speed increased with the increase of height inside and outside shelterbelt, which was expressed as a relationship

of a power function. The wind direction was mainly W, WNW and NE, but the proportion of each direction was different inside and outside shelterbelt.

3. The horizontal aeolian sediment flux decreased significantly with the increase of height outside shelterbelt, while increased slowly with the increase of height inside shelterbelt. The aeolian deposition flux decreased significantly with the increase of height which was expressed as a power function relationship. Wind speed was significantly weakened, the horizontal and vertical fluxes of aeolian sediment flux were reduced when sandstorm passed through oasis shelterbelts.

Acknowledgements

This research was supported by Operation Subsidy of Inner Mongolia Dengkou Desert Ecosystem National Observation Research Station (2021132013), Science and Technology Planning Project of Inner Mongolia Autonomous Region (2020GG0125).

Author details

Fengmin Luo*, Zhiming Xin, Junliang Gao, Yuan Ma, Xing Li and Huaiyuan Liu
Experimental Center of Desert Forestry, Chinese Academy of Forestry, Dengkou, Inner Mongolia, China

*Address all correspondence to: lfm359541965@126.com

References

[1] Wang T. Some issues on oasification study in China. Journal of Desert Research. 2010,30(5):995-998. DOI: http://ir.casnw.net/handle/362004/10812

[2] Hao L, Su X, Singh V P, et al. Suitable oasis and cultivated land scales in arid regions based on ecological health. Ecological Indicators. 2019,102:33-42. DOI: 10.1016/j.ecolind.2019.01.053

[3] Zhang C L, Shen Y P, Li Q J, et al. Sediment grain-size characteristics and relevant correlations to the aeolian environment in China's eastern desert region. Science of the Total Environment. 2018,627:586. DOI: 10.1016/j.scitotenv. 2018.01.270

[4] Mu G J, He J X, Lei J Q, et al. A discussion on the transitional zone from oasis to sandy desert: a case study at Cele Oasis. Arid Land Geography. 2013,36(2):195-202. DOI: CNKI:SUN:GHDL.0.2013-02-001

[5] Mctainsh G, Strong C. The role of aeolian dust in ecosystems. Geomorphology. 2007,89(1-2):39-54. DOI: 10.1016/j.geomorph.2006.07.028

[6] Webb N P, Galloza M S, Zobeck T M, et al. Threshold wind velocity dynamics as a driver of aeolian sediment mass flux. Aeolian Research. 2016,20:45-58. DOI: 10.1016/j.aeolia.2015.11.006

[7] Zhou C L, Yang X H, Zhong X J, et al. Dust weather in hinterland of the Taklamakan desert. Arid Zone Research. 2017,34(2):324-329. DOI: 10.13866/j. azr.2017.02.11

[8] Wang T. Desert and desertification in China. Hebei Science and Technology Press.2003. Shijiazhuang

[9] Li Z, Wang N, Li R, Ning K, et al. Indication of millennial-scale moisture changes by the temporal distribution of Holocene calcareous root tubes in the deserts of the Alashan Plateau, Northwest China. Palaeogeography, Palaeoclimatology. Palaeoecology. 2015, 440:496-505. DOI: 10.1016/j.palaeo. 2015. 09.023

[10] Zhang C, Li Z, Chen Q, et al. Provenance of aeolian sands in the Ulan Buh Desert, northwestern China, revealed by heavy mineral assemblages. Catena. 2020,193:104624. DOI: 10.1016/j.catena.2020.104624

[11] Wang N A, Li Z L, Cheng H Y, et al. High lake levels on Alxa Plateau during the Late Quaternary. Chinese Science Bulletin. 2011,56:1799-1808. DOI: 10.1007/s11434-011-4498-8

[12] Wang H, Jia X, Li Y, et al. Selective deposition response to aeolian–fluvial sediment supply in the desert braided channel of the upper Yellow River, China. natural Hazards and Earth System Sciences. 2015,15(9):1955-1962. DOI: 10.5194/nhess-15-1955-2015

[13] Li H, Xu F, Li Z, et al. Forest Changes by Precipitation Zones in Northern China after the Three-North Shelterbelt Forest Program in China. Remote Sensing. 2021,13(4):543. DOI: 10.3390/rs13040543

[14] Bao Y F. Windbreak effects of shelterbelt in oases based on wind velocity flow field. Beijing: Beijing Forestry University, 2015.

[15] Van Thuyet D, Van Do T, Sato T, et al. Effects of species and shelterbelt structure on wind speed reduction in shelter. Agroforestry System. 2014,88(2): 237-244. DOI: 10.1007/s10457-013-9671-4

[16] Gao J L, Xin Z M, Liu F, et al. Analysis of the characteristics and affecting factors of atmospheric dustfall in northeastern Ulan Buh Desert. Journal of Arid Land Resources and Environment. 2014,28(8):145-150. DOI: CNKI:SUN:GHZH.0.2014-08-025

[17] Wang J, Dong Z. Research on grain characteristics of falling dust and different surfaces and their relationships on oasis. Journal of Soil and Water Conservation. 2005,19(6):9-11,14. DOI: 10.3321/j.issn:1009-2242.2005.06.003

[18] Luo F M, Xin Z M, Gao J L, et al. Characteristics of near-surface wind speed and sand-dust flux at northeast edge of Ulan Buh Desert. Transactions of the Chinese Society of Agricultural Engineering. 2016,32(24): 147-154. DOI: 10.11975/j.issn.1002-6819.2016.24.019

[19] Reynolds R L, Yount J C, Reheis M, et al. Dust emission from wet and dry playas in the Mojave Desert, USA. Earth Surface Processes and Landforms. 2007,32(12):1811-1827. DOI: 10.1002/esp.1515

[20] Qian Y B, Wu Z N, Zhang L Y, et al. Ground-surface conditions of sand-dust event occurrences in the Southern Junggar Basin of Xinjiang, China. Resources Science. 2006,28(5):185-189. DOI: 10.1016/S1001-0521(06)60029-6

[21] Song Y, Liu L Y, Yan P, et al. Study on the influence of five kinds of underlying matches on sandstorm in North China. Journal of Soil and Water Conservation. 2005,19(6):15-18. DOI: CNKI:SUN:TRQS.0.2005-06-004

[22] Wei Q, Long X, Tian C, et al. Multiscale meteorological characteristics during a sandstorm in Minqin. Arid Zone Research. 2018,35(6):1352-1362. DOI: 10.13866/j.azr.2018.06.12

[23] Zhang H L, Zhang Q L, Ma L Q. Study on microclimate effect of different deploy structure of farmland sheltbelt in Ulanbuh Desert. Journal of Arid Land Resources and Environment. 2009,23(11):191-194. DOI: CNKI:SUN:GHZH.0.2009-11-034

[24] Yang Q, Lei J Q, Wei W S, et al. Effects of artificial oases on climate change trend. Acta Ecologica Sinica. 2004,24(12):2728-2734.

[25] Song J, Wen L, Wang F G, et al. Spatiotemporal dynamics of ecosystem service value in Ulan Buh Desert. Acta Ecologica Sinica. 2021,41(6):2201-2211. DOI: 10.5846/stxb202005141228

[26] Luo F M, Gao J L, Xin Z M, et al. Characteristics of sand-driving wind regime and sediment transport in northeast edge of Ulan Buh Desert. Transactions of the Chinese Society of Agricultural Engineering. 2019,35(4): 145-152. DOI: CNKI:SUN:NYGU.0.2019-04-018

[27] China Meteorological Administration. Ground Meteorological Observation Specification. Beijing: Meteorological Press, 2003: 11. ISBN: 7-5029-3690-4

[28] Zhui R Z, Tan G R, Wang S L. Introduction to Applied Climatology. Beijing: Meteorological Press, 2005: 2-3. ISBN: 7-5029-4036-7

[29] Dong Z B, Zhao A G, Deng J. The surveyor of horizontal sand-dust flux: China, ZL0313453414. 2008.

[30] Zhang F, Tashpolat·Tiyip, Ding J L, et al. The change of land use/cover and characteristics of landscape pattern in arid areas oasis: a case study of Jinghe County, Xinjiang Province. Acta Ecologica Sinica. 2009,29(3):1251-1263. DOI: 10.3321/j.issn:1000-0933.2009.03.021

[31] Zhang P, Zhao X F, Zhang T, et al. Leaching salinity effect of drip irrigation on soil of oasis shelter forests in arid area. Transactions of the Chinese Society of Agricultural Engineering. 2011,27(5):25-30. DOI: 10.3969/j.issn.1002-6819.2011.05.005

[32] Zhang L Y, Wang R A. Deserts and Oasis in China. Lanzhou: Gansu Education Press, 1994. ISBN:7-5423-0477-1

[33] Fang L D, Ning Q R, Guo J J, et al. Hydraulic limitation underlies the

dieback of *Populus pseudo-simonii* trees in water-limited areas of northern China. Forest Ecology and Management. 2020,483:118764. DOI: 10.1016/j.foreco. 2020.118764

[34] Kong D S, Jin B W, Jin M, et al. Microclimate effects of farmland shelterbelt in middle reaches of Heihe basin. Journal of Arid Land Resources and Environment. 2014,28(1):32-36. DOI: 10.3969/j.issn.1674-6813.2014.04.097

[35] Wang X L, Wu Y J. Study on the microclimate effect of forest shelter network in wetland agricultural ecosystem of Jianghan plain-lake district. Resources and Environment in the Yangtze Basin. 1999,8(4):418-420. DOI: CNKI:SUN:CJLY.0.1999-04-013

[36] Yang Y P. Research on Shelterbelt of Upper Yangtze River (Chuanjiang). Beijing: Science Press, 1993: 7-31. ISBN: 7-03-004164-X

[37] Zhao M, Zhan K J, Yang Z H, et al. Characteristics of the lower layer of sandstorms in the Minqin desert-oasis zone. Science China: Earth Sciences. 2011,41(2):234-242. DOI: 10.3724/ SP.J.1011.2011.00181

[38] Liu X D. Analyses of the spring dust storm frequency of Northern China in relation to antecedent and concurrent wind, precipitation, vegetation, and soil moisture conditions. Journal of Geophysical Research. 2004,109(16): 1-16. DOI: 10.1029/2004JD004615

[39] Deng X Y, Yao J Q, Liu Z H. Spatiotemporal dynamic change of vegetation coverage in arid regions in Central Asia based on GIMMS-NDVI. Arid Zone Research. 2017,34(1):10-19. DOI: 10.13866/j.azr.2017.01.02

[40] Zhang Z C, Dong Z B, Zhao A G, et al. Features of sand drift movement in desert: A case study at sand drift observation station of Chinese Academy of Sciences. Arid Zone Research. 2007,24(4):550-555. DOI: 10.1016/ S1872-5791(07)60044-X

[41] Yang X H, Li H J, He Q, et al. Blown sand activities in spring in the desert transitional zone of the Taklimakan Desert: A case in Xiaotang area. Journal of Desert Research. 2012,32(4):915-920. DOI: CNKI:SUN:ZGSS.0.2012-04-004

[42] Yang D L, Wang X Q, Hu Y F, et al. Vertical distribution of aeolian sand mass flux based on field observation at southern rim of the Taklimakan Desert. Journal of Desert Research. 2012,32 (3):631-639. DOI: CNKI:SUN:ZGSS.0. 2012-03-009

[43] Yang X H, He Q, Ali Mamtimin, et al. A field experiment on dust emission by wind erosion in the Taklimakan Desert. Acta Meteorologica Sinica. 2012,26(2):241-249. DOI: 10.1007/ s13351-012-0209-x

[44] Waring R H, Running S W. Forest ecosystem analysis at multiple time and space scales. Forest Ecosystems. Amsterdam: Elsevier, 2007:1-16. ISBN: 9780123706058

[45] Deng R X, Zhang S W, Li Y. Protective effects of farmland shelterbelts in Northeast China: a field scale analysis. Chinese Journal of Ecology. 2009,28(9):1756-1762. DOI: CNKI:SUN:STXZ.0.2009-09-015