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The impact of reclamation on aeolian desertification of four species in the Otindag Desert, China

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ABSTRACT

We used field investigations, wind tunnel experiments and particle size analyses to examine the impact of reclamation practice such as tillage on aeolian desertification associated with four species that represent different stages of the desertification process in the Otindag Desert: *Caragana microphylla*, *Artemisia frigida*, *Leymus chinensis*, and *Stipa grandis* P. A. Smirn. Among the four species investigated, our wind tunnel experiments showed that after the surface vegetation and soils were fully disturbed, the aeolian intensity associated with the *S. grandis* communities was the lowest recorded, whereas that associated with the *C. microphylla* communities was far higher than that in the other communities. These results indicate that aeolian desertification is more likely to occur in *C. microphylla* communities. After the ground surface structures were destroyed, there were no significant differences in the aeolian intensities associated with each species, although the sites were in different stages of degradation. The aeolian processes caused no great difference between the soil and transported materials in the < 50 μm particle size fraction, whereas the proportion of sands (100–250 μm) was higher in the transported material than in the surface soils, indicating that surface coarsening caused by aeolian processes may result in land degradation in the region. Our wind tunnel experiments showed that, under the influence of reclamation, aeolian processes play a critical role in localized aeolian desertification associated with specific species in the Otindag Desert.

1. Introduction

Desertification triggered by aeolian processes, including anchored dune reactivation, the coarsening of surface sediments, the sandification of grassland, and other related processes (Schlesinger and Pilmanis, 1998; Ravi et al., 2009), is the dominant form of desertification in arid, semiarid, and some other regions of semihumid China (Wang, 2013). The Otindag Desert covers an area of 5.2×10^5 km^2, is an area greatly affected by human–environment interactions (Fig. 1), and is a source region of the ancient Chinese civilization (Yang et al., 2015). > 1 million people live in this region at present, where the economy is based on land reclamation and grazing (IMGR, 1990). However, the region is highly sensitive to aeolian desertification (Zhu and Chen, 1994), and from the Holocene to the present, desertification at different scales has frequently occurred (Fang, 1999; Liu et al., 2002; Yin et al., 2011; Yang et al., 2011). In recent decades, as the population pressure has increased and ecological and environmental degradation has continued, the scale of aeolian desertification in the Otindag Desert has become a matter of great concern. For instance, some studies (Sun and Li, 2002; Liu et al., 2006; An et al., 2006; D'Odorico et al., 2012) have suggested that the differing development of various community species indicates the current stage of aeolian desertification in the region, and others (Qiu et al., 2005;Wang et al., 2007; Feng et al., 2016) have suggested that, in recent decades, variations in aeolian intensity has resulted in fluctuations in aeolian desertification. Wang et al. (2006, 2008) also suggested that aeolian desertification in the 1970s was triggered by high aeolian intensities, which caused mobile dunes and sand sheets to develop, covering almost the entire desert and adjacent regions, whereas the reduction in aeolian intensity from the late 1980s to the present has allowed the rehabilitation of the region.

The changing extent of aeolian desertification through the Holocene in the Otindag Desert can be traced using variations in the dominant

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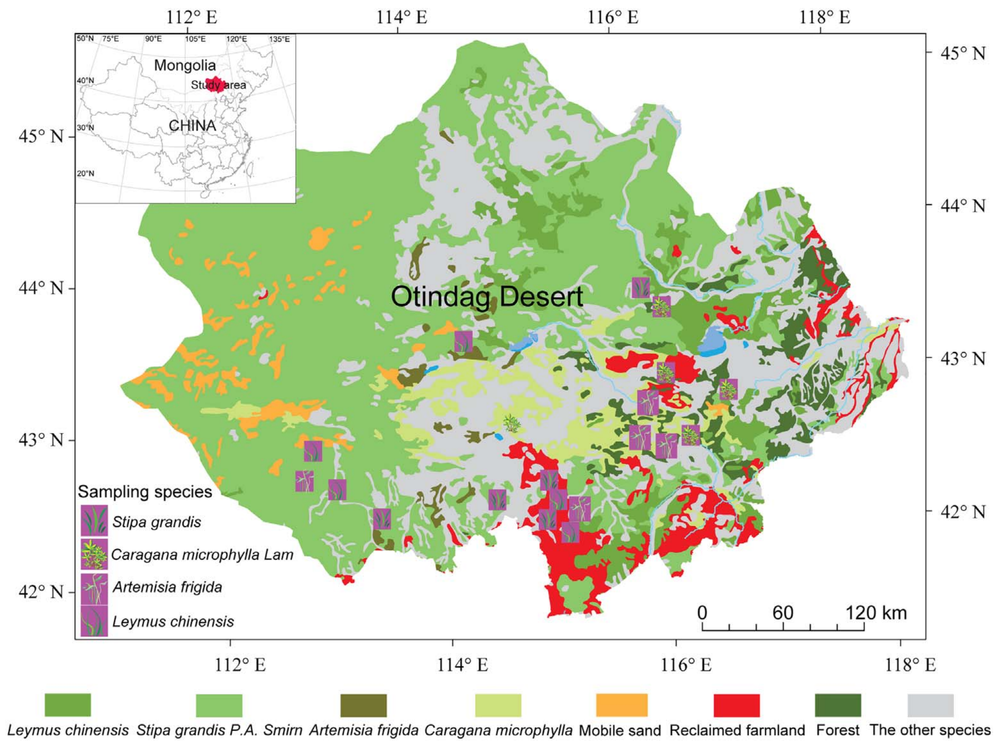

Fig. 1. Location map of the Otindag Desert showing the spatial distributions of *Stipa grandis*, *Artemisia frigida* Willd., *Leymus chinensis*, and *Caragana microphylla* Lam. communities and our sampling sites.

plant species, which are consistent with variations in precipitation, wind activity, evaporation, and other conditions, such as groundwater levels and the extent of grazing (Liu et al., 2002; Schönbach and Taube, 2011). Although from the late 1980s onwards, changes to the dominant community species led to the onset of the ongoing phase of rehabilitation in the desert, this has been mainly restricted to the western regions as a result of the anchoring of mobile dunes there (Wang et al., 2008). Based on the temporal and spatial trends in aeolian processes and the dominant community species, the aeolian desertification of the Otindag Desert has been classified into different grades (Zhu, 1985, 1994; Zhou et al., 2016), and for each aeolian desertification stage there are associated differences in the community species. For instance, after the region has experienced high levels of aeolian desertification, the appearance of *Agriophyllum squarrosum* and *Corispermum* communities indicates that the region is in the early stages of rehabilitation, whereas the appearance of *Artemisia intramon golica* and *Caragana microphylla* Lam. communities indicates that high levels of aeolian desertification have occurred in the region (e.g., Zhao et al., 2005). However, from the early 21st century, with improvements in moisture conditions, some regions have been reclaimed and converted to farmland, and therefore, these practices specifically the fresh-turned soils for seeds may make the surfaces fully disturbed, and consequently result in increases of aeolian desertification in the region.

Rapid increases in reclamation combined with aeolian processes have serious potential impacts, and can also alter the conventional forms and scales of aeolian desertification (Lozano et al., 2013; Asensio et al., 2015). However, in the Otindag Desert, under intense human activity the variations in aeolian intensity and its effects on the composition of surface soils and community species in different degradation stages remain poorly understood. Therefore, in this study, we used field investigations and wind tunnel experiments to evaluate the impacts of reclamation on aeolian desertification in the Otindag Desert. The results should extend our understanding of the role of aeolian transport within the evolution of regional ecosystems, and the relationship between aeolian processes and desertification, thereby providing support for those attempting to combat localized desertification in the Otindag Desert.

2. Materials and methods

2.1. Sampling sites

Field investigations were carried out throughout the Otindag Desert, and the sampling area (42.2–43.7°N, 112.7–116.6°E) contained 20 sites (Fig. 1) with elevations varying between 1032 and 1412 m above sea level. During our field investigation periods, these sites we sampled have not been reclaimed, and the lands were used only for grazing. Based on data from meteorological stations within and around the desert, annual mean precipitation in the desert varies between 200 and 400 mm, mean wind speed at the standard measuring height of meteorological stations varies between 3.5 and 5.3 m/s, the dominant wind direction is NE, annual mean temperature varies between 1.5 °C and 2.5 °C, and the dominant soil in our sampling sites are the aeolian sand (Wang et al., 2006).

2.2. Methodology

In August 2015, we collected 20 surface soil samples from *S. grandis* P. A. Smirn., *A. frigida* Willd., *L. chinensis*, and *C. microphylla* Lam. communities (Fig. S1), and for each community, one sample from different degradation stages (Fig. S2 and Table S1) was obtained for the wind tunnel experiments and further analysis. Soil disturbance by human activity such as reclamation, only extends to a depth of about 30 cm in the Otindag Desert, so we restricted our sample collection to within this uppermost layer (i.e., Su et al., 2007; Zhao et al., 2009). The wind tunnel experiments were conducted at the Key Laboratory of Desert and Desertification at the Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China. The blow-type non-circulating wind tunnel has a total length of 37.8 m, with a 16.2-m-long test section. The cross-sectional area of the test section is 0.6 × 1 m. The free-stream wind velocity in the wind tunnel can be adjusted from 1 m/s to 40 m/s. Additional