Summary

Thesis title: Processes linking wind erosion and ecosystem dynamics in a dust source hotspot in East Asia
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Wind erosion is an important environmental phenomenon in arid and semi-arid regions worldwide. It has substantial influences on human and livestock health conditions, economic activities, and ecosystem dynamics, in both the source and downwind areas. The Mongolian grasslands are a dust hotspot with the highest frequencies of dust outbreaks in East Asia and an increasing number of dust events since the 2000s.

The occurrence of wind erosion depends on the erosivity (i.e., wind speed) and the erodibility (i.e., land surface conditions). The vital land surface conditions in the Mongolian dust source area are the amount and distribution of vegetation and soil moisture. In addition, soil freeze–thaw processes and snow cover should be taken into consideration as the erodibility factors in this high-latitude area. Despite the importance of this dust source hotspot in East Asia, very little observation has been done on the complex processes of how those land surface conditions seasonally affect wind erosion in and around the hotspot. In turn, wind erosion is a major abiotic mechanism for moving material and thus responsible for cascading land-degradation phenomena in drylands. When topsoil is eroded by wind, the soil properties (e.g., soil texture, nutrients and organic material) are changed and redistributed, and thus affect the amount and distribution of vegetation. However, there is a lack of knowledge on the effects of wind erosion on ecosystem dynamics.

In this study, we used a process-based ecosystem (DAYCENT) model and field observation dataset (e.g., weather, saltation and vegetation) to investigate (1) the impacts of land surface conditions on wind erosion, and (2) the potential impacts of wind erosion on ecosystem dynamics, in a dust source hotspot of Mongolia (Tsogt-Ovoo in the desert steppe) in the 2000s.

In the first part, we integrated a unique 6-year measurement of saltation and simulated land surface elements (vegetation components of litter, live, and standing dead

and soil temperature and moisture) by the DAYCENT ecosystem model, to investigate the effects of land surface conditions on wind erosion at Tsogt-Ovoo (TsO) in the desert steppe during 2012–2017. Saltation tended to occur during February–June with strong westerly winds (>10 m s^{-1}) and the highest frequencies in 2012 and 2015. The saltation season was divided into two periods based on seasonal variations in threshold wind speed for saltation (U_{t}): spring (February–early May) with an increase in saltation (i.e., a decrease in U_{t}); and early summer (late May–July) with a decrease in saltation (i.e., an increase in U_{t}). Multiple regression analysis revealed that for 2012 and 2015, U_{t} was negatively correlated with soil surface temperature in spring and positively correlated with vegetation components of live and standing dead in early summer. These correlations suggest that saltation was enhanced through soil freeze–thaw processes in spring and suppressed during early summer through plant growth in addition to dead leaves that are residues from the preceding summer. We propose a novel predictive tool to explain the temporal changes in U_{t} during the saltation seasons of 2012–2017. The results show that frequent saltation in 2012 and 2015 resulted from a combination of frequent strong winds and a low U_{t}, which was related to changes in soil temperature and low standing dead and live grasses.

In the second part, to explore the potential impacts of wind erosion on ecosystem dynamics, we assumed a scenario of topsoil (0–0.1 m depth) for simulation: a potentially wind-eroded coarse-textured topsoil (the wind-eroded scenario), which comprised 1% clay and 99% sand. This scenario represents an extremely wind-eroded topsoil that had permanently lost the fine particles and gained sand particles due to wind erosion. We then used the DAYCENT model to simulate vegetation dynamics and how much of the changes in plant production were attributable to environmental factors (water, nitrogen, and temperature). Finally, we compared the simulations of the wind-eroded scenario and the actual condition in two Mongolian grasslands (desert steppe and steppe). Generally, stresses owing to a lack of water and nitrogen had the most influence on plant production in the wind-eroded scenario. For the wind-eroded topsoil, plant production decreased with increasing water stress in the desert steppe. However, it slightly increased in the steppe because of an inverse texture effect, where water infiltrated from the coarse topsoil to the deeper root-zone due to lower soil evapotranspiration and thus facilitated vegetation growth. At that time, nitrogen supply became the primary factor limiting plant growth.

In conclusion, we highlight that it is important that vegetation components of live and standing dead and soil freeze–thaw processes affect wind erosion in the dust source hotspot in East Asia. Moreover, we deduce that water stress, which is caused by the wind-eroded topsoil, significantly affects plant production in the Mongolia grasslands, when compared with temperature and nitrogen stresses. This outcome is expected to contribute to improving the accuracy of dust emission model and designing effective land use management to control wind erosion in the Mongolian grasslands. This study provides new insights into the complex interactions between wind erosion and ecosystem dynamics.