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Aeolian sediment transport and spatial patterns of sand deposition in vegetation canopies: Observations from wind tunnel experiments using coloured sand

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Desertification is a major environmental hazard directly affecting about 250 million people through the loss of soil resulting in a reduction in the land's productivity and potentially concerns about 2.5 billion people living in drylands worldwide. Additionally, the importance in view of global change is increasingly recognised. Shifts in vegetation structure and albedo as a result of desertification can significantly affect regional climate, with feedbacks to ecosystem dynamics.

Today, re-vegetation is accepted as the most efficient and promising strategy to combat wind erosion and desertification in the long term. Vegetation plays an important role in reducing soil erosion by wind in arid and semi-arid environments. Plants protect the soil from wind erosion by (i) covering a proportion of the surface and thereby sheltering the soil from the erosive force of the wind, (ii) extracting momentum from the wind, and (iii) trapping soil particles in transport. Furthermore, plants reduce wind erosion by altering soil and atmospheric characteristics, such as soil structural stability and near-surface air and soil moisture.

The objective of this study was to compare the total sediment mass flux, the fine dust concentration and the vertical profile of sediment mass flux in three different canopy densities of Perennial Ryegrass (*Lolium perenne*) and on a bare sand surface. In our wind tunnel study we examined aeolian sediment transport in live plant canopies, instead of employing model plants as in most previous studies. The results show that both total sediment mass flux Q and PM_{10} concentration in the air decreased exponentially with increasing canopy density. In the high-density canopy (frontal area index λ = 0.58), Q and PM_{10} concentration were reduced to 0.01% and 0.4% of the unplanted bare surface configuration. In the medium-density canopy (λ = 0.16), Q and PM10 concentration were reduced to 6.6% and 48.5%. In the low-density canopy (λ = 0.03), however, Q and PM_{10} concentration were increased to 117.5% and 145.6%. This is attributed to elevated shear stress on the sand bed caused by flow acceleration around the tussocks and vortical structures in their lee. Furthermore, the grasses were observed to trigger erosion by oscillating movements at the ground surface. It was also found that the vertical profiles of sediment mass flux in the medium- and high-density canopy strongly deviated from the exponential decay curve of the unplanted configuration, showing a local maximum at approximately twice the canopy height.

Furthermore, we used coloured quartz sand to visualise spatial patterns of sediment deposition within grass canopies and to identify areas of net deposition. In the low- and medium-density canopy, the wake areas downstream of the tussocks were the main locations of sediment deposition. In the medium-density canopy, these wedge-shaped wake deposits overlapped with the adjacent downstream tussocks, while in the low-density canopy they did not, indicating a wake-interference flow and an isolated roughness flow, respectively. In the high-density canopy, only few sand grains were entrained by the wind and they deposited mainly within reach of the grass tussocks. The deposited sand grains were evenly distributed around the tussocks, without pronounced accumulations on their upstream, downstream or lateral sides, suggesting a skimming flow regime. The fraction of the non plant covered (nc) sand surface which was potentially exposed to erosion (EP_{nc}) was notably smaller than the area which was not covered by grasses. It accounted for 67-78 % of the non-covered surface in the low-density canopy, and for 44-77 % in the medium-density canopy. This finding indicates that wind erosion models overestimate the sediment source area if they approximate the erodible area with the total surface not covered by roughness elements.