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Secondary Airflow Structure around Clustered Shrubs and Its Significance for Vegetated Dune Evolution

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Shrubs have an important significance in aeolian processes due to their disturbance of the local airflow. In the formation of vegetated dunes, there is an iterative interaction between shrub geometry, the structure of the secondary airflow, and the interaction between neighboring shrubs. Understanding the dynamics of vegetated dunes thus requires an insight into the airflow fields around shrubs. Based on aerodynamic and aeolian sand physics theory, this project measured the complex secondary flow field and aeolian sand deposition pattern around single and cluster shrubs with varied densities (i.e. 0.05, 0.08, 0.15, 0.20) and gap ratios (the ratio of the gap spacing between the shrub models to the center-to-center distance for the shrub models, ranged from 1.1 to 1.8 with side-by-side arrangement and 1.2 to 4.3 with tandem arrangement) using the particle image velocimetry system through wind tunnle simulation. The relationship between the secondary airflow structure and the shrub's porosity and arrangement was analyzed quantitatively. Research results revealed that porosity (density) is the key parameter to affect the flow patterns around single shrub. Compared to solid obstacles, bleed flow through the shrubs has great influence on the secondary airflow patterns around itself. Under cluster modes, the distance between two adjacent shrubs has great influence on flow field structures around them. The flow patterns around two side-by-side arranged shrubs can be classified into three kinds of modes, that is: single-bluff-body, biased flow pattern and parallel vortex streets. The flow patterns around two tandem arranged shrubs can be classified into three regimes, that is: the extended body regime, reattachment regime and co-shedding regime. The "shadow zone" with low velocity in the lee of shrubs is the optimal position for sand deposition, but its form, size and orientation would varied with the shrub porosity and gap ratio between them. With the increase of the gap ratio, the flow reattachment distance, vortex core position and Reynold shear stress location are all moved downwind. Gap ratio between two adjacent vegetated obstacles was the key factor to determine the sand drifts deposition area and position in their lee side. Under complicated wind regimes in the field, sand deposition patterns around shrubs were the equilibrium of erosion and deposition. Furthermore, sand shadows in the lee of clustered shrubs link together should have important contribution to sand patch formation that may be the initial stages of barchans in the field.