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Formation of Vegetated Linear Dunes and their instability under vegetation cover removal: Conceptual model and verification in numerical simulations

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Vegetated linear dunes (VLDs) are the most common and dominant dune type in the world's deserts. However, the processes of formation and elongation of VLDs, which are partly or fully vegetated, are not well understood because all contemporary VLDs are stable, located in areas that are under low wind power and active varieties are not available for study. Nevertheless, it is assumed that vegetation cover is the main reason for VLD formation, and several theories have been proposed for their formation.

According to our conceptual model, VLDs were formed under conditions that prevailed during the Pleistocene but are not present today. Those ancient conditions are characterized by higher wind power that can reduce, but not completely destroy, vegetation cover, leading to the formation of big nebkhas with lee (shadow) dunes behind each nebkha. The lee dunes connect to the nebkha in front of it, forming one elongated linear vegetated dune. The wind that formed the nebkhas and lee dunes also eroded the swales that run parallel to the lee dunes. Accordingly, VLDs develop by elongation of lee dunes and formation of downwind nebkhas, where shrubs or grasses develop. Such nebkhas will form another lee dune, which elongates and forms its own nebkha, and so on.

We apply a numerical tool to simulate the formation and elongation dynamics of a linear dune in presence of vegetation, as well as its destabilization after removal of the vegetation cover. In previous work, we modeled the morphodynamics of barchan, transverse, seif and parabolic dunes, as well as the formation of aeolian dune fields under constant vegetation growth rate. Our simulations reproduce the morphology and dynamic behaviour of aeolian dunes while agreeing with quantitative measurements. However, so far there is no model that produces longitudinal alignment of mobile dunes in the presence of a vegetation cover under unidirectional wind. Here we have found that such longitudinal alignment can be obtained by applying a cyclically varying vegetation growth rate with suitably chosen oscillation time period and amplitude. Under these conditions, straight, elongating vegetated dunes develop, which resemble closely the shape of real VLDs. By removing the vegetation cover from a VLD, the dune surface becomes unstable and a train of transverse bedforms (surface sand-waves) develops on the VLD. The size of these transverse bedforms is consistent with the values expected from theory and with field observations performed on a VLD field in NW Negev by Roskin et al. (2011) [Quatern. Sci. Rev. 30, 3364–3380].

Overall, field observations and numerical simulations corroborate our conceptual model for VLD formation and instability, and show that the Earth's large VLD fields currently stabilized by vegetation cover can give place to active, migrating transverse dunes if vegetation cover in these fields is reduced as a consequence of 21st century climate change.