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Numerical modelling activation of vegetated parabolic dunes driven by climatic change and anthropogenic disturbance

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Parabolic dunes are a quintessential example of the co-evolution of soil, landform, and vegetation, and they are found around the world, on coasts, river valleys, lake shores, and margins of deserts and steppes. These areas are often sensitive to changes in natural and anthropogenic forcings and socio-economic activities. Some studies have indicated parabolic dunes can lose vegetation and transform into barchan and transverse dunes by environmental change such as decreased precipitation or lowered water table, as well as anthropogenic stress such as increased burning and grazing. These transformations and shifts between states of eco-geomorphic systems may have significant implications on land management and social-economic development.

This study utilises the Extended-DECAL - parameterised by field measurements of dune topography and vegetation characteristics combined with remote sensing - to explore how increases in drought stress, wind strength, and grazing stress may lead to the activation of stabilised parabolic dunes into highly mobile barchans. The modelling results show that the mobility of an initial parabolic dune at the outset of perturbations determines to a large extent the capacity of a system to absorb the environmental change, and a slight increase in vegetation cover of an initial parabolic dune can increase the activation threshold significantly. Plants with a higher deposition tolerance increase the activation threshold for the climatic impact and sand transport rate, whereas the erosion tolerance of plants influences the patterns of resulting barchans. The change in the characteristics of eco-geomorphic interaction zones may indirectly reflect the dune stability and predict an ongoing transformation, whilst the activation angle may be potentially used as a proxy of environmental stresses. In contrast to the natural environmental changes which tend to affect relatively weak and young plants, grazing stress can exert a broader impact on all plants indiscriminately. A small increase in grazing stress just above the activation threshold can significantly accelerate the dune activation.

