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Environmental Controls and Eco-geomorphic Interactions of the Barchan-to-parabolic Dune Stabilisation and the Parabolic-to-barchan Dune Reactivation

Na Yan and Andreas Baas
Department of Geography, King's College London, London, UK

Parabolic dunes are one of a few common aeolian landforms which are highly controlled by eco-geomorphic interactions. Parabolic dunes, on the one hand, can be developed from highly mobile dune landforms, barchans for instance, in an ameliorated vegetation condition; or on the other hand, they can be reactivated and transformed back into mobile dunes due to vegetation deterioration. The fundamental mechanisms and eco-geomorphic interactions controlling both dune transformations remain poorly understood.

To bridge the gap between complex processes involved in dune transformations on a relatively long temporal scale and real world monitoring records on a very limited temporal scale, this research has extended the DECAL model to incorporate 'dynamic' growth functions and the different 'growth' of perennial shrubs between growing and non-growing seasons, informed by field measurements and remote sensing analysis, to explore environmental controls and eco-geomorphic interactions of both types of dune transformation. A non-dimensional 'dune stabilising index' is proposed to capture the interactions between environmental controls (i.e. the capabilities of vegetation to withstand wind erosion and sand burial, the sandy substratum thickness, the height of the initial dune, and the sand transport potential), and establish the linkage between these controls and the geometry of a stabilising dune. An example demonstrates how to use the power-law relationship between the dune stabilising index and the normalised migration distance to assist in extrapolating the historical trajectories of transforming dunes. The modelling results also show that a slight increase in vegetation cover of an initial parabolic dune can significantly increase the reactivation threshold of climatic impact (both drought stress and wind strength) required to reactivate a stabilising parabolic dune into a barchan. Four eco-geomorphic interaction zones that govern a barchan-to-parabolic dune transformation and a parabolic-to-barchan dune transformation have been identified. These zones exhibit different characteristics and dynamics that are sensitive to changes in environmental forces, and can be potentially used as a proxy to monitor the mobility of a dune system.