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Predicting vegetation-stabilized dune morphology

T. Barchyn (1) and C. Hugenholtz (1,2)

(1) University of Lethbridge, Lethbridge, Canada (tom.barchyn@uleth.ca), (2) University of Calgary, Calgary, Canada

The morphology of vegetation-stabilized dune fields on the North American Great Plains mostly comprises parabolic dunes; stabilized barchan and transverse dunes are rare. One notable exception is the Nebraska Sand Hills (NSH), where massive grass-covered barchan and transverse dunes bear proof of former desert-like conditions. We present a hypothesis from a numerical dune field model to explain the vegetation-stabilized morphology of dunes. The model incorporates a growth curve that preferentially grows vegetation in regions of sediment deposition with a sharp drop in growth at the peak depositional tolerance of vegetation, qualitatively matching biological response to erosion and deposition. Simulations on a range of pre-stabilization dune morphologies, from large closely-spaced transverse dunes to small dispersed barchans, indicate that the stabilized morphology is largely determined by the ratio of slipface deposition rate to peak depositional tolerance of vegetation. Conceptually, slipface deposition rate is related to dune height and celerity. By keeping depositional tolerance constant (representing a constant vegetation type and climate) the model shows that large slow-moving dunes have low slipface deposition rates and essentially 'freeze' in place once vegetation is introduced, retaining their pre-vegetation morphology. Small fast-moving dunes have higher slipface deposition rates and evolve into parabolic dunes. We hypothesize that, when barchan and transverse dunes are subjected to a stabilizing climate shift that increases vegetation growth rate, they retain their pre-stabilization morphology if deposition rates are below the depositional tolerance of stabilizing vegetation, otherwise they become parabolic dunes. This could explain why NSH dunes are stabilized in barchan and transverse morphologies while elsewhere on the Great Plains dune fields are dominated by smaller parabolic dunes.