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State Variables and Phase Space Construction for Ecogeomorphic Complex Systems

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The evolution of aeolian dune fields in vegetated environments is a good example of an ecogeomorphic system where ecological and geomorphic processes interact dynamically on various scales to produce complex and varied landscapes. Cellular automaton simulations using the DECAL model have shown the feasibility of replicating some of the more salient features of these landscape dynamics as a result of self-organisation of a discrete non-linear system subject to a simple set of fundamental rules. Simulations of parabolic dune fields, blowouts, and coppice dunes compare favourably with current descriptive understanding of vegetated aeolian landscape development and the model is used to investigate exactly how and why various kinds of plant species and vegetation patterns influence the dynamics of dune development in aeolian environments.

The further development and practical application of a reduced-complexity model like this faces severe challenges in quantifying the landscape characteristics in a numerical framework of state variables that can capture all the relevant aspects of both the ecological and geomorphic conditions. A related problem is the definition of a phase-space that can be used universally to describe and analyse time evolution of the system as well as for quantifying metrics of chaotic behaviour, divergence, and attractor basins. In addition such a framework should be tailored to the resolution, coverage, and types of data available from real-world landscapes in a variety of environments for deriving comparable and testable system metrics.

This paper presents the methods, findings, and limitations of using advanced statistical

techniques - including Principal Component Analysis, multi-collinearity reduction, and Cluster Analysis - for analyzing state variables and constructing a suitable phase-space for the DECAL model.