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Form-process relations versus multi-process landscape evolution models

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This contribution focuses on the perceived conceptual difficulty faced when building multi-process landscape evolution models based on single-process form relations. It sketches how conventional field-based geomorphology both helps and hampers the formulation, parameterization and calibration of such models, and discusses directions for future research that follow from this issue.
Landscape evolution models have become geomorphology's virtual laboratories, in which wide ranges of assumptions and conditions can be simulated over large spatial and temporal scales. Over timescales that are relevant to landscape evolution, the "laws of nature" in these virtual laboratories are process-form relations derived from fieldwork. With measurements of landform evolution rates, such process-form relations can be expressed in mathematical formulas as a function of variables such as slope, overland waterflow or vegetation density. For example, erosion due to overland waterflow at landscape evolution timescales is often expressed as a power function of both slope and overland waterflow.
In this way, form-process relations have helped landscape evolution models. Many valuable studies have been performed where the activity of a geomorphic process and the rate of landform evolution have been related to external factors such as tectonic activity or climatic drivers. An example are modelling studies showing that the wide variety of sand-dunes observed worldwide can be explained with a single process; aeolian sand transport, while varying conditions such as the amounts of vegetation and sand and wind force and direction.
Currently, landscape evolution models are being used in more complex and spatially larger case studies where landscapes react to - and landforms result from - the activity of multiple processes. We run the risk of contradicting ourselves: if our models are based on single-process form relations, then why do landforms in our models result from the interaction between multiple processes?
This contradiction may be solved by arguing that the landforms resulting from interactions between multiple processes are not the (apparently extraordinary) landforms that we used to derive the single-process form relations – or more acceptably, that there is a continuum of landforms ranging from the completely single-process landforms to the landforms that result from strong interaction between several processes. Even if we agree, several other problems with simulating multiple geomorphic processes in landscape evolution models remain.
Arguably, the largest of these problems is the fact that the process-form method of formulation is no guarantee that process formulations cover the complete range of forces and material properties. Or worse, that there is even no information at all about which part of that range a certain process is valid for – besides the zero-activity thresholds that are sometimes defined. Taking an example from hillslope processes, many researchers would say that mudflows occur in wetter soil material than earthflows. Yet I argue that almost nobody would be able to say under which wetness earthflow stops and mudflow starts. Therefore, process descriptions could overlap or underlap, leaving geomorphic activity described twice or not at all.
If we are ultimately interested in building continental or even global landscape evolution models in which a much wider range of environments (i.e. forces and material properties) is simulated than has been done so far, we must be sure that geomorphic activity over that entire range of forces and material properties is captured – and is captured only once. Guidelines about how to deal with the problems associated with the simulation of multiple processes should therefore be a topic of concern in future landscape evolution modelling research.
I will illustrate this conceptual issue with a simple model-based exploration of the effect of overlap between geomorphic processes. Suggestions for implications for current research are made.