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Pattern and Landscape Metrics: Tools for Basin Comparison and Insight in Hydrological Processes

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The control heterogeneous landscapes exert on the hydrological functioning of a basin necessitates a profounder understanding of their complex interaction in order to allow appropriate extrapolation to ungauged basins. Spatial structures, such as the mosaic-like pattern of water contributing and accepting areas and the network of flow paths, have been identified as a significant control on the surface hydrology of semi-arid areas and as a valuable means to classify catchments. An insightful analysis of how patterns act on processes forces itself therefore to the fore.

To this end, a virtual model was developed combining a hydrological surface model with varying artificial landscapes. The former worked with a distributed grid of model cells. A network of converging flow paths linking the cells was built according to Mandelbrot's fractal squig. Fixed model parameters for a hydrological sink and source class were distributed over the model cells following five different mapping algorithms which resulted in spatial patterns ranging from the completely random to the highly clustered. Green-Ampt infiltration governed the vertical component of the hydrological model and a kinematic wave equation the lateral routing. The resulting basin response in the form of an outlet hydrograph for a single rainfall event was related to spatial characteristics of the structural landscape pattern. The latter quantified in 23 landscape metrics drawn from both ecology and hydrology.

Results of statistical analyses show that patterns with a random distribution of sinks and sources have, ceteris paribus, a much smaller variability in their response than patterns organised in distinct patches. Random patterns can therefore be seen as a homogeneous group in which the particular spatial organisation can be neglected when modelling, while more clustered patterns do exhibit an important control on the basin response depending on the connectivity of the pattern, driven by the specific location in the landscape of runoff sources and sinks. The analyses thus elicited that different organised patterns demand different model structures as other mechanisms predominate. Pattern can therefore be useful as a means to extrapolate to ungauged basins but in order to allow comparison, appropriate spatial information needs to be meaningfully quantified.

Landscape metrics based on source patch size and sources' distance to the outlet proved most significant to explain the variability in hydrological behaviour. Other metrics, stressing other aspects of pattern, were less correlated to the outlet hydrograph. Landscape metrics therefore represent a valuable tool to elicit relevant pattern characteristics while excluding irrelevant properties, thus allowing insight in the mechanisms which govern hydrological processes and in the dominant processes taking place in differently structured landscapes.

Changes and similarities in pattern constitute a crucial leverage when comparing hydrological landscapes and when determining the extent of model structure. Landscape metrics offer a ready tool to set up quantitative relations between different basins and to expand our knowledge of the control of the landscape on function and process. The search for complete explanative measures, however, remains challenging.