Scaling of interactions between individuals to landscape patterns

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In scaling up, researchers must consider patchiness, interactions, non-linearities, and processes that can be considered constant at one scale may become important at another. A process-aware way of scaling up is to make a model of the scaling process. Results of simulations with validated fine-grained models are condensed by applying formal statistical analyses to quantitative or qualitative relationships with high explanatory power and therefore, reliability. These relationships are then used as instructions in coarser-grained models. The fine-grained simulations must cover the range of conditions expected in the coarse-grain model, either as independent variables or by using scenarios. The condensation may be in time, space, or other units, including individuals or taxa, and can be repeated more than once.

For example, we simulated the performance of individual annual plants (grain size 1 cm^2) in semi-arid climates to study the effect of changes in rainfall variability. The density of the seed bank and annual mean water availability were the most important predictors of biomass. In order to simulate the dynamics of annual plants at the landscape scale (grain size 25 m^2), we carried out simulations for a range of classes of seed bank densities in factorial combination with classes of mean annual precipitation (representing climate). The simulated productivity of the vegetation and its variability were expressed as non-linear regressions of five quantiles of productivity on mean annual precipitation for each factorial category (Fig. 1). In the landscape model the annual vegetation was modelled by selecting the appropriate seed bank and climate combination and a random quantile to calculate productivity based on the annual rain volume. This integrated smaller effects of germinability, density-dependent competition, and daily rain variability of the fine-grained model in the coarse-grain model. In a similar way the small-scale dynamics of dwarf shrubs were included in the landscape model. We added grazing by sheep and goats and fire as landscape-scale processes. The landscape model was validated with air photographs. For scaling up the change of vegetation to the scale of countries, we repeated the simulations for characteristic wadi landscapes differing in their slope angle for five climatic regions. The results were also expressed as non-linear regressions of productivity on mean annual precipitation.

The equations were applied to maps of the median slope of the landscape within 1 km^2 (calculated from 90 m DEMs) and mean annual precipitation (Fig. 1). Using this hierarchical modelling approach, we were able to produce country-wide maps of rangeland productivity for various scenarios of climate change and land-use scenarios.

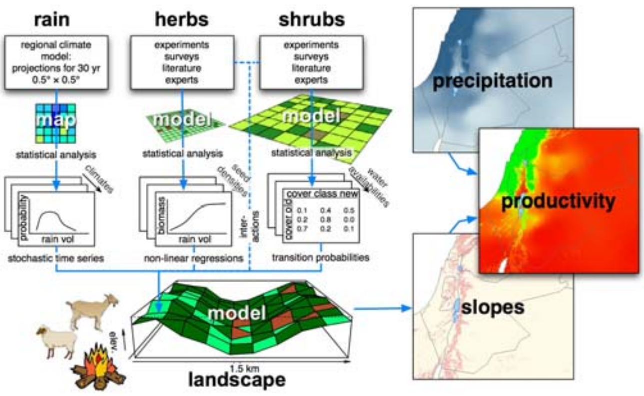

Figure 1. Visualization of hierarchical scaling.