N-dimensional hypervolumes to study stability of complex ecosystems under environmental change

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Abstract

Gradual climate change, changes in extreme events and in land-use threaten ecosystems worldwide. Mountain ecosystems are particularly sensitive to these changes, since species often live at their environmental tolerance limits and/or have been limited by historical land-use, as happens in the European Alps. Yet, the combined impacts of these three fronts of global change – gradual climate change, changes in patterns of extreme events, and land-use changes – have seldom been investigated. Using a previously validated dynamic vegetation model, FATE-HD, parameterised for plant communities in the Ecrins National Park (French Alps), we explored how the forest-grassland ecotone will respond to gradual climate warming, drought events and land-use change. Our results showed that intense and frequent drought impacts forest expansion and taxonomic turnover differently from gradual climate change and land-use abandonment. This indicates that plant communities in the forest-grassland ecotone, but also across mountain ecosystems in the French Alps, may be driven unto different vegetation states in result of environmental changes. To investigate ecosystem stability in such a diverse landscape, we propose a framework that considers the contribution of multiple ecosystem components to stability. Using n-dimensional hypervolumes built from ecosystem components (e.g. species or functional groups, to functional traits, habitat cover, amongst others) we can quantitatively assess how much ecosystems have shifted after environmental changes have occurred. We demonstrate the value and flexibility of this framework by analysing responses of Alpine ecosystems to environmental changes, highlighting the importance of a multidimensional approach to study ecosystem stability and transient dynamics.

Keywords: ecosystem stability, n, dimensional hypervolumes, perturbations, climate change, land, use changes, drought, extreme events, ecological modelling

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