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The nonlinearly combined response of the grassland ecosystem to human activity and climate change

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Human activity and climate change are important factors that affect grassland ecosystems. A new optimization approach, the approach of conditional nonlinear optimal perturbation (CNOP) related to initial and parameter perturbations, is employed to explore the nonlinearly combined impacts of human activity and climate change on a grassland ecosystem using a theoretical grassland model. In our study, it is assumed that the initial perturbations and parameter perturbations are regarded as human activities and climate change, respectively. Numerical results indicate that the climate changes causing the maximum effect in the grassland ecosystem are different under disparate intensities of human activities. This implies the pattern of climate change is very critical to the maintenance or degradation of grassland ecosystem in light of high intensity of human activities and that the grassland ecosystem should be rationally managed when the moisture index decreases. The grassland ecosystem influenced by the nonlinear combination of human activities and climate change undergoes abrupt change, while the grassland ecosystem affected by other types of human activities and climate change fails to show the abrupt change under a certain range of perturbations with the theoretical model. The further numerical analyses also indicate that the growth of living biomass and the evaporation from soil surface shaded by the wilted biomass may be crucial factors contributing to the abrupt change of the grassland equilibrium state within the theoretical model.