A Model Analysis for the Regime Shift in Alpine Vegetation

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Abstract

In alpine ecosystems, global warming may accelerate the time of snowmelt in spring, which shortens the duration of snowmelt-water supply in alpine regions, resulting in drier soil conditions in mid-summer. This may influence the species composition of alpine vegetation especially inhabiting moist habitat. Using a dynamic mean field model, the regime shift of vegetation change in alpine ecosystem under warming is theoretically analyzed.
Our model is based on the observed vegetation change, rapid expansion of dwarf bamboo (*Sasa kurilensis*) into snow-meadow vegetation, in the Daisetsuzan National Park, Northern Japan. A positive feedback mechanism is considered in the model, that is, dwarf bamboo favorably expands the distribution area under early -snowmelt conditions and soil water contents are more suppressed due to high transpiration ability of dwarf bamboo. This feedback mechanism is formulated as two equations. First, the effect of dwarf bamboo B on soil water content W is introduced through a differential equation in which a decreasing period of snowmelt-water supply caused by an increase in air temperature T is contained. Secondly, the effect of W on B is represented by a function $B = B(W,\ T)$, which is based on the empirical photosynthesis responses of B to W and T. The former gives an indirect effect of T on B via a change in snowmelt period due to a change in T, while the latter gives a direct effect of T on B.

It is found by our model analysis that a regime shift, i.e., quasi irreversible drastic change from snow-meadow to bamboo shrubland, can occur substantially not through the direct effect of temperature but through indirect effect of temperature via early snowmelt followed by soil aridification. This result suggests that drastic change in alpine vegetation may occur by small shift in snow regime.

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