A Model Analysis for the Regime Shift in Alpine Vegetation Under Climate Change

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Global warming may accelerate the time of snowmelt in spring, which extends the annual growth period of plants but shortens the duration of snowmelt-water supply in alpine regions, resulting in drier soil conditions in mid-summer. This may influence the growth and 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 once it develops dense clonal patches. The feedback mechanism between the abundance of dwarf bamboo (***B***) and soil water content (***W***) is formulated as two equations. The effect of ***B*** on ***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. Invasion of dwarf bamboo to early-melting places accelerate the soil aridification due to high transpiration action of dwarf bamboo. The effect of ***W*** on ***B*** is represented by a function ***B*** = ***B***(***W***, ***T***), which is based on the empirical photosynthesis responses of dwarf bamboo 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***. We analyzed numerically the occurrence of regime shift in various parameter regions such as transpiration and evaporation rate. It is found by our 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 ***T*** on ***B*** via early snowmelt followed by soil aridification.

This work was supported by Grant-in-Aid for Scientific Research (C) 15K00524 by the Japan Society for the Promotion of Science.

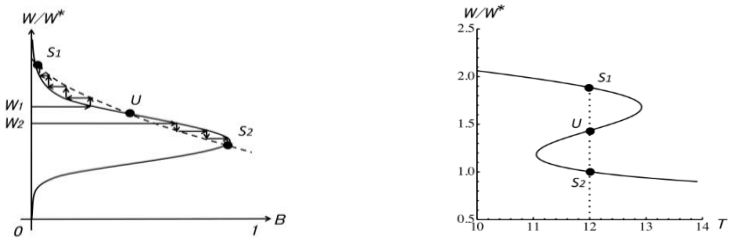

Fig. 1. (Left) A positive feedback mechanism between the abundance of dwarf bamboo (***B***) and soil water content (***W***). (Right) Hysteresis graph peculiar to regime shift. (S_1 and S_2 are the stable states of snow-meadow and bamboo shrubland respectively, and U is the unstable state.)

References:

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