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Modelling forest transition: Bistability of forested and abandoned landscapes

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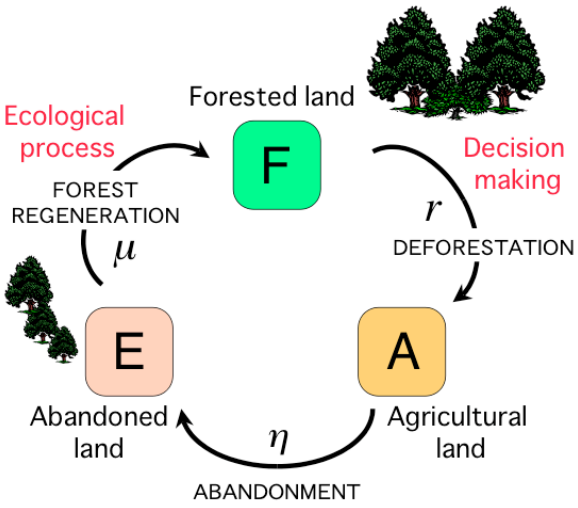
A historical generalization about forest cover change in which rapid deforestation gives way over time to forest restoration is called “the forest transition”. Prior research on the forest transition leaves three important questions unanswered. (1) How does forest loss influence an individual landowner’s incentives to reforest? (2) How does the forest recovery rate affect the likelihood of forest transition? (3) What happens after the forest transition occurs? The purpose of this paper is to develop a minimum model of the forest transition to answer these questions (Satake and Rudel, 2007). We assume that a forest is composed of many land parcels, each of which is in one of a finite list of land-use states. The land-use state of each land parcel changes stochastically. The transition probability is determined by two processes: the forest succession and the decision of landowners. The landowner tends to choose the land-use state which has a high expected discounted utility, i.e., the sum of the current and the future utilities of the land parcel. Landowners take the likelihood of future landscape changes into account when making decisions. We focus on a three-state model in which forested, agricultural, and abandoned states are considered (Figure). We assume that deforestation caused by landowners' decisions and forest regeneration initiated by agricultural abandonment have aggregated effects that characterize entire landscapes. These effects include feedback mechanisms called the 'forest scarcity' and 'ecosystem



service' hypotheses. In the forest scarcity hypothesis, forest losses make forest products scarcer which increases the economic value of forests. In the ecosystem service hypothesis, the environmental degradation that accompanies the loss of forests causes the value of ecosystem services provided by forests to decline. We examined the impact of each mechanism on the likelihood of forest transition through an investigation of the equilibrium and stability of landscape dynamics. We found that the forest transition occurs only when landowners employ a low rate of future discounting. After the forest transition, regenerated forests are protected in a sustainable way if forests regenerate slowly. When forests regenerate rapidly, the forest scarcity hypothesis expects instability in which cycles of large-scale deforestation followed by forest regeneration repeatedly characterize the landscape. In contrast, the ecosystem service hypothesis predicts a catastrophic shift from a forested to an abandoned landscape when the amount of deforestation exceeds the critical level, which can lead to a resource degrading poverty trap. These findings imply that incentives for forest conservation seem stronger in settings where forests regenerate slowly as well as when decision makers value the future.

Reference

Satake, A., Rudel, T.K., 2007. Ecological Applications 17, 2024-2036.