

Biodiversity loss, ecosystem service debt, and the sustainability of social-ecological systems

Anne-Sophie Lafuite^{a*}, François Salanié^b, Michel Loreau^a

^a Centre for Biodiversity Theory and Modelling, Theoretical and Experimental Ecology Station, CNRS and Paul Sabatier University, 09200 Moulis, France

^b Toulouse School of Economics, Université Toulouse Capitole (INRA), 21 Allée de Brienne, 31000 Toulouse, France

* Corresponding author: lafuite.as@gmail.com

Abstract

Biodiversity supports a wide range of ecosystem services, and its current decline in terrestrial systems is mostly due to natural habitat destruction and fragmentation for human use. These spatial changes generate time-delayed extinctions, and hence a biodiversity-dependent ecosystem service debt. We investigate how the long-term dynamics of social-ecological systems (SESs) is affected by the delayed erosion of ecosystem services, when they feed back on agricultural production. This delayed ecological feedback generates large transient reductions in population size, biodiversity and well-being, which amplitude increases with the extinction and recolonization delays, and with the size of the human population at equilibrium, i.e. its carrying capacity. We derive a sustainability criterion that captures the sensitivity of an SES to environmental crises, and show that land-use intensification can preserve biodiversity, while increasing both sustainability and human carrying capacity, provided that (1) it increases labor intensities and/or land conversion costs, rather than efficiency, (2) it remains moderate so as to avoid negative rebound effects on biodiversity, and (3) it limits habitat fragmentation, which worsens environmental crises by increasing biodiversity loss. Our model thus provides a long-term perspective and new insights into the land-sharing vs. land-sparing debate, and proposes an additional step towards integrative human-biodiversity models.

Keywords: Extinction debt; land-sharing vs. land-sparing; social-ecological system; environmental crisis; sustainability; collapse.