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

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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 lack of economic internalization of ecosystem services, when their delayed erosion feeds back on agricultural production. Our model shows that a delayed ecological feedback generates large transient reductions in population size, biodiversity and well-being, which amplitude increases with the times to extinction and recolonization, 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 a SES to environmental crises, and use this criterion to compare the long-term effects of agricultural intensification on sustainability and human carrying capacity. We find *win-win* situations where agricultural intensification effectively spares land for nature and preserves biodiversity, while increasing both sustainability and human carrying capacity. These win-win effects arise if land-use intensification (1) is achieved through increases in labor intensities and/or land conversion costs, but not in efficiency, (2) remains moderate in order to avoid negative rebound effects on biodiversity, and (3) limits habitat fragmentation, in order to mitigate the loss of ecosystem services which reduces human carrying capacity. Our model thus provides a long-term perspective and new insights into the land-sharing vs. land-sparing debate, as well as an additional step towards integrative human-biodiversity models.

Keywords: Biodiversity, dependent ecosystem service debt, extinction debt, land, sharing vs. land, sparing, social, ecological system, environmental crisis, sustainability, collapse, human carrying capacity.

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