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Sustainability and collapse in a coevolutionary model of local resource stocks and behavioral patterns on a social network

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When investigating the causes and consequences of global change, the collective behavior of human beings is considered as having a considerable impact on natural systems. In our work, we propose a conceptual coevolutionary model simulating the dynamics of local renewable resources in interaction with simplistic societal agents exploiting those resources. The society is represented by a social network on which social traits may be transmitted between agents. These traits themselves induce a certain rate of exploitation of the resource, leading either to its depletion or sustainable existence. Traits are exchanged probabilistically according to their instantaneous individual payoff, and hence this process depends on the status of the natural resource. At the same time agents may adaptively restructure their set of acquaintances. Connections with agents having a different trait may be broken while new connections with agents of the same trait are established.

We investigate which choices of social parameters, like the frequency of social interaction, rationality and rate of social network adaptation, cause the system to end in a sustainable state and, hence, what can be done to avoid a collapse of the entire system.

The importance and influence of the social network structure is analyzed by the variation of link-densities in the underlying network topology and shows significant influence on the expected outcome of the model.

For a static network with no adaptation we find a robust phase transition between the two different regimes, sustainable and non-sustainable, which co-exist in parameter space. High connectivity within the social network, e.g., high link-densities, in combination with a fast rate of social learning lead to a likely collapse of the entire co-evolutionary system, whereas slow learning and small network connectivity very likely result in the sustainable existence of the natural resources. Collapse may be avoided by an intelligent rewiring, e.g. adaptation, of the social network that may also lead to the isolation of misbehaving parts of the society.

Our results may suggest that with the current trend to faster imitation and ever increasing global network connectivity, societies are becoming more vulnerable to environmental collapse if they remain myopic at the same time.