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Towards a common formalization of resilience and vulnerability to natural hazards

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Resilience and vulnerability are two widely-used concepts when it comes to describe the potential impacts of natural hazards on a social and ecological system. They are an attractive way to communicate both with stakeholders and between the different disciplinary fields that use them in that context. Therefore, a formal definition of the concepts is warranted so as to provide a non-ambiguous reference for discussion and avoid misunderstandings. Besides, such a formalization should strive to formalize both concepts together so as to use their complimentarity.

This abstract uses a stochastic controlled dynamical system formulation to propose a common framework for the definition of both resilience and vulnerability. Stochasticity represents all sources of uncertainty post-hazard, and the hazard is assumed to be an exogenous input. This mathematical representation highlights how the interplay between a natural hazard, the system's dynamic and the possible action policies influence the final outcome after the hazard hits. It also clarifies the role of normative choices in defining indicators that may inform or guide the system's management. More importantly, we demonstrate how the proposed framework may serve as a basis to generate indicators that are representative of general definitions of the concepts, yet flexible enough to be easily adapted to very diverse situations. Resilience is the ability for the system to keep or recover its properties of interest after a perturbation, while vulnerability is defined in a most general way as a measure of future harm. The definition of vulnerability leads to a variety of possible indicators, and ultimately to the identification of safe configurations of the system. Being resilient is then the fact of returning to a safe configuration, and the probability of resilience is that of doing so within a pre-defined time frame. Then, indicators may be designed around the probability distribution of return times. We show how viability, a control theory that aims at keeping a system in a desirable state, is relevant to the definition of safe configurations in a system, no matter how complex.

A simple lake eutrophication model illustrates how resilience and vulnerability can be made complimentary through the proposed framework. It also highlights potential trade-offs between some resilience and vulnerability indicators, and showcases the relationship between indicators, management objectives and recovery trajectories after a hazard hits a system. We insist that the framework provides a meaningful basis to think about resilience to natural hazards, no matter the existence of a dynamical system representation for a given system.