Adaptive Governance of Alternate Stable States in Social Ecological Systems: Simulating the Impacts of Alternative Policy Mixes on Farmer Behaviors

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When exposed to exogenous shocks or endogenous surprises, recent complexity science-informed research on social ecological systems has demonstrated that these systems do not necessarily go through "gradual" change rather "abrupt shifts" in alternate stable states can suddenly take place. It is hypothesized that a loss of resilience usually triggers such critical transitions in the phase spaces of social ecological systems that leads the state variables in the system to be tipped into a contrasting state. It is however not well known when and how exactly the social ecological systems undergo abrupt shifts into alternate stable states. Further, if social ecological modeling approaches could be used to generate an early warning or foresight about the tipping points in a complex system, it is not certain whether the social/human components of the system would use the early warning/foresight to adapt and adjust their behavioral patterns to avoid the worst case scenarios. Different policy regimes with differential mixes of policy instruments could lead to competing outcomes on societal, economic and environmental criteria. This paper examines these questions in the light of social ecological system governing water quality in Lake Champlain. The multi-jurisdictional Lake Champlain Basin (LCB), situated in NY, VT and Quebec, covers approximately 21,326 square kilometers. Anthropogenic climate change could induce abrupt alternate stable states in the Lake Champlain from more frequent and more intense flooding events in LCB as well as reduced ice cover internally in the lake system. Under a baseline scenario of human induced climatic change, increasing agricultural landscape and rapid urbanization in the Lake Champlain Basin, the Lake Champlain can abruptly switch to a eutrophic state unless proactive adaptive management strategies, such as rapid adoption of nutrient management practices (NMPs) at the watershed scale, are implemented in LCB. Purely regulatory (sticks) or purely incentive based (carrots) policies can result in differential NMP adoption patterns by the farmers in LCB watersheds. There is however potentially a continuum of regulatory and incentive based policy mixes that could potentially induce more proactive behavioral response from farmers in the face of climate change induced risks in LCB. To understand the relative differences in the impacts of regulatory and incentive-based policy mixes, this paper presents an agent based model of Missisquoi watershed in LCB system and tests the impacts of baseline and alternate policy mix scenarios on farmer behaviors in adopting NMPs. Experimental simulations from the agent based model are used to generate foresight about the likelihood of NMP adoption by farmers of heterogeneous political and economic groups. In the light of findings from this agent based model, this study draws broad theoretical implications for adaptive governance of alternate stable states in social ecological systems; with an emphasis on steering the behaviors of non-point source polluters through variegated policy mixes that balance carrots and sticks for retaining socially and environmentally desirable stable states in social ecological systems.