NATIONAL SOCIO-ENVIRONMENTAL SYNTHESIS CENTER



Rivers naturally meander across the landscape and sometimes even create full loops.
Photo Credit: South Florida Water Management District.

Explainer – Feedback Loops and Socio-Environmental Systems

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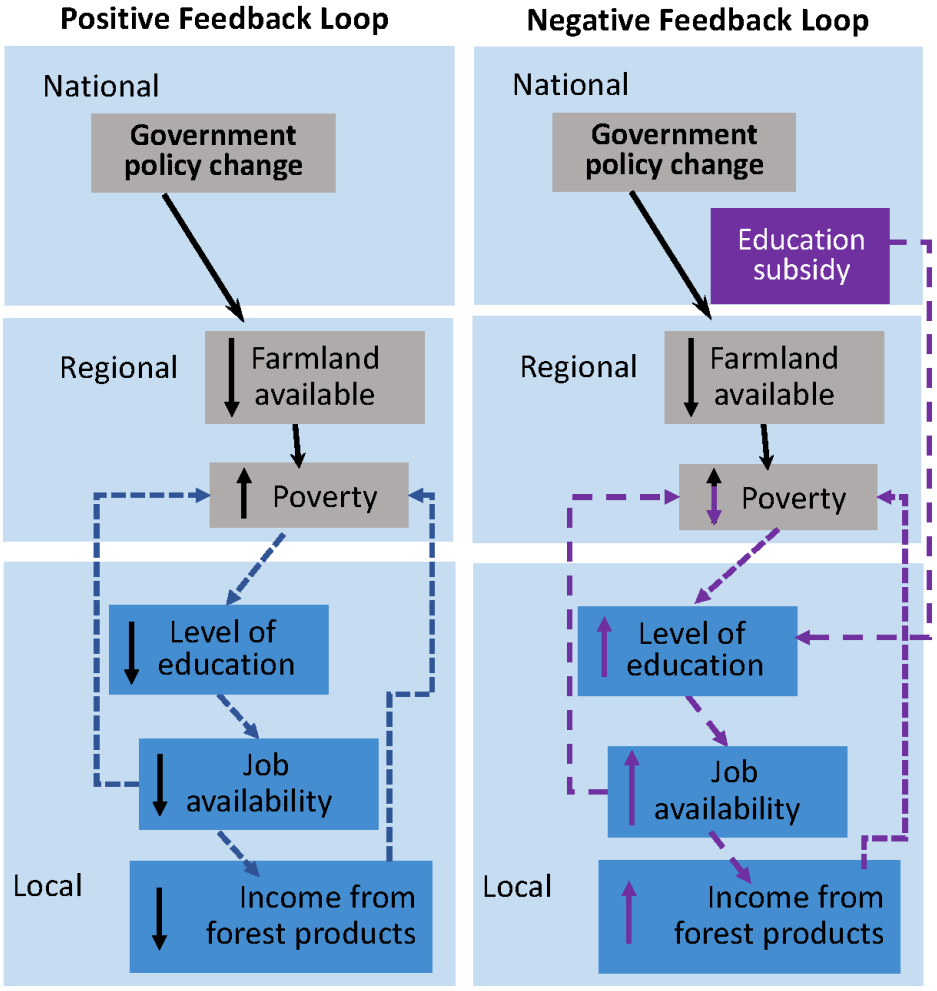
Introduction:

Like economic systems, traffic patterns, and immune systems, socio-environmental systems are examples of complex adaptive systems (CAS)—namely, changes in one part of the system cause disproportionate and unpredictable changes in other parts, which in turn influence additional parts of the system (Preiser et al. 2018). Furthermore, each part that has changed can cause alterations back in the part that caused the initial change. Known as feedback loops, these circular chains of interactions can either magnify (increase) or suppress the initial change.

Positive feedback loops reinforce (enhance) an effect. A well-known positive feedback loop of current interest is the effect of the warming climate on melting Arctic ice. When the ice melts, it exposes soil, which results in the absorption of heat—causing even more melting and warmer temperatures. Although the word positive is used to describe this feedback loop, it should not be construed to imply that it causes something "good." Indeed, positive feedback loops often result in detrimental social changes as illustrated with the example in the figure below (left panel) for a rural community subjected to a policy change.

Negative feedback loops are balancing—they are circles of cause and effect that counter a change with a change in the opposite direction. A thermostat is a textbook negative feedback system, in which

a change in temperature prompts heating or cooling to bring it back to the set point. For the rural community example in the figure below, if the government realized that their change in policy was resulting in severe poverty, they could enact a new policy providing education subsidies for farmers with insufficient income (right panel in figure). With additional education, farmers could enhance their skills and enjoy new employment opportunities, potentially counteracting the troublesome effects of higher poverty due to less land for farming. This is a good example of socio-environmental resilience.



In this example of a positive feedback loop (left), the dashed blue lines show that poverty increases when policies reduce the amount of farmland available. Such actions mean that farmers can't afford as much education, which has cascading effects that decrease job availability, as well as forestry income; both these events then further increase poverty. The negative feedback loop (right) shows that a change from outside the system—the education subsidy—counteracts the reduced poverty that resulted from less farmland. The increase in education increases job options, as well as forestry income, which, in turn, further reduces poverty.

System-Level Changes Are Difficult to Predict and Can Be Dramatic

The complex interactions that characterize socio-environmental systems make it **difficult to predict** how they will evolve (or adapt) in response to internal and external circumstances. For example, after some environmental or economic disaster, will unemployment persist for a long time, homes remain unrepaired, and invasive species become dominant on the landscape? Or will there be corrective measures to ensure that there are actually improvements in human well-being and ecosystem health?

This unpredictability is exacerbated by the fact that the interactions and feedbacks are typically nonlinear, meaning the changes imparted are not directly proportional to the magnitude of the causal

'force.' As a result, small changes in one part of the system can cause a large change in another part. If unemployment increased by 10% or deforestation increased by 10%, the impact on homeowners or bird diversity, respectively, may be far greater.

Obviously, major events like hurricanes and war can cause dramatic and long-lasting impacts on people and the natural resources upon which they depend; however, small changes can also lead to large impacts. This kind of transformation occurs when a system is near a **tipping point**, in which it is very sensitive to even small changes. When socio-environmental systems cross tipping points, the system sometimes undergoes what is called a **regime shift**—a transition to a state that is very different from its prior one that is persistent and difficult to reverse (Biggs et al. 2018).

A classic ecological example of a regime shift is when a lake changes from relatively clear to cloudy with high phytoplankton abundance. This change can happen if small increases in phosphorus inputs eventually exceed some concentration threshold (Carpenter et al. 2008). Socio-ecological examples include: 1) eutrophication-related fishery collapses that bring persistent economic changes to a community; and 2) policies to reduce community poverty in some developing regions that have resulted in an increase in livestock production and consequent land degradation that reduces biodiversity and conservation efforts. In many cases, it is the interaction between social and environmental processes that lead to regime shifts (Biggs et al. 2016), e.g., when cooperation intended to prevent overharvesting of a common pool resource breaks down (Lade et al. 2013).

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