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Exploring the emergence of tipping points in the social-ecological system at the border of Peru, Brazil and Bolivia (MAP region)

Alberto Andrino and the Prodigy Team
A full list of authors appears at the end of the abstract

Soils are a key component of the Critical Zone of continental surfaces, ranging from the atmosphere to bedrock, guaranteeing the functioning of the Earth's ecosystems and ensuring the continuity of life on Earth. Our assumption is that highly biodiverse and functional soils provide the underpinning of indispensable services that ensure the basis for sustainable economic livelihoods and societies. Soils are susceptible to degradation through misuse, leading to a reduction in their functional diversity and redundancy. The adoption of a systemic approach, such as the social-ecological systems (SES) framework, may contribute to the identification of the adaptive capacities of societies to this expected reduction in soil functioning. In a SES framework, humans are embedded in natural systems and are understood to profoundly affect these system's functions/services, interacting through feedbacks and cascading dynamics at different spatial and temporal scales. A SES framework is a suitable analytical tool that can provide insight on sensitive components and constellations of them, which likely may led to the crossing of a tipping point (TP), resulting in undesired alternative steady states of the system.

We aim to identify potential TPs, via an in-depth characterization and understanding of the SESs in the tri-national MAP region (Southwestern Amazon). For this purpose, we have delimited key underlying interconnected subsystems within the study region: the soil ecosystem, the livelihood system, the regional social system and the regional climate system. In our SES framework, we focus on relevant component's functions for the tipping dynamics relating land use change and loss of ecosystem services. Our objective is to provide a set of early warning indicators of the impact and legacy damage of disturbances and the regulatory feedback dynamics between the different subsystems. Our hypothesis is that the crossing of a TP as consequence of reduced soil functions may exert pressure on livelihoods, as people shift to a new level of welfare or adapt their land use or income-generating activities. If this process leads to additional deforestation, it will likely lead to the amplification of regional drought events due to the loss of moisture convection that forests provide. Increasing drought due to the loss of forests will (self)amplify and lead to increased forest wildfires and more opportunities for illegal deforestation and land use change. Further, increasing livelihood and income insecurity, combined with insufficient provision of state services and regulation, as well as weak law enforcement, may exert pressure on social systems by e.g. making illegal and criminal activities more attractive, ultimately undermining social cohesion. In addition, a central aspect of our research is to investigate options for counteracting this cascade of detrimental/harmful and potentially self-amplifying positive feedbacks. This might be achieved

by interfering with self-enhancing positive feedback loops, the stimulation of negative, stabilizing feedbacks, e.g. forest recovery or reflexive governance, especially on the local to regional level in order to prevent the crossing of TPs or even to stimulate non-linear dynamics towards positive TPs.

Prodigy Team: Rebecca Froese, Simone Kilian, Diana Boy, Claudia Pinzón, Elisa Díaz, Georg Guggenberger, Marcus A. Horn, Merel Jansen, Christopher Jung, Elisabeth Lagneaux, Katharina Meurer, Sabina Ribeiro, Rüdiger Schaldach, Oliver Frör, Jan Göpel, Renzo Giudice, Benjamin Stuch, Janpeter Schilling, Fernando Schmidt, Regine Schönenberg, Jürgen Böhner, Jan Börner, Daniel Callo-Concha, Galia Selaya, Claudia Vega, Vanessa Vetter, Jens Boy & Hermann Jungkunst