The Western Amazon social-ecological system at risk of tipping: A transdisciplinary modelling approach

Benjamin Stuch¹, Rüdiger Schaldach¹, Regine Schönemberg², Katharina Meurer³, Merel Jansen⁴¹⁵, Claudia Pinzon Cuellar², Shabeh Ul Hasson⁵, Christopher Jung¹, Ellen Kynast¹, Jürgen Böhner⁵, and Hermann Jungkunst⁴

¹Kassel University, Kassel Institute for Sustainability, Center for Environmental Systems Research, Germany (stuch@uni-kassel.de)
²Free University of Berlin, Institute for Latin American Studies, Germany
³Swedish University of Agricultural Sciences – SLU, Department of Soil & Environment, Uppsala, Sweden
⁴RPTU Kaiserslautern-Landau, iES Landau, Germany
⁵University of Hamburg, Institute of Geography, CEN, Germany

The Amazon rainforest is a tipping element of the global climate system due to its high carbon storage potential and its flying rivers providing rain for South America. Studies suggest that land use and land cover change (LUCC) in the Amazon, i.e. deforestation, strongly disturb regional convective rain pattern, which could lead to an increase of drought frequencies and intensities. Under increasing drought stress, the evergreen tropical rainforest may transform into a seasonal forest or even a savannah ecosystem. Such a transformation would likely activate the Amazon tipping element and may affect global climate change by triggering other critical tipping elements of the global climate system.

Here we present our transdisciplinary research approach in the Western Amazon rainforest developed in context of the PRODIGY research project. We apply a social-ecological system approach to account for the dynamic interactions and feedbacks between people and nature, which could either stabilize or self-enforce regional tipping cascades. For example, regional land users may suffer declining yield and net primary production from decreasing precipitation. Land users may compensate the drop in production/income e.g. by cultivating more land or seeking for other income sources. As a response, deforestation could increase which may drive a self-enforcing feedback loop that further decrease precipitation.

In a participatory process, together with regional stakeholders we develop land use related explorative scenarios. Preliminary results from the scenario exercise show that future agricultural production increases in all scenarios (crops between 20% and 200% and livestock between 0% and 300%). In the first modelling step, these changes drive the regionally adjusted spatial land system model LandSHIFT. Simulation results indicate that deforestation increases in all scenarios depending on the production technology and the reflexivity of institutions establishing appropriate management options.
In an integrated modelling step, the calculated LUCC maps serve as input to a regional climate model (WRF), which simulates respective changes in regional temperature and precipitation. Then, temperature and precipitation changes are applied to the biogeochemical model CANDY to simulate the impact (of regional deforestation) on crop yields, Net Primary Production (NPP) and changes in soil C and N cycling. In an iterative process, the yield and NPP responses are fed back to the land-use change model to simulate the required land use adaptations, accordingly. By closing the feedback loop between deforestation, climate, yield and NPP as well as respective land use adaptation, we are able to simulate a cascade of endogenous key process in the regions social ecological system. The integrated modelling results will support the stakeholders in identifying key measures/options/policies that could increase resilience of the regional social-ecological system to prevent crossing destructive regional tipping points.