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Recurrent droughts increase risk of cascading tipping events by outpacing adaptive capacities in the Amazon rainforest

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Since the foundational paper by Lenton et al. (2008, PNAS), tipping elements in the climate system have attracted great attention within the scientific community and beyond. One of the most important tipping elements is the Amazon rainforest. Under ongoing global warming, it is suspected that extreme droughts such as those in 2005 and 2010 occur significantly more often, up to nine out of ten years from the mid to late 21st century onwards (e.g. Cox et al., 2008, Nature; Cook et al., 2020, Earth's Future).

In this work, we quantify how climates ranging from normal rainfall conditions to extreme droughts may generate cascading tipping events through the coupled forest-climate system. For that purpose, we make use of methods from nonlinear dynamical systems theory and complex networks to create a conceptual model of the Amazon rainforest, which is dependent on itself through atmospheric moisture recycling.

We reveal that, even when the rainforest is adapted to past local conditions of rainfall and evaporation, parts of the rainforest may still tip when droughts intensify. We uncover that forest-induced moisture recycling exacerbates tipping events by causing tipping cascades that make up to one-third (mean+-s.d. = 35.9+-4.9%) of all tipping events. Our results imply that if the speed of climate change might exceed the adaptation capacity of the forest, knock-on effects through moisture recycling impede further adaptation to climate change.

Further, we use a network analysis method to compare the four main terrestrial moisture recycling hubs: the Amazon Basin, the Congo Rainforest, South Asia and the Indonesian Archipelago. By evaluating so-called network motifs, i.e. local-scale network structures, we quantify

the fundamentally different functioning of these regions. Our results indicate that the moisture recycling streams in the Amazon Basin are more vulnerable to disturbances than in the three other main moisture recycling hubs.