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Estimating Amazonian rainforest stability and the likelihood for large-scale forest dieback

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Annually, tropical forests process approximately 18 Pg of carbon through respiration and photosynthesis – more than twice the rate of anthropogenic fossil fuel emissions. Current climate change may be transforming this carbon sink into a carbon source by changing forest structure and dynamics. Increasing temperatures and potentially decreasing precipitation and thus prolonged drought stress may lead to increasing physiological stress and reduced productivity for trees. Resulting decreases in evapotranspiration and therefore convective precipitation could further accelerate drought conditions and destabilize the tropical ecosystem as a whole and lead to an "Amazon forest dieback". The projected direction and intensity of climate change vary widely within the region and between different scenarios from climate models (GCMs). In the scope of a World Bank-funded study, we assessed the 24 General Circulation Models (GCMs) evaluated in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4) with respect to their capability to reproduce present-day climate in the Amazon basin using a Bayesian approach. With this approach, greater weight is assigned to the models that simulate well the annual cycle of rainfall. We then use the resulting weightings to create probability density functions (PDFs) for future forest biomass changes as simulated by the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJmL) to estimate the risk of potential Amazon rainforest dieback. Our results show contrasting changes in forest biomass throughout five regions of northern South America: If photosynthetic capacity and water use efficiency is enhanced by CO_2, biomass increases across all five regions. However, if CO_2-fertilisation is assumed to be absent or less important, then substantial dieback occurs in some scenarios and thus, the risk of forest dieback is considerably higher. Particularly affected are regions in the central Amazon basin. The range of potential biomass change arising from the weighting of rainfall patterns is smaller than the uncertainty arising from CO_2-fertilisation effects, which highlights the importance of reducing the uncertainties in the direct effects of CO_2 on tropical ecosystems. Strong biomass changes also imply changes in forest structure and thus, forest stability. Our results display shifts in forest composition from closed rainforest to more open forest or even shrubland. Our probability-based risk analysis could be used to advise regional forest protection.