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Fire prevents the regrowth of the Amazon rainforest after complete deforestation in a fire-enabled Earth system model

Markus Drüke, Werner von Bloh, Boris Sakschewski, Wolfgang Lucht, and Kirsten Thonicke
Potsdam Institute for Climate Impact Research, Earth System Analysis, Germany (drueke@pik-potsdam.de)

The terrestrial biosphere is exposed to land use and anthropogenic climate change, which not only affects vegetation dynamics, but also changes land-atmosphere feedbacks. In particular, tropical rainforests are endangered by anthropogenic activities and are recognized as one of the terrestrial tipping elements. An ecosystem regime change to a new state could have profound impacts on regional and global climate, once the biome has transitioned from a forest into a savanna or grassland state. Fire is a potentially major driver in the position of the transition boundary and could hence impact the dynamic equilibrium between these possible vegetation states under a changing climate. However, systematic tests of fire-controlled tipping points and hysteretic behaviour using comprehensive Earth system models are still lacking.

Here, we specifically test the recovery of the Amazon rainforest after a complete deforestation at different atmospheric CO2 levels, by using the Earth system model CM2Mc-LPJmL v1.0 with a state-of-the-art representation of vegetation dynamics and fire. We find that fire prevents large-scale forest regrowth after complete deforestation and locks large parts of the Amazon in a stable grassland state. While slightly elevated atmospheric CO2 values had beneficial effects on the forest regrowth efficiency due to the fertilization effect, larger CO2 amounts further hampered the regrowth due to increasing heat stress. In a no-fire control experiment the Amazon rainforest recovered after 250 years to nearly its original extent at various atmospheric CO2 forcing levels. This study highlights the potential of comprehensive fire-enabled Earth system models to investigate and quantify tipping points and their feedback on regional and global climate.