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How drought events during the last Century have impacted biomass carbon in Amazonian rainforests

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During the last two decades, droughts have recurrently impacted the Amazon forests, as in the severe drought events of 2005, 2010 and 2015/16. The analysis of forest inventory plots suggests that these droughts have resulted in a reduction of the carbon sink of intact forests by causing mortality to exceed growth. Process-based models have struggled to include drought-induced responses of growth and mortality, and have not been evaluated against plot data. In this study, we use ORCHIDEE-CAN-NHA, a DGVM which includes modules of forest demography with different tree size cohorts dynamically influenced by growth, self-thinning from light competition and recruitment, a detailed tree hydraulic architecture function of each tree cohort, and drought-driven mortality due to the loss of tree conductance to simulate the impact of drought on biomass dynamics. We calibrated the model at a long drought experiment site (Caxiuanã). We then ran the model over Amazonia forests using as an input gridded climate fields and rising atmospheric CO_2 from 1901 to 2019. The model reproduced the drought sensitivity of aboveground biomass (AGB) growth and mortality observed at forest plots across selected Amazon intact forests for 2005 and 2010, and the net balance between these two carbon fluxes. No plot data have been published yet for the recent 2015/16 El Nino, but we predict a more negative sensitivity of the net carbon sink during this event compared to the former 2005 and 2010 droughts. We then ranked all past drought events of the last century based on their maximum cumulated water deficit anomalies, and found that 2015/16 was the most severe drought in terms of both AGB loss and area experiencing a severe carbon loss. Because of the 2015/16 event, together with the 2005 and 2010 droughts, the last 20 years was the period with the largest climate-driven cumulative AGB loss than any other previous 20-years period since 1901. Factorial simulations allowed us to separate the individual contribution of climate change and rising CO_2 concentration on AGB dynamics. We found that even if climate change did increase mortality, increased CO_2 concentration contributed to balance the C loss due to mortality. This is because, in our model, CO_2-induced stomatal closure reduces transpiration and increases soil moisture, offsetting increasing transpiration from CO_2 induced higher foliage area.