Current and future patterns of fire-induced forest degradation in Amazonia

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Supplementary data

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S1. Model uncertainty
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Figure S1. To quantify the uncertainties associated with drought-induced increases in fuel and potential impacts on fire intensity, we calculated the difference between our baseline map of fire intensity (i.e., where all fuel were available during the dry season of the
drought year) and three scenarios of fuel accumulation: (A) woody fuels were evenly distributed throughout the year; (B) most of the woody fuel increased during the fire season; and, (C) half of woody fuel increased during the dry season and half throughout the year. These simulations provide information on how the timing of fuel availability resulting from droughts influences fire intensity and severity. These figures show that CARLUC-Fire was highly sensitive to the timing of fuel accumulation. When fuels were evenly distributed across the year, for example, fire intensity decreased up to 360 kW m$^{-1}$ in southeast Amazonia compared to the baseline map (Panel A). On the other hand, when 80% of the fuel created due to drought-induced tree mortality was distributed during the season of a given drought year, fire intensity was much higher (Panel C).
Figure S2. Fires usually are much hotter during the day than during the night. Our assumption that these fires equally impact these forests therefore could lead to an overestimation of fire severity. To deal with this potential problem, we ran new CARLUC-Fire simulations with VPD representing low monthly values (e.g., nighttime values) and high monthly values. The difference between these two simulations was assumed to
provide the uncertainty associated with the use of averaged monthly VPD. Our simulations show that differences between low and high VPDs could have important influences on fire intensity and severity, particularly in the southeast Amazonia (Panel A). This suggests that under the assumption that all fires occurred during the day, CARLUC-Fire could overestimate fire intensity and severity by up to 290 kW m\(^{-1}\).
In our simulations, we assumed that VPD peaked during the month of the drought, but it is likely that VPD peaks months after drought-induced tree mortality occurs. To address this potential bias in our model, we ran CARLUC-Fire under the assumption that changes in MCWD lagged VPD by one, two, and three months. Our model simulations show that fires would be 19, 55 and 64% less intense, on average, if we assumed that there is a lagged response. Upper panel: simulations showing how lagged VPD affects fire intensity. Lower panel: distribution of fire intensity across the Amazon for the three scenarios of lagged VPD. These uncertainty analyses also show that differences between nighttime and daytime VPD would have a stronger effect on fire intensity across southeast Amazonia.
Supplementary information 4. Multi-model ensemble

In our simulations, CARLUC-Fire was forced by averaged air temperature and precipitation from the CMIP-5 multi-model ensemble. To quantify how averaging those climatic variables influenced our results, we calculated the upper and lower quartiles of VPD and MCWD based on the different climate models participating in the CMIP-5 model inter-comparison project. Figure S4 shows projected changes in VPD (%) based on the upper (left panels) and lower quantiles (right panels) over time. In Figure S5, we show projected changes in MCWD based on the upper (left panels) and lower quantiles (right panels) over time.
Figure S4. Left panels (A): changes in VPD from 2000s to 2100 based on the lower percentile in temperature, which was calculated based on the CMIP-5 model ensemble.

Right panels (B): changes in VPD from the 2000s to 2100 based on the upper percentile in temperature, which was calculated based on the CMIP-5 model ensemble.
Figure S4. Left panels (A): changes in MCWD from 2000s to 2100 based on the lower percentile in precipitation, which was calculated across climate models. Right panels (B): changes in MCWD from the 2000s to 2100 based on the upper percentile in precipitation, which was calculated across climate models.
S2. Fire Scars maps

Figure S6 - Burned scar maps from 1999 to 2010 (Morton et al. 2013). Red areas indicates extent of forest fire for a given year.
S3. Forest fire emissions

Figure S7. Forest fire emissions under business-as-usual (RCP8.5) for near (nf), middle (mf), and distant (df) futures, given conditions from two observed droughts (2005, 2010).

Blue: Live carbon losses by fire induced tree mortality. Red: Combustion of fuel loads.