LETTER

REPLY TO SCHÖNGART ET AL.:

Forest resilience variation across Amazonian floodplains

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Our recent findings that floodplain ecosystems harbor the most fragile forests of the Amazon (1) was seen by Schöngart et al. (2) as an oversimplification of a complex ecosystem. They argue that the majority of floodplain forests are associated with fertile soils, and should therefore be highly resilient. Indeed, the differences between nutrient-rich white-water and nutrient-poor black-water systems have been long-known (3). However, as our study (1) illustrates, alternate perspectives can sometimes reveal surprising features of a well-known system. Our study compares the resilience of floodplain and upland forests with observations at the basin scale. Moreover, despite the existence of detailed field evidence on the vulnerability of black-water forests to fire (4–6), the scale and implications of this disturbance factor were still broadly neglected. Here we expand our previous analyses (1) to explore how floodplain forest resilience varies across subbasins and regions, testing hypotheses raised by Schöngart et al. (2).

In the past two decades, drought events allowed wildfires to penetrate Amazonian forests, challenging their resilience. Our observations demonstrate that wildfires occurred in floodplain forests across the Amazon, including subbasins of major white-water rivers, the wettest regions, as well as the north and south of the basin (Fig. 1). According to Schöngart et al. (2), nutrient-poor *igapó* ecosystems cover less than 30% of Amazonian floodplains (7), and are the only floodplains vulnerable to fires. We disagree with the estimated *igapó* extent (7) because it does not account for the numerous tributaries with less than 150 m of width, most of which are black-water rivers (3, 8), implying that the proportion of *igapó* floodplains is much higher. Moreover, at the mouth of these tributaries, white-water floodplains are more influenced by black water, which may increase forest flammability (4, 9), and help explain floodplain fires observed across the Amazon (Fig. 1).

One reason to assume white-water forests to be less flammable than black-water forests is their lower accumulation of fuel in the form of fine roots (10). In addition, white-water forests might recover much faster from disturbances due to their higher fertility, as suggested by Schöngart et al. (2). Those arguments seem reasonable, since nutrient availability can in part determine forest recovery rate after disturbances (11). For example, our previous findings show that burned *igapó* forests lose soil fertility and persist in an open vegetation state (5), whereas burned upland forests maintain fertility and recover fast (1). Our new observations from remote sensing suggest that even in the Madeira basin, the largest white-water system of the Amazon, floodplains may become trapped in an open state after wildfires (Fig. 2). The idea that these floodplain forests are not very resilient is supported by the density distribution of tree cover, revealing a clear savanna mode, at least in the driest southern parts of the Madeira basin (Fig. 1). This new finding supports the view that, despite the enormous diversity of floodplain ecosystems (3, 8), their inferred fragility and vulnerability to wildfires may well be quite consistent across the basin. Indeed, floodplain forests may turn out to be an unsuspected Achilles' heel of the Amazon forest in a changing climate, and this particular aspect should be taken seriously in conservation planning.

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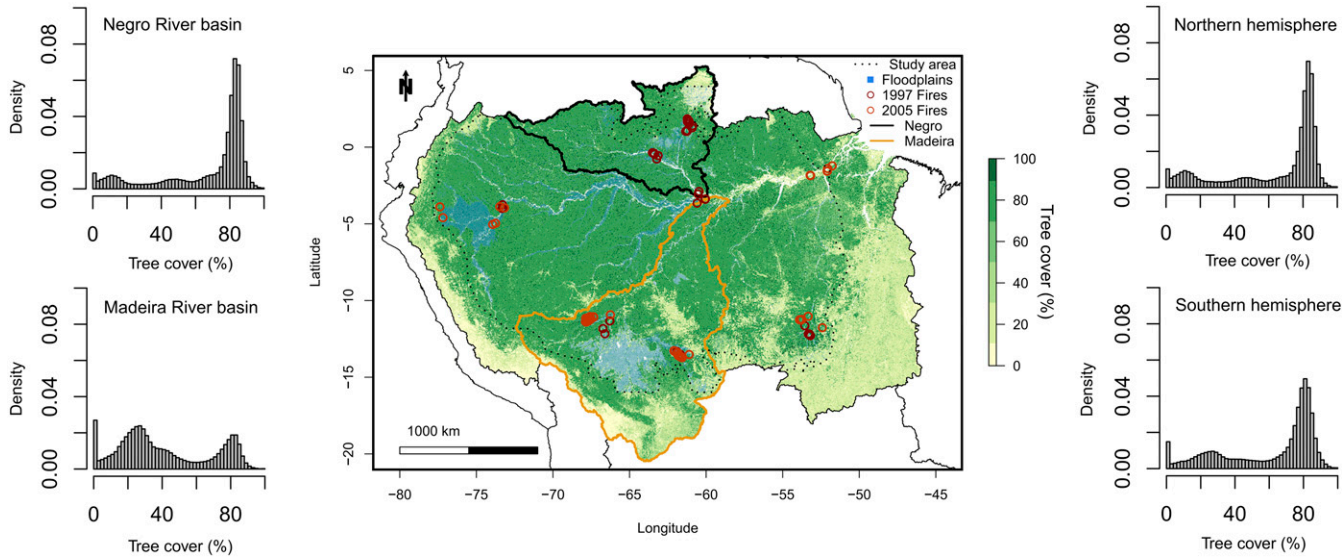

Fig. 1. Regional variation in the density distributions of floodplain tree cover and in fire occurrence across the Amazon. Histograms are density distributions of tree cover values from different parts of the study area, which is the whole Amazon basin below 500 m of altitude, excluding deforested areas. The Madeira and Negro basins, with contrasting fertilities (8), are shown in orange and black lines, respectively. North and south are separated at 0° latitude. In the Madeira basin floodplains, there is a pronounced savanna mode, not observed in the Negro basin floodplains. Open circles show the 128 floodplain fires we detected, which penetrated floodplain forests during the 1997 (dark red circles) and 2005 (orange circles) droughts. Detailed methods can be found in Flores et al. (1).

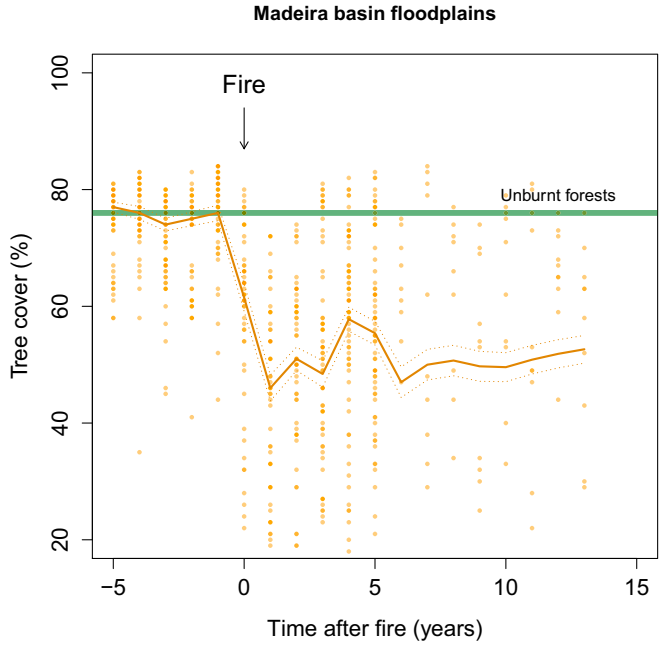

Fig. 2. Sensitivity of floodplain forests to fire in the main Amazonian white-water river basin. Time series of annual tree cover (median ± SE) showing changes after fire in the Madeira basin floodplains. After fire (time = 0), tree cover median persists around 50%. Of the studied 69 burned sites in the Madeira basin, 10 were burned in 1997 and 59 in 2005, and their locations can be seen in the southern region of the map of Fig. 1.

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