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Mind the gap: New insights on large-scale forest dynamics over Amazonian forests from airborne lidar and canopy gap data

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Tree mortality has been pointed out as a key factor to quantify global forests carbon stocks and turnover. While there have been recent developments on observational studies aiming at detection and attribution of tree mortality using remote sensing data in temperate forests, the spatial and temporal distribution of tropical forests mortality is still poorly understood. Tropical forests pose a challenge for mortality detection due to its rich diversity of plant species and heterogeneous canopy structure, which also leads to the occurrence of very frequent and localized mortality events rather than widespread mortality as seen in some temperate forests. Here, we report on recent developments on estimates of spatialized forest dynamics over tropical forests leveraging large datasets of airborne lidar and a newly established link between canopy gaps and canopy mortality. Using multi-temporal lidar datasets collected at five Brazilian Amazon forests with varied forest structure, we linked static gaps, i.e. holes in the forest observed at one date, to dynamic gaps, i.e. gaps that opened from one date to another. Using 610 flight lines of airborne lidar data covering an area >2,300 km² across the Brazilian Amazon, we mapped the static gaps and used them to analyze potential natural and human-induced drivers using generalized linear models. Finally, we produced estimates of annual dynamic gap rates (% yr^{-1}) for the whole Amazon using the combination of the environmental-climate model and the static-dynamic gaps relationship. Our findings show well-defined spatial patterns of dynamic gaps over the Amazon, with 20-35% faster dynamics in the west and southeast than in the central-east and north. Higher gap fractions were more often found at southern and eastern Brazilian Amazon, bordering the 'deforestation arch', i.e. regions with increased human influence. Dynamic gaps showed a significant relationship with field mortality rates (R^2 = 0.40), but with 60% lower magnitude. In fact, what we have detected is very likely mortality with the predominant emphasis of lidar on detecting uprooted and broken mode of death. The analysis also provided new insights on the dynamics of remote areas where we have never visited before. New challenges include testing the gap-method over other sites with multi-temporal data, developing methods to detect standing dead trees, and mapping other drivers such as liana-infested forests. Merging improved regional quantification of dynamic gap estimates with vegetation modelling offers potential to explore how forest dynamics

is influencing carbon stocks and turnover, and how they may evolve in the future.