Contrasting patterns of damage and recovery in logged Amazon forests from small footprint LiDAR data

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Abstract

Tropical forests ecosystems respond dynamically to climate variability and disturbances on time scales of minutes to millennia. To date, our knowledge of disturbance and recovery processes in tropical forests is derived almost exclusively from networks of forest inventory plots. These plots typically sample small areas (≤1 ha) in conservation units that are protected from logging and fire. Amazon forests with frequent disturbances from human activity remain under-studied. Ongoing negotiations on REDD+ (Reducing Emissions from Deforestation and Forest Degradation plus enhancing forest carbon stocks) have placed additional emphasis on identifying degraded forests and quantifying changing carbon stocks in both degraded and intact tropical forests. We evaluated patterns of forest disturbance and recovery at four ~1000 ha sites in the Brazilian Amazon using small footprint LiDAR data and coincident field measurements. Large area coverage with airborne LiDAR data in 2011-2012 included logged and unmanaged areas in Cotriguaçu (Mato Grosso), Flona do Jamari (Rondônia), and Floresta Estadual do Antimary (Acre), and unmanaged forest within Reserva Ducke (Amazonas). Logging infrastructure (skid trails, log decks, and roads) was identified using LiDAR returns from understory vegetation and validated based on field data. At each logged site, canopy gaps from logging activity and LiDAR metrics of canopy heights were used to quantify differences in forest structure between logged and unlogged areas. Contrasting patterns of harvesting operations and canopy damages at the three logged sites reflect different levels of pre-harvest planning (i.e., informal logging compared to state or national logging concessions), harvest intensity, and site conditions. Finally, we used multi-temporal LiDAR data from two sites, Reserva Ducke (2009, 2012) and Antimary (2010, 2011), to evaluate gap phase dynamics in unmanaged forest areas. The rates and patterns of canopy gap formation at these sites illustrate potential issues for separating logging damages from natural forest disturbances over longer time scales. Multi-temporal airborne LiDAR data and coincident field measurements provide complementary perspectives on disturbance and recovery processes in intact and degraded Amazon forests. Compared to forest inventory plots, the large size of each individual site permitted analyses of landscape-scale processes that would require extremely high investments to study using traditional forest inventory methods.