Monitoring Strategies for REDD+: Integrating field, airborne, and satellite observations of Amazon Forests

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Bulleted list of abstract highlights:

- **Objectives:** We summarize recent advances in forest monitoring that combine data at different spatial and temporal resolutions to target the main sources of uncertainty in emissions estimates for REDD+.
- **Methods:** Time series of field observations, airborne LiDAR, Landsat, and MODIS data provide complementary information on the condition and fate of deforested and degraded Amazon forests. We combine observations using the Carbon Emissions Simulator (CES) model to quantify forest carbon emissions and uncertainties based on different scenarios of remote sensing data.
- **Results:** Consistent methods to estimate annual forest area changes indicate lower rates of deforestation, forest degradation from fire, and land abandonment to secondary forest than in previous studies. Together, these findings alter the timing and magnitude of forest carbon emissions from the region.
- **Discussion:** Time series of optical and LiDAR data capture the fate of degraded or deforested lands—a critical component of the net carbon emissions calculation.

Extended Abstract:

Objectives

Large-scale tropical forest monitoring efforts in support of REDD+ (Reducing Emissions from Deforestation and forest Degradation plus enhancing forest carbon stocks) confront a range of challenges. REDD+ activities typically have short reporting time scales, diverse data needs, and low tolerance for uncertainties. Meeting these challenges will require innovative use of remote sensing data, including integrating data at different spatial and temporal resolutions. The global scientific community is engaged in developing, evaluating, and applying new methods for regional to global scale forest monitoring. Pilot REDD+ activities are underway across the tropics with support from a range of national and international groups, including SilvaCarbon, an interagency effort to coordinate US expertise on forest monitoring and resource management. Early actions on REDD+ have exposed some of the inherent tradeoffs that arise from the use of incomplete or inaccurate data to quantify forest area changes and related carbon emissions. Here, we summarize recent advances in forest monitoring to identify and target the main sources of uncertainty in estimates of forest area changes, aboveground carbon stocks, and Amazon forest carbon emissions.

Methods

Satellite data have been the mainstay of regional forest monitoring in the tropics for several decades. Early efforts to estimate gross forest cover losses over 1-10 year time scales have been updated to capture deforestation activity in near real time. However, data requirements for REDD+ are more extensive than many current satellite or forest inventory programs provide for environmental enforcement or resource management. These additional requirements include detailed characterization of forest degradation, consistent information on forest cover transitions over time, and forest carbon stock estimates along the land use frontier (Morton *et al.* 2012). Overall uncertainty in forest carbon emissions estimates therefore requires careful quantification and propagation of uncertainties from remote sensing estimates of forest cover change, field and remote sensing estimates of forest carbon stocks, and time-varying emissions from combustion and decay of forest biomass. Here, we summarize recent research with time series of optical and LiDAR data to better constrain sequential land use transitions and forest recovery following degradation or land abandonment. We construct forest carbon emissions scenarios based on new Landsat and MODIS time series of deforestation and post-clearing land use, forest degradation, and land abandonment to secondary forest. Finally, we use a new model, the Carbon Emissions Simulator (CES), to separate model and source data uncertainties in estimates of forest carbon emissions in Amazonia using Monte Carlo and error propagation techniques, respectively.

Results

Time series of satellite data provide critical information on the interannual variability in forest area changes and the fate of degraded or deforested areas over time. MODIS-based estimates of forest degradation from fire indicate widespread understory fire activity in eastern and southern Amazonia during 1999-2010. However, forest fire emissions were partially offset by forest recovery in subsequent years because repeated fire damages and deforestation of burned forests were rare. Time series methods yielded lower estimates of deforestation than in previous satellite-based assessments due to careful separation of deforestation and forest degradation. Satellite-based information on post-clearing land use (e.g., pasture, cropland, or urban expansion) directly addresses reporting requirements for the drivers of deforestation and can improve emissions estimates. For example, long-term land abandonment to secondary forest in Amazonia constituted only 2-3% of the area of deforestation during 2002-2006.

Three sets of CES model simulations illustrate the impact of improved forest monitoring capabilities for estimating net forest carbon emissions. First, we explored the impact of tracking sequential forest disturbances on emissions estimates, including deforestation following forest degradation and multiple degradation events. Spatially explicit satellite data time series eliminated double-counting errors, reducing the emissions estimates for both forest degradation and deforestation. Second, we modeled the importance of improved forest carbon stock data for net forest carbon emissions. Forest carbon stock estimates accounted for the majority of the variance in CES simulations. Recent data products that incorporate LiDAR-based estimates of canopy height indicate lower biomass in areas where historic deforestation was concentrated. Smaller uncertainties with satellite-based biomass estimates partially compensated for lower deforestation emissions in these scenarios. Finally, we explored the influence of interannual variability in deforestation and regrowth as a function of post-clearing land use. In these emissions simulations, post-clearing land use was used to constrain combustion completeness and the cumulative area of regrowing forest. The combination of higher combustion completeness and lower rates of land abandonment altered the timing and magnitude of carbon emissions in regions with large-scale deforestation activities.

Discussion

The fate of degraded or deforested lands is a critical component of the net carbon emissions calculation. Previous studies have suggested that forest regrowth following logging or land abandonment constitutes a sizeable carbon sink across the tropics (e.g., Pan *et al.* 2011). Using time series of annual satellite data for the Amazon region, we show that long-term land abandonment to secondary forest is rare, resulting in a smaller offset for modeled forest carbon emissions. Long time series of data are also critical to estimate net carbon emissions from forest degradation. In the past decade, burned forests were not cleared as frequently as logged forests (e.g., (Asner *et al.* 2006). If logging is a precursor to deforestation, then monitoring forest degradation may remain a priority for REDD+, even if net carbon emissions from logging are small. Forest degradation from fire does not appear to predispose areas for agricultural expansion in the same manner. Consistent, time series approaches to monitoring the condition of forests at the deforestation frontier are a critical first step to improve operational forest monitoring efforts and forest carbon emissions estimates for REDD+.

References

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