susceptibility and biogeochemical processes throughout the Amazon basin.

21.2: Micrometeorology, CO2 and H2O Exchange of a Tropical Rainforest Before and After Selective Logging

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We are using long-term eddy covariance to study the effects of selective logging on the energy and trace gas exchange at km 83 in the Tapajos National Forest, Para, as a component of LBA. In addition to the core flux measurements of carbon dioxide, water vapor, momentum and heat, sensors were installed to measure vertical profiles of CO2, H2O, wind velocity, and temperature within and above the forest. Continuous tower and biometric measurements began a year before logging (June 2000) when the forest was still considered primary. A similar tower in an unlogged area of the same forest (km 67) provides a control for the logged site measurements. Selective logging in fall 2001 was conducted by a local firm using reduced impact procedures, and included ~400-ha of forest that extended ~2-km upwind of the tower. The loggers removed ~6% of the biomass in large trees, left another ~18% of the biomass in large trees as slash, and eliminated ~13% of the canopy on an area basis. Tower and biometric measurements at both sites continued throughout the 3 month logging period and up to the present. After the logging, a second 65 m tall tower was installed in a large gap created by the logging, and similarly instrumented, in order to address the role of gaps in affecting forest atmosphere exchange. Preliminary analysis of the tower observations indicate that canopy photosynthesis declined following logging, and that ecosystem respiration increased in the subsequent wet season.

21.3: Selective Logging Effects on Carbon Budgets at Three Sites in the Brazilian Amazon

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Single tree selection is the predominant approach to logging in the Brazilian Amazon today. While removal of logs (usually less than 40 m^{-3} ha^{-1} on a first entry) off-site has a minor effect on site carbon stocks, collateral damage caused by felling, skidding, and road building results in signficant mortality and canopy opening. Reduction of canopy leaf area should reduce productivity while the increase in necromass should augment ecosystem respiration. We aim to quantify these effects in both conventional (CL) and reduced impact (RIL) harvest management at sites in the municipalities of Paragominas and Santarem in Para State and in Juruena in Mato Grosso state. Canopy gap fraction (Licor, LAI-2000) and both standing and fallen coarse woody debris (line intercept sampling) were measured at logged and unlogged sites. For logging intensities in the range of 20 to 30 m^{-3} ha^{-1}, CL and RIL increased canopy gap fraction to approximately 20% and 10% compared to approximately 3% gap fraction at undisturbed forest sites. Logging also greatly increased necromass stocks. For example,at the sites in Paragominas, necromass stocks increased by 95% and 35% for CL and RIL over a background of about 28 Mg-C ha^{-1} in undisturbed forest. We modeled the effects on carbon flux using stand table models and simple compartment models to estimate post-site carbon balance. Based on simple extrapolation from our limited sites, we estimate that logging leads to a net loss of at least 30 Tg-C y^{-1} from the Brazilian Amazon.

21.4: Biomass and Necromass in Three Undisturbed Forests in the Brazilian Amazon

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Necromass (Coarse Woody Debris [CWD]) is important component of the carbon cycle in tropical forests. The relationship between necromass and biomass may provide interesting insight into the functioning of a forest. Forests with the same biomass but differing necromass pools might have experienced different disturbance and mortality events or have different decomposition histories. This study examined three undisturbed Amazonian forests, Cauaxi, Para (3.75° S, 48.37° W), Tapajos National Forest, Para, Brazil (3.08° S, 54.94° W) and Juruena, Mato Grosso, Brazil (10.48° S, 58.47° W). We compared biomass, DBH distributions, standing necromass, fallen necromass and CWD decay class distributions. Relationships between each of these parameters were used to compare carbon cycling across the sites. At Tapajós, the average mass (+/- S.E.) of fallen CWD was 50.7 (1.1) Mg ha^{-1} for duplicate sites. The average mass of fallen CWD at Juruena was 44.4 (16.3)Mg ha^{-1} for duplicate sites. At Cauaxi, fallen CWD mass average was 55.2 (4.7) Mg ha^{-1}. Small (> 2 cm and < 5 cm dia) and medium sized material (> 5 cm and < 10 cm dia) accounted for 8-18% of the total fallen CWD mass. Standing dead average mass was 33.5 (4.0) Mg ha^{-1} for duplicate sites at Tapajos. At Juruena, the average mass of standing dead was 24.8 (6.5) Mg ha^{-1} for duplicate sites. Standing dead was not measured at Cauaxi. The biomass estimate for > 10 cm DBH for Juruena was 313 Mg ha^{-1}. Cauaxi biomass for trees > 20 cm DBH was 249 Mg ha^{-1}. Tapajos

biomass estimate for trees > 15 cm was 224 Mg ha^{-1}. Finally, estimates from an automated crown detection algorithm were used to compare disturbances across each of these sites.

21.5: Canopy structure and radiation environment metrics indicate forest developmental stage, disturbance, and certain ecosystem functions

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The structural and environmental complexity of a forest is the compound result of a development sequence overlain with perturbations. To date, these complexities have been poorly quantified. Here we introduce some potentially useful metrics derived from measurements of canopy structure and radiation environment and discuss known and potential implications of these measures for understanding forest developmental stage, disturbance intensity, and some ecosystem functions.

Common summaries of forest structure include maximum height, and overall surface area density and cover. However, these measures are inadequate characterizations and provide little indication of forest state or function. High-frequency first-return LIDAR measurements obtained from forest floor or from aircraft can yield summary and distributional measures that are interpretable in terms of whole canopy structure and function.

Most canopy volumes are dominated by open space; various sorts of "porosity" may be defined and specific classes of interior environments may be recognized. The shape of the spatially averaged vertical profile of surface is also a useful descriptor. "Heaviness" is the relative height of median canopy surface. In "top-heavy" canopies ,the majority of surfaces are near the top, whereas "bottom-heaviness" indicates a distribution skewed toward the forest floor. The outer canopy surface is the primary interface interacting with the free atmosphere - its texture is important. Various measures of the complexity of its shape may be defined, including the variability in its shape ("rugosity"). The overall canopy gap fraction is likely less important than the distribution of openings penetrating to the ground ("gappiness"). The balance of large and small gaps is described by the slope of the gap-size distribution function.

We discuss how these measures alone and in combination can be used to indicate developmental stage, degree of disturbance or intervention, and some aspects of ecosystem function, including potential growth, radiation balance, the coupling with atmosphere, mixing, storage, and the spatial distribution of sources and sinks of energy and carbon.

21.6: Natural disturbance regimes and tropical forest carbon balance: integrating canopy structure, flux measurements, and modeling across the landscape

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Natural disturbance events play a critical role in the carbon cycling of tropical forests, and hence estimating carbon balance over large spatial scales depends on: (1) understanding how local carbon balance depends on local disturbance status and history; and (2) accurate characterization of the distribution of disturbance states across those larger spatial scales. Here we use ground-based lidar measurements of canopy height (Parker and Lefsky, 2004) to characterize local disturbance status of plots in the Tapajós National Forest of Brazil. Following the approach of Hurtt et al (2004), we then use the observed canopy height distribution to constrain a size-structured forest biogeochemistry model (the Ecosystem Demography model, ED). Finally, we compared the predictions of the constrained ED model to eddy flux and biometric estimates of ecosystem carbon balance at the local scale, and found that the model correctly predicts that the forest around the flux tower is a net carbon source to the atmosphere. This analysis suggests that remote-sensing based estimates of canopy height (like those that would be provided by NASA's airborne Laser-Vegetation Imaging Sensor, LVIS, proposed to fly as part of LBA) can constrain model predictions of carbon balance at landscape scale. Such predictions could be independently tested at the landscape scale by measurements now underway (Santoni et al., this LBA meeting) in large-scale biomass plots spatially distributed across the Tapajós landscape.

21.7: What's driving regional changes in old-growth tropical forests?

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A number of dramatic changes have been observed in tropical forest structure and functioning. Many of these studies cite the rising concentration of atmospheric CO2 as the most likely driver, but in general these are not rigorous quantitative assessments. Using an individual-based model that simulates tree stand dynamics (recruitment, growth, mortality and decomposition) we explore what factors can explain the observed changes at a regional scale. The model was initially parameterized using extensive field data from forests in the Central Amazon, and has been modified to simulate stand dynamics for sites spanning a productivity and dynamism gradient across the entire Amazon basin. The model has also been modified to include potential drivers for observed changes including: (i) explicitly modeling changes in forest