The Flux Of Carbon From Selective Logging, Fire, And Regrowth In Amazonia

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Abstract

Most analyses of land-use change and estimates of carbon flux for large regions have concentrated on deforestation and subsequent regrowth, ignoring wood harvest and fires. In Amazonia, the area of forest annually affected by harvest and fire has increased recently, and we seek to determine the annual fluxes of carbon from the disturbances and subsequent forest regrowth. The work consists of model development, remote sensing, and fieldwork.

The primary goal of this research is a model that calculates terrestrial sources and sinks of carbon from selective logging and fire and land-use change. A simple bookkeeping model has been used in the past, but it has limitations in addition to being non-spatial. The new model will be spatially specific and will incorporate recent advances made in ecosystem models.

The model requires ground- and satellite-based data on the spatial extent and the intensity of forest disturbance (forest mortality, biomass removed, and rates of wood decay and regrowth). Fieldwork will identify and measure above-ground biomass and regrowth at three study sites with varying levels of burning and logging (Paragominas, Santarem, and northern Mato Grosso). Above-ground biomass, LAI, and fuel loads will be measured at three intensities of disturbance and in control areas.

For each study site, a 10 x 10 km area will be identified using a Landsat ETM+ data, and the spectral responses of burned and logged forest will be identified and checked in the field.

Approaches

Modeling

We are developing a model (CARLUC, for Carbon and Land-Use Change) that extends an existing bookkeeping model in two respects. First, it is spatially explicit, with the landscape divided into 1-hectare pixels. Second, forest productivity and dead organic matter decomposition are driven by climate and soil characteristics. The incorporation of processes in the model not only allows rates of production and decomposition to vary through time. It also allows for a greater variety of ecosystem types (e.g., biomass) in space.

CARLUC simulates the cycling of carbon associated with both natural ecological processes. It has compartments representing live tree components, dead organic matter, soil and wood products.

Productivity is calculated as in the 3-PG model of Landsberg and Waring (1997). Photosynthesis is driven by the photosynthetically active radiation (PAR) absorbed by plants, and productivity is controlled by forest light use efficiency (LUE), which is reduced by climatic or soil conditions that are not optimal for growth.

Fieldwork

We measured above-ground biomass and in different types of burned forest in Paragominas, Santarem, and northern Mato Grosso. For each study area, a landscape reference of 10 x 10km area was identified using a Landsat ETM+ satellite image, and the spectral responses of burned forest were identified and checked in the field. Three types of burn intensity were chosen for surveying and biomass measurement. Five plots of 500 x 20 meters were sampled in each of the 3 burned areas and in a control area of unburned primary forest. Above-ground biomass, LAI, and fuel loads were measured along these transects.

Remote Sensing

The goal of the work is to develop a rapid and reliable method for measuring areas selectively logged and burned. So far, visual interpretation of 1997 and 1998 Landsat TM imagery has identified logging and burn scars. Classifications are nearly complete for our three study areas. Forest fire and logging scars have been mapped for a three-year time series in Santarem and Paragominas study areas. For Mato Grosso area (Guaranta and Matupa) an unsupervised image classification has been done and checked in the field.

Publications

Alencar, A., L. Solorzano, and D. Nepstad. Modeling forest understory fires in an eastern Amazonian Landscape. Ecological Applications (in press).

Houghton, R.A., D.L. Skole, C.A. Nobre, J.L. Hackler, K.T. Lawrence, and W.H. Chomentowski. 2000. Annual fluxes of carbon from deforestation and regrowth in the Brazilian Amazon. *Nature 403*:301-304.

Houghton, R.A., K.T. Lawrence, J.L. Hackler, and S. Brown. 2001. The spatial distribution of forest biomass in the Brazilian Amazon: A comparison of estimates. *Global Change Biology* **7**:731-746.

Hirsch, A.I., W.S. Little, R.A. Houghton, N.A. Scott, and J.D. White. The net carbon flux due to deforestation and forest re-growth in the Brazilian Amazon: Analysis using a process-based model. Submitted to *Global Change Biology*.

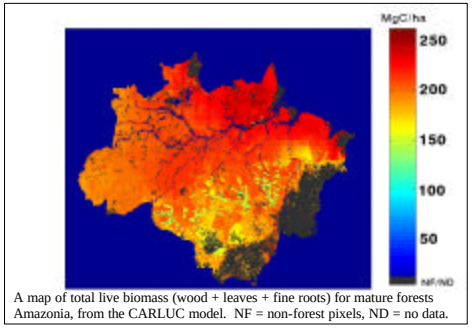
Scientific objectives

1. Development of a process-based carbon model that will calculate changes in terrestrial carbon in response to disturbance and land-use change.

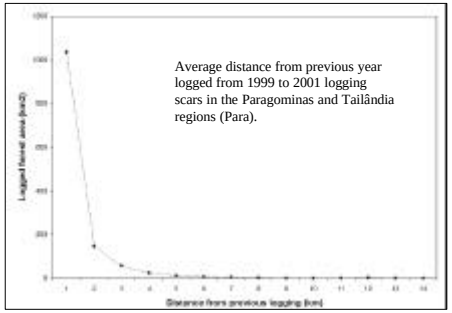
2. Determination of empirical relationships between satellite data and intensity of disturbance (fire and selective logging).

Key Results

1. Analysis of deforestation and agricultural abandonment over the Brazilian Amazon with the new model CARLUC gave results generally similar to those obtained with the bookkeeping model (Houghton et al. 2001): a net release from land-use change averaging about 0.2 PgC yr^{-1} over the period 1978-1998. The reanalysis gave a smaller net release (about 0.15 PgC yr^{-1}) because new data show the area of secondary forest to be larger than indicated by the data initially available.

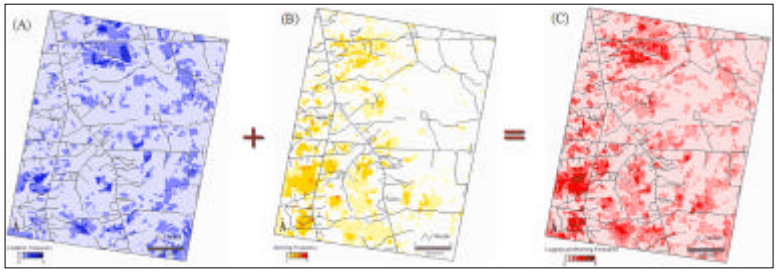


A map of total live biomass (wood + leaves + fine roots) for mature forests Amazonia, from the CARLUC model. NF = non-forest pixels, ND = no data.



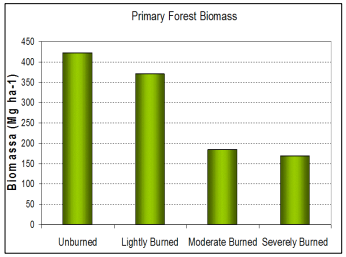
2. Most logging takes place within 1 to 3 km of secondary roads, and radiated out into new forests an average distance of 3 km yr^{-1}.

3. Areas logged or burned are more likely to burn than undisturbed forests. Based on reconstruction of a 17-year history of Paragominas through field interviews and field work, most forest fires were found to occur in small forest fragments partially surrounded by cattle pasture. Forest understory fires were significantly correlated with the percentage of the forest fragment that had previously been logged or burned.



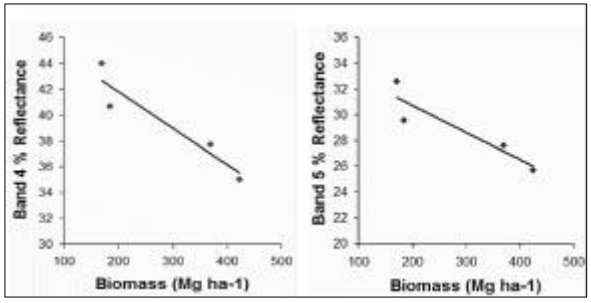
Maps of logging (A) & burning (B) frequency in Paragominas used to calculate the intensity of forest disturbance by logging and fire (C).

4. Understory fires reduce forest biomass. Fieldwork in 6 sites in Paragominas showed the combination of logging and understory fire to reduce live aboveground biomass by >50%. The effects of understory fire on forest biomass are larger than previously reported.



5. Landsat Bands 4 and 5 show potential for monitoring the effect of fire on forest biomass. A combination of field measurements in a large understory fire scar 100 km south of Santarém and multi-date analysis of Landsat TM and ETM images of the region revealed the potential for monitoring the effect of fire on forest biomass with TM bands 4 and 5.

6. Landsat data may indicate areas of forest burned by low to moderate intensity surface fires. ETM+ data look promising in detecting recent fire scars in the transition forest region of Mato Grosso. Preliminary results suggest that in 2001 roughly 1% of the area in two Landsat scenes burned. The method of burn scar detection is currently being applied with 1999 ETM+ data throughout the transition forest zone to estimate the area of burned forest and the biomass loss over the entire region.



Relationship among reflectance and biomass in different intensities of burned forest.