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Second (Final) Year Progress Report

Low-Cost Evaluation of EO-1 Hyperion and ALI for Detection and Biophysical Characterization of Forest Logging in Amazonia (NCC5-481)

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A. PROJECT ABSTRACT

Major uncertainties exist regarding the rate and intensity of logging in tropical forests worldwide: these uncertainties severely limit economic, ecological, and biogeochemical analyses of these regions. Recent sawmill surveys in the Amazon region of Brazil show that the area logged is nearly equal to total area deforested annually, but conversion of survey data to forest area, forest structural damage, and biomass estimates requires multiple assumptions about logging practices. Remote sensing could provide an independent means to monitor logging activity and to estimate the biophysical consequences of this land use. Previous studies have demonstrated that the detection of logging in Amazon forests is difficult and no studies have developed either the quantitative physical basis or remote sensing approaches needed to estimate the effects of various logging regimes on forest structure. A major reason for these limitations has been a lack of sufficient, well-calibrated optical satellite data, which in turn, has impeded the development and use of physically-based, quantitative approaches for detection and structural characterization of forest logging regimes.

We propose to use data from the EO-1 Hyperion imaging spectrometer to greatly increase our ability to estimate the presence and structural attributes of selective logging in the Amazon Basin. Our approach is based on four "biogeophysical indicators" not yet derived simultaneously from any satellite sensor: 1) green canopy leaf area index; 2) degree of shadowing; 3) presence of exposed soil and; 4) non-photosynthetic vegetation material. Airborne, field and modeling studies have shown that the optical reflectance continuum (400-2500 nm) contains sufficient information to derive estimates of each of these indicators. Our ongoing studies in the eastern Amazon basin also suggest that these four indicators are sensitive to logging intensity. Satellite-based estimates of these indicators should provide a means to quantify both the presence and degree of structural disturbance caused by various logging regimes.

Our quantitative assessment of Hyperion hyperspectral and ALI multi-spectral data for the detection and structural characterization of selective logging in Amazonia will benefit from data collected through an ongoing project run by the Tropical Forest Foundation, within which we have developed a study of the canopy and landscape biophysics of conventional and reduced-impact logging. We will add to our base of forest structural information in concert with an EO-1 overpass. Using a photon transport model inversion technique that accounts for non-linear mixing of the four biogeophysical indicators, we will estimate these parameters across a gradient of selective logging intensity provided by conventional and reduced impact logging sites. We will also compare our physically-based approach to both conventional (e.g., NDVI) and novel (e.g., SWIR-channel) vegetation indices as well as to linear mixture modeling methods. We will cross-compare these approaches using Hyperion and ALI imagers to determine the strengths and limitations of these two sensors for applications of forest biophysics. This effort will yield the first physically-based, quantitative analysis of the detection and intensity of selective logging in Amazonia, comparing hyperspectral and improved multi-spectral approaches as well as inverse modeling, linear mixture modeling, and vegetation index techniques.

B. SUMMARY OF ACTIVITY IN YEAR 2

Overview

Much progress was made in the second year of this project. The following lists our major activities in support of the project goals: (1) a spatially extensive field measurement effort in Brazil was continued to support analysis of canopy structural damage from the EO-1 ALI and Hyperion and Landsat ETM+ sensors; (2) a geographic information system (GIS) was updated to support the remote sensing analyses; and (3) an inter-comparison of ALI, ETM+ and Hyperion image analyses was continued to assess the relative capabilities of each instrument.

Field Studies

Satellite data analyses of selective logging extent and intensity are being based on chronosequences of heavy (conventional) and light (reduced-impact) selective logging as well as control plots of undisturbed forest. We established these chronosequences to allow us to study of the temporal evolution of canopy damage, biomass losses and regrowth and the sensitivity of EO-1 ALI and Hyperion in comparison to our ongoing Landsat 7 ETM+ analyses. One such sequence is shown in Figure 1.

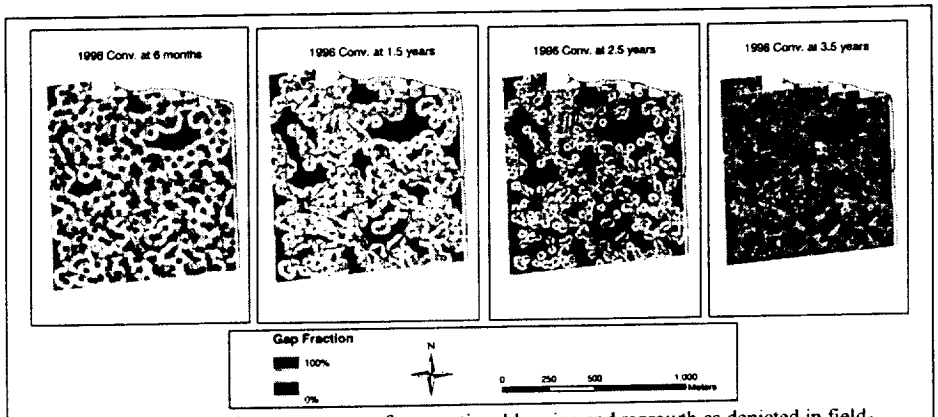

Figure 1. Example of a chronosequence of conventional logging and regrowth as depicted in field-measured forest canopy gap fraction [Asner et al. in prep].

Fazenda Cauaxi: The Fazenda Cauaxi in the municipality of Uliolandia, Para has been the center of our logging research, which we conduct with our partner, the Tropical Forest Foundation (TFF; Headed by Co-PI Zweede and managed by Co-PI Pereira). We worked closely with TFF foresters to collect detailed field data on the forest structure, infra-structural and canopy damage, wood volume/biomass, and post-harvest recovery from these sites (Table 1). We created detailed geographic information system (GIS) coverages from a combination of TFF survey maps and these field measurements. During these campaigns, we also collected data on forest spectral-optical characteristics in each logging treatment and on forest canopy structure in control (unlogged) plots. We acquired EO-1, Landsat TM/ETM+, IKONOS, and SPOT satellite data, from which we are completing an analysis of forest canopy damage from the remote sensing observations of the conventional and RIL plots [Pereira et al. in press, Asner et al. in press, Asner et al. in review; SEE ATTACHED PDFs]. Our GIS is the central organizing tool for integrating field, modeling, and remote sensing data at the landscape and regional scale.

Floresta Nacional de Tapajos and Fazenda Fortaleza: The Tapajos National Forest (Floresta Nacional (FLONA) de Tapajos) covers 600,000 ha in the municipalities of Santarem, Belterra, and Aveiro. Our work included a survey of trees over a 5000 ha area. We also acquired detailed tree species and diameter data, Landsat and SPOT imagery, and field measurements of LAI, canopy gap fraction, and spectral-optical properties of vegetation and soils (Table 1).

Table 1. Basic physical and logistical characteristics of our logging research sites, and ongoing field and remote sensing data collections in preparation for EO-1 Ali and Hyperion data analyses.

	Fazenda Cauaxi	**FLONA-Tapajos and Faz. Forteleza**
Central Lat./Long.	3°43'S, 48°17'W	3°3'S, 54°58'W
Dry season	July – November	
Logging treatments	Conventional and Reduced-impact Logging	
Treatment Years	RIL and Conv: 1996-2000+	RIL: 1997, 2001+ / Conv: 1991-1999
Ongoing Field Measurements	Stand density; tree height; crown dimensions; LAI; canopy gap fraction and cover; road, skid, log deck locations; wood volume/biomass removed GPS; field spectroscopy	
Ongoing Remote Sensing Observations	Landsat 5 TM, Landsat 7 ETM+; SPOT; ASTER, IKONOS Airborne LIDAR & digital videography; JERS-1 SAR; MODIS; MISR; AVHRR	

Remote Sensing (see attached journal article abstracts for details)

We completed a detailed analysis of how well Landsat ETM+ can detect the extent and intensity (canopy damage) of selective logging at the Cauaxi and Tapajos sites in Brazil. These results are forthcoming [Asner et al. in press, Asner et al. in review; SEE ATTACHED PDFs]. We completed the first set of Hyperion and ALI studies of canopy damage as well. These results were presented at Goddard Space Flight Center to the EO-1 mission operations staff, including Dr. Stephen Ungar and at the NASA Land-cover Land-use Change Science Team Meeting in College Park, MD in November, 2001.

We are in the process of completing the final EO-1 Hyperion and ALI studies of the selective logging sites. Final steps include a detailed analysis of Hyperion and ALI capabilities in comparison to completed ETM+ studies. These results will be presented in 2002 at various meetings and will be submitted for publication in leading peer-review journals.

C. PEER-REVIEWED PAPERS SUPPORTED UNDER THIS PROJECT

Asner, G.P. 2001. Cloud cover in Landsat observations of the Brazilian Amazon. *International Journal of Remote Sensing* 22:3855-3862.

Asner, G.P., M. Keller, R. Pereira, and J. Zweede. 2002. Remote sensing of selective logging in Amazonia: Assessing limitations based on detailed field measurements, Landsat ETM+ and textural analysis. *Remote Sensing of Environment* 80(3):483-496.

Pereira, R., J. Zweede, G.P. Asner, and M. Keller. Forest canopy damage from conventional and reduced impact selective logging in Eastern Amazon, Brazil. *Forest Ecology and Management*. In press.

Asner, G.P., M. Keller, R. Pereira, J. Zweede, and J.N.M. Silva. Forest canopy damage and closure following selective logging in Amazonia: Landsat ETM+ and spectral mixture modeling. *Ecological Applications*. In press in LBA special issue.

Asner, G.P., J.A. Hicke, and D.B. Lobell. 2002. Per-pixel analysis of forest structure: Vegetation indices, spectral mixture analysis and canopy reflectance modeling. In M. Wulder and S.E. Franklin (eds.), Methods and applications for remote sensing of forests: Concepts and case studies, Kluwer Academic Publishers, New York.

Asner, G.P., M. Keller, J.N.M. Silva, R. Pereira, and J. Zweede. Estimating canopy structure in an Amazon forest from laser rangefinder and IKONOS satellite observations. *Biotropica*. To be submitted immediately.

Asner, G.P., M. Keller, J.N.M. Silva, R. Pereira and J. Zweede. Finding cryptic deforestation in the Amazon using hyperspectral satellite observations. To be submitted to Science in June 2002.

D. PERSONNEL WHO HAVE BEEN SUPPORTED UNDER THIS PROJECT

Susan Parks, Professional Research Assistant; Focus: Geographic information systems analysis, Image processing of Landsat 7 ETM+ and SPOT satellite data

Kathy Heidebrecht, Professional Research Assistant; Focus: Radiative transfer modeling, spectral mixture modeling, EO-1 Hyperion/ALI algorithm conversion, parallel computing

Jeffrey Hicke, Post-doctoral Researcher; Focus: Remote sensing image analysis and field work

Amanda Warner, Professional Research Assistant; Focus: EO-1 Hyperion/ALI algorithm development, image inventory and pre-processing, image processing