Examination of Canopy Disturbance in Logged Forests in the Brazilian Amazon using IKONOS Imagery

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Abstract

Structural properties of forests are closely linked with ecosystem functioning. Forest gaps are important in an ecological sense because they are involved with tree regeneration dynamics and species diversity and distribution (Schemske and Browkaw 1981, Denslow 1987, and Vitousek and Denslow 1986). The spatial patterning and distribution are of interest to ecologists. Gaps increase light levels in understory, release nutrients, and create structural habitat for some species of flora, fauna, and fungi (Schemske and Browkaw 1981, Denslow 1987, and Vitousek and Denslow 1986). Previously, we developed a crown detection algorithm that used high resolution satellite image data. We applied this algorithm in an undisturbed tropical forest with good results. In this work we have further developed the algorithm to examine logged forests and the disturbances of such forests. Patios and gaps created by logging create a spectral signature that is different then local maxima associated with tree tops. By using the multi-spectral image of IKONOS along with the higher resolution panchromatic image, our refined algorithm was able to filter out these features. Ability to estimate logging impacts in vast areas of the Brazilian Amazon using IKONOS imagery is vital in attempts to understand the regional carbon balance.

Algorithm

Currently, there are two primary algorithms used in high-resolution canopy automated analysis. These two techniques are local maximum filtering and local minima value finding. Local maximum filtering has proven accurate in estimating the number of trees using the assumption that the brightest local value represents the characteristic of a single crown (Wulder *et al*. 2000). Local minima value finding has been used to detect the area between two crowns, using the assumption that the darker image values are created by shadows between crowns (Pouliot *et al.* 2002).

Our algorithm combines local maximum and minima finding methods. It introduces three new concepts in crown detection analysis. These are the analysis of ***iterative local*** maximum analysis, a derivative threshold that ends ordinal transect analysis, and the removal of previously analyzed pixels from further analysis.

Preprocessing
1. Modal, maximum, and minimum brightness values (DN) found
2. Moving window 3x3 averaging filter

Crown Detection
1. Local Maxima Analysis
2. Brightness value (highest to modal brightness values examined in an iterative step)
3. Local maxima seeds ordinate analysis

Ordinate Analysis
1. Ordinate analysis (series of DN values in straight line) radiates out in multiple directions from the local maxima or seeded pixel. Number of ordinates defined by user (64 in this study).
2. End ordinate when the next pixel DN value is 2 greater then current pixel
3. Ordinate may not proceed into previously determined crowns

Crown Determination
1. Two longest opposite ordinates determined (crown width)
2. Crown drawn as circle using radius of one-half of the longest crown width
3. DBH and Biomass estimate conducted based on crown width
4. Once a crown is determined, no new local maxima in that area may be analyzed

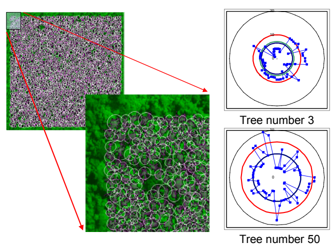

Figure 1. Example of analysis of a 240 by 240 meter section of undisturbed tropical forest. White circles are delineated crowns, black polygons trace the outline of transects, pink pixels indicate area of polygons.

Study Area and Data

Study Areas and Satellite Observations
Two IKONOS panchromatic images were used from two time periods from an Amazonian forest in Para, Brazil: the Tapajos National Forest, (3.08° S, 54.94° W).

Stand Data and Biomass Data
Tree geometry data from Asner *et al.* 2002 was used in analysis of crown width distribution. Stand data from Rice *et al.* 2004 and Keller *et al.* 2001 were used for validation of stand characteristics.

Allometric Equations
The crown width to DBH allometric equation used here was developed in Asner *et al.* 2002. The DBH to biomass equation used here is from Brown *et al.* 1997.

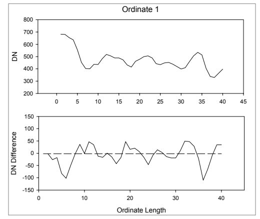

Figure 2. Digital number data used for termination of an ordinate. The crown edge is estimated to be 8 pixels from the local maxima.

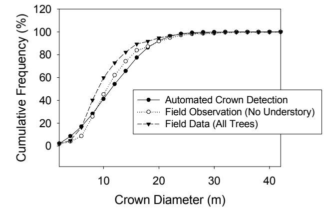

Figure 3. – Cumulative frequency distribution for field observed canopy diameters and automated crown estimate at Cauaxi.

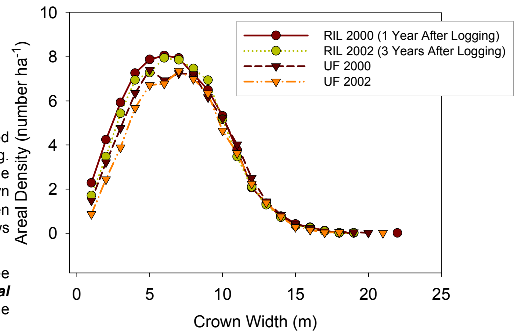

Figure 5. Comparison of Crown distribution derived from an automated crown detection algorithm. Two areas from two IKONOS images.

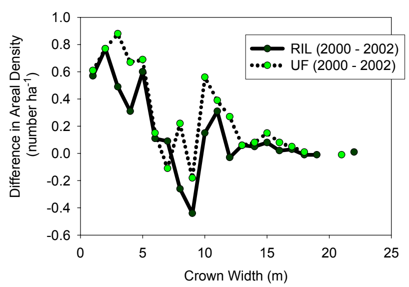

Figure 7. Difference in areal density between 2000 and 2002 at Tapajos for a Undisturbed Forest (UF) and a Reduced-Impact Logging Area (RIL).

Future Work

The use of the multi-spectral bands and an NDVI filter are future endeavors that will aid in logged area studies using IKONOS imagery.

Other Areas and Other Platforms

Quickbird Images
Videography
Aerial Photography

New Steps with Multi-Spectral IKONOS Bands
Texture Filter (remove non-forested areas from analysis)
Use NDVI as filter in Local Maxima Analysis (No seeding allowed in areas filtered)
Compare pixels within a determined crown for spectral similarity
Mean and standard deviation for each crown for pan, ndvi and four spectral bands recorded
Kmeans cluster analysis on crown information
Sobell Filters used for edge detection

Results

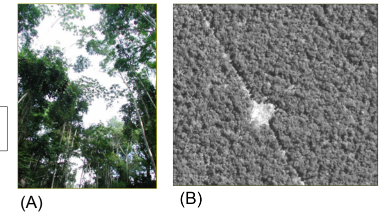

Figure 4. – (A) Photograph of a one year old forest gap produced by selective logging. (B) IKONOS image of a selectively logging tropical forest.

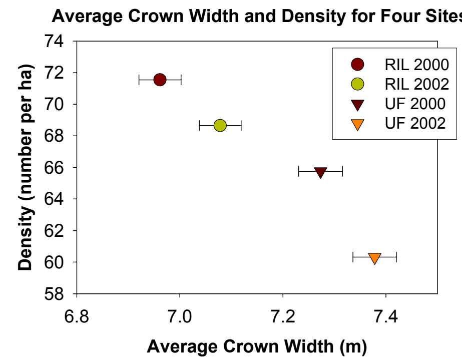

Figure 6. Comparison of average crown width and areal density derived from an automated crown detection algorithm. Two areas from two IKONOS images.

Summary

We examined two IKONOS images of the same area containing undisturbed and RIL logged forest. Differences were found between the undisturbed and logged sites within each image. Temporal differences were also found for the same area between the two images. Logged areas had smaller average crown sizes and more trees. The removal of larger trees for timber exposed smaller canopies previously shaded by the large trees. These initial results suggest that our automated crown detection algorithm may be useful for identification of logged areas and diagnosis of logging damage and regeneration.

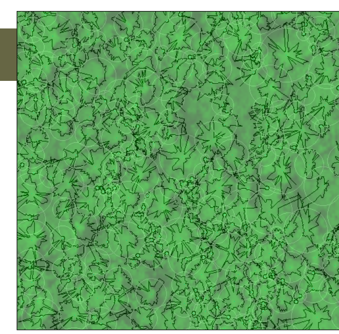

Figure 8. A 200 m by 200 m IKONOS image analyzed for crown geometry using a automated crown detection algorithm. White circles are delineated crowns based on the black polygons, which represent a series of ordinal transect radiating out from the local maximum.