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

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Introduction

Gap dynamics and importance

Remote sensing platform (IKONOS)

Crown detection algorithm

Site Comparison (7 LBA sites)

Single Site Comparison using Logged and Undisturbed Areas

Single Site Comparison using Two Images taken at Different Times

Background

Forest canopy gaps resulting from natural tree mortality and logging increase light in the understory, release nutrients, and create structural habitat for some species of flora, fauna, and fungi.

The measurement of gap formation using remotely sensed data over broad areas would allow foresters and ecologists to study forest dynamics over greater areas than those available from plot level surveys.

Background (2)

Remote sensing can aid ecological studies

High Resolution ($\leq$1 m) can examine details in forest structure

- gaps
- tree size
- disturbances (recovery and creation)
- differences in forest structure across vast areas of the Amazon

Crown Detection

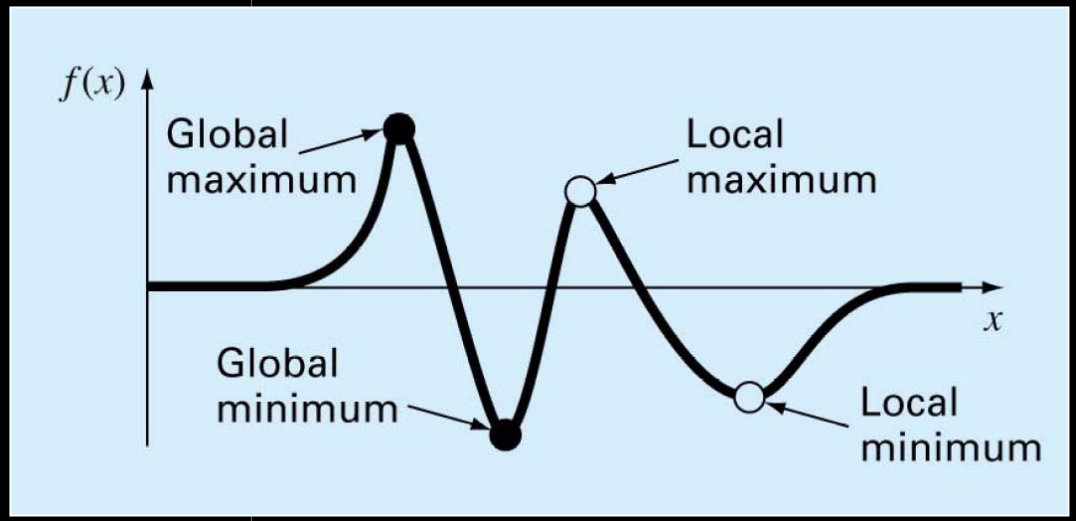
Our algorithm combines local maximum and minima finding methods.

Three new concepts in crown detection analysis.

- ***iterative local maximum analysis***
- ***derivative threshold***
- ***removal of previously analyzed pixels***

Our algorithm simultaneously estimates multiple canopy structural parameters, rather than just the number of trees per hectare.

Local Maximum and Minimum

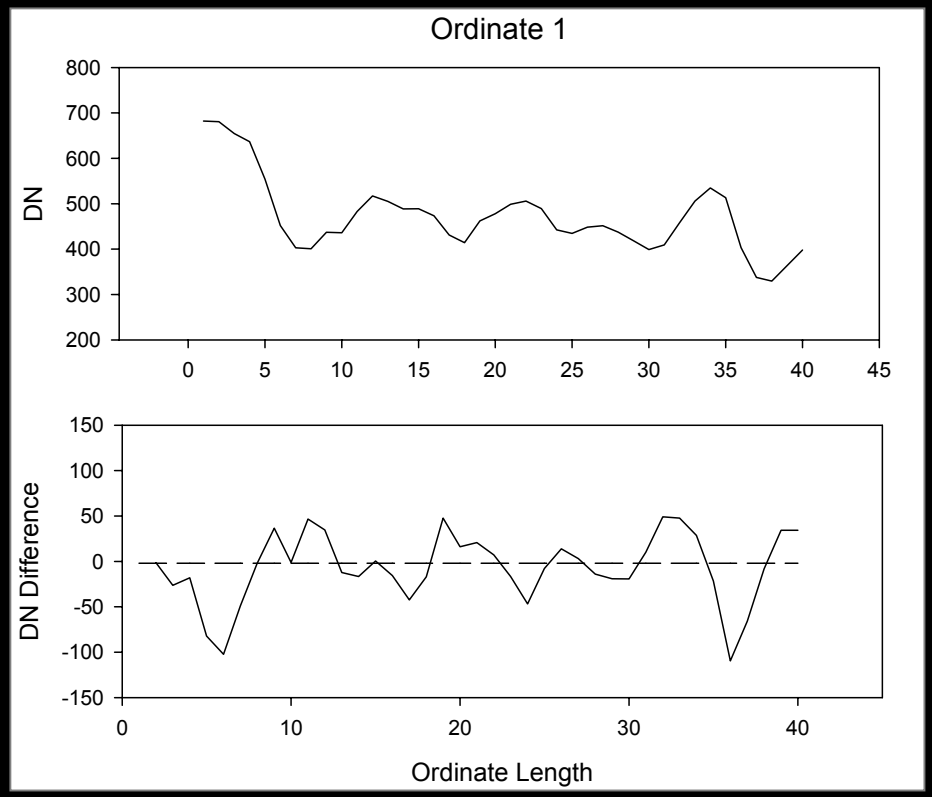


Local Maxima Finding

- Bright pixels are the top of trees

Local Minima Value Method

- Dark pixels are the valleys between trees



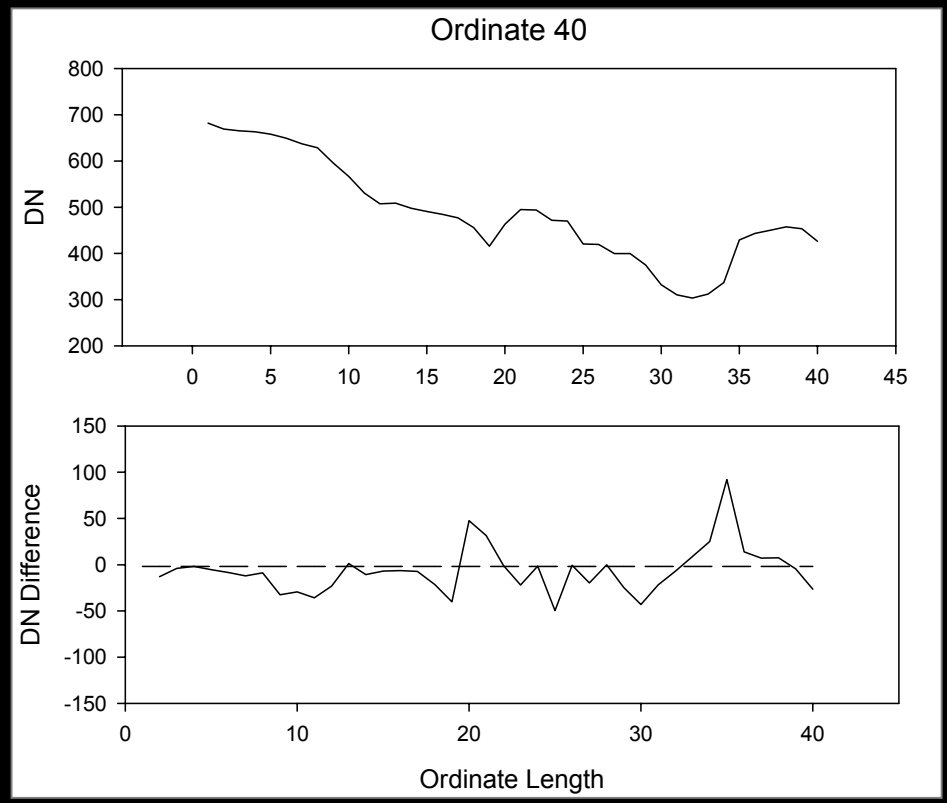
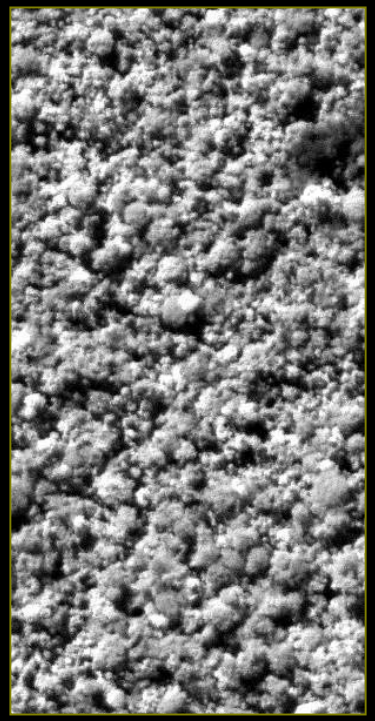


FIGURE 1 a-b. **a.** Digital number data used for termination of an ordinate. In this figure the crown edge is estimated to be 8 pixels from local maxima. **b**. In this figure the crown edge is estimated to be 20 pixels from local maxima.



Preprocessing

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

Crown Detection

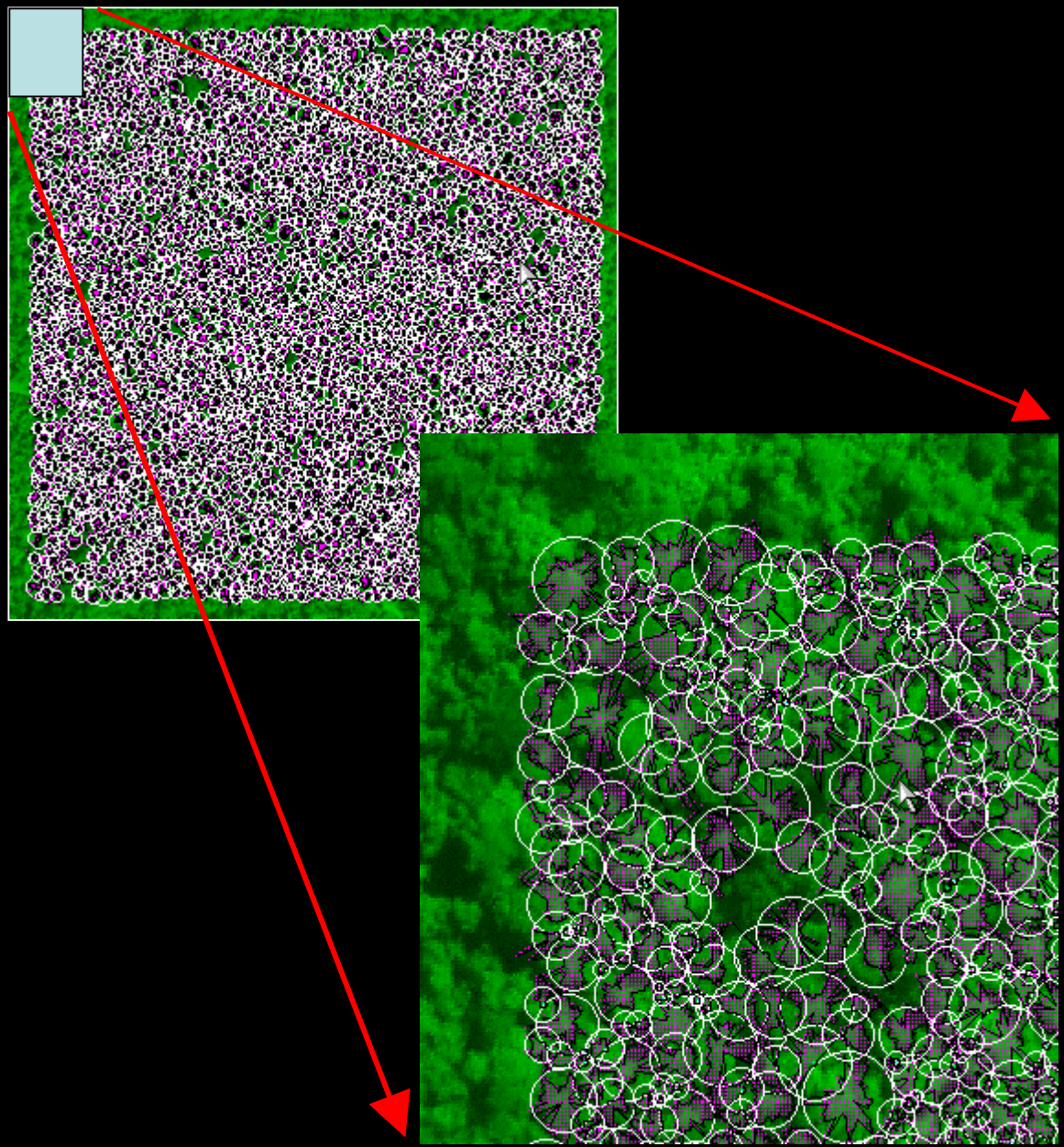
1. Local Maxima Analysis
2. Brightness value (highest to modal brightness values examined in an iterative step)
3. Local maxima seeds ordinate analysis

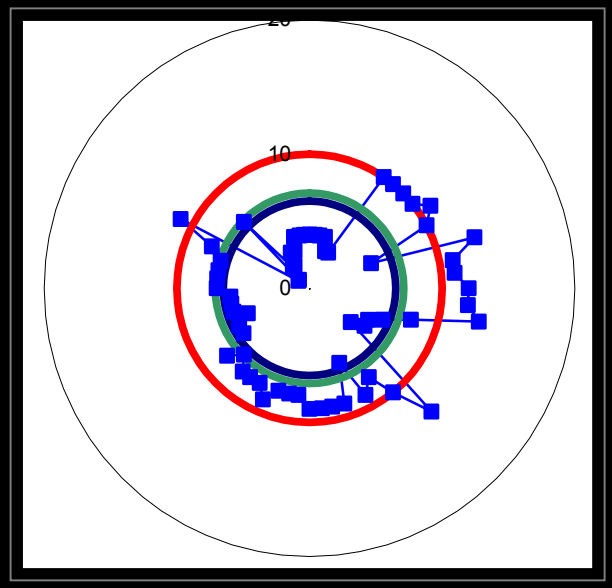
Ordinate Analysis

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 (360 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

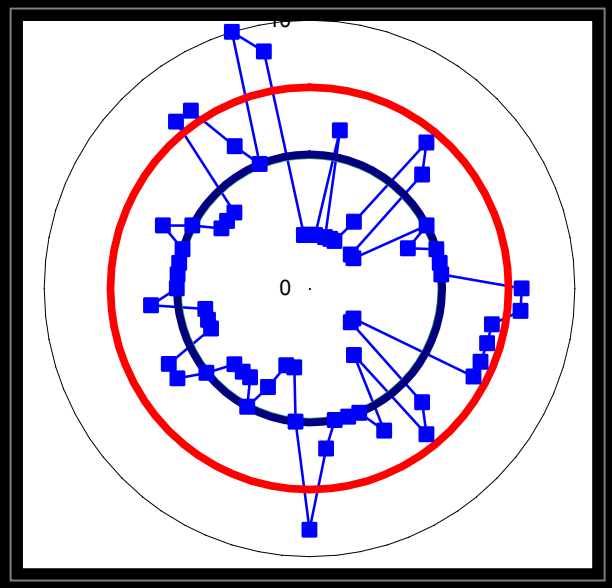
Crown Determination

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





Tree number 3



Tree number 50

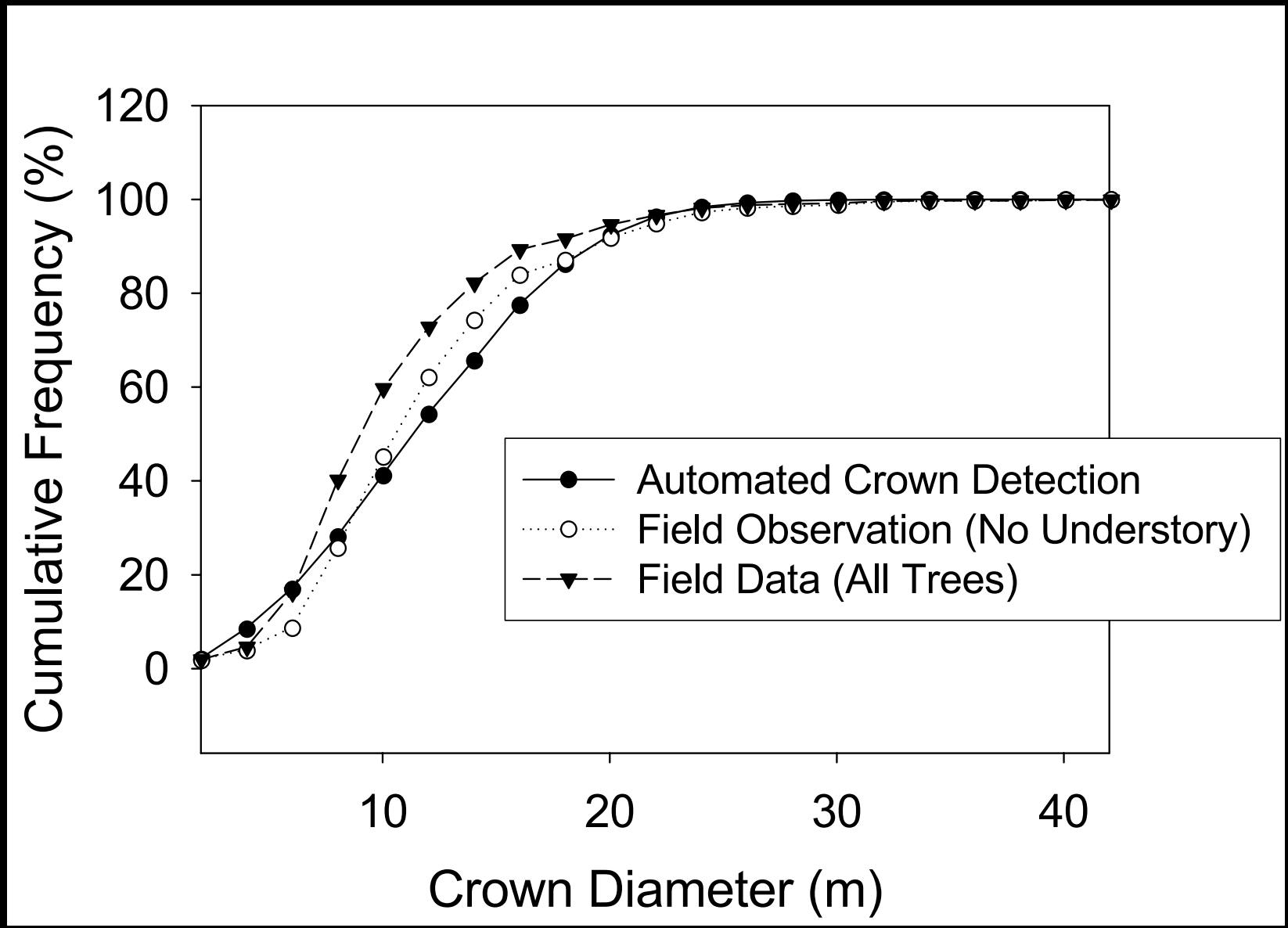


FIGURE 2. Based on least-squares goodness of fit, a cumulative frequency distribution for field observed canopy diameters and automated crown estimate at Cauaxi.

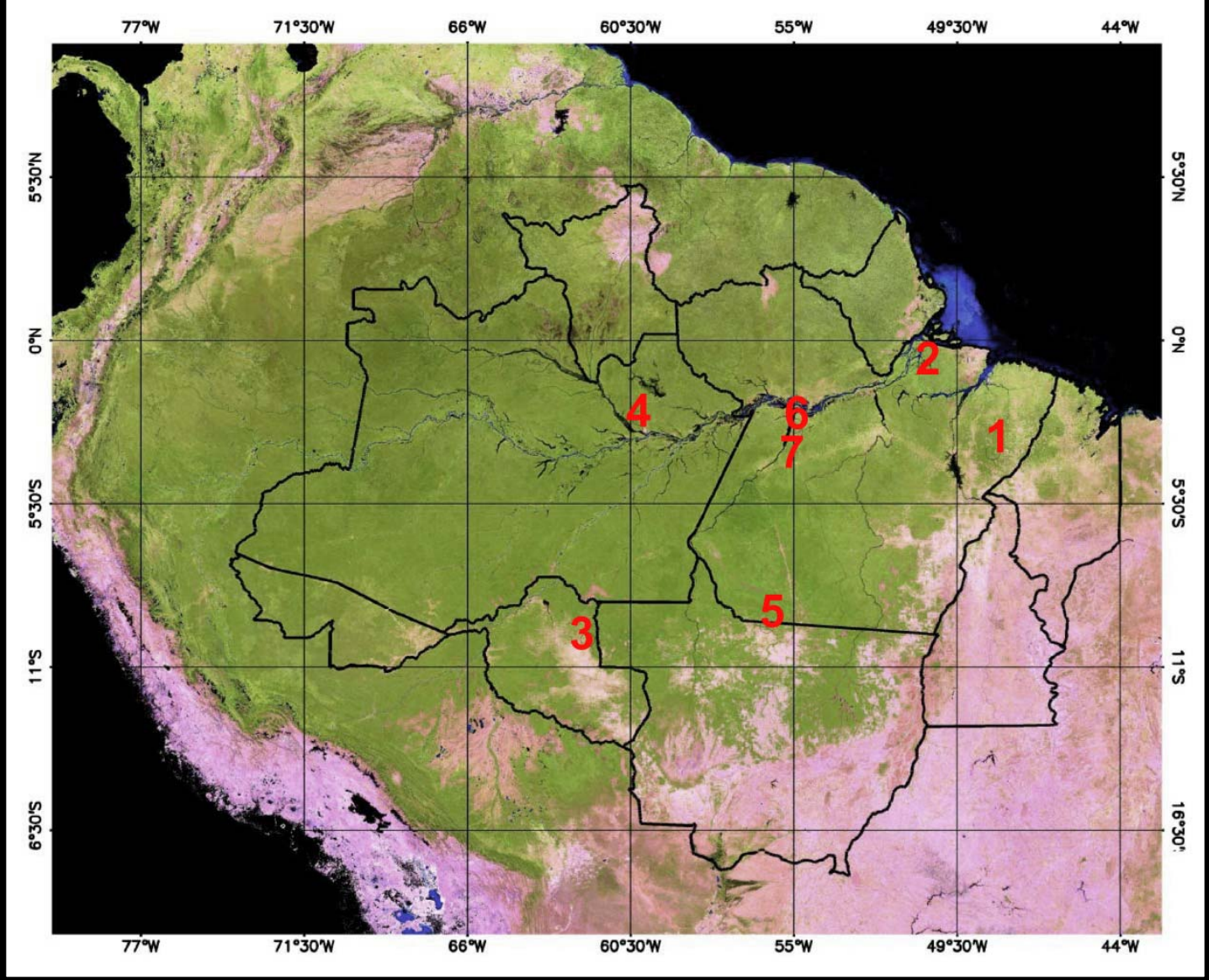
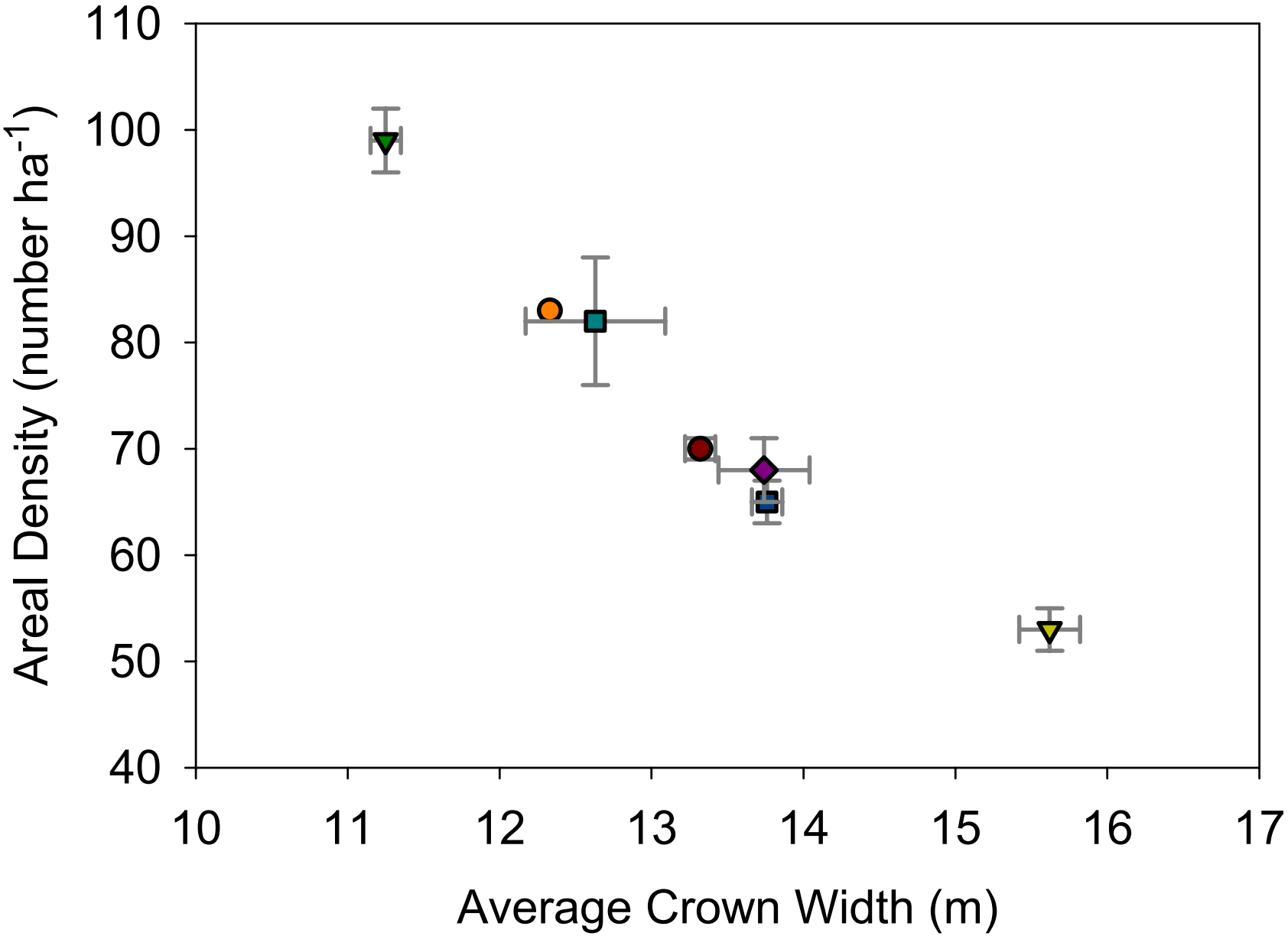
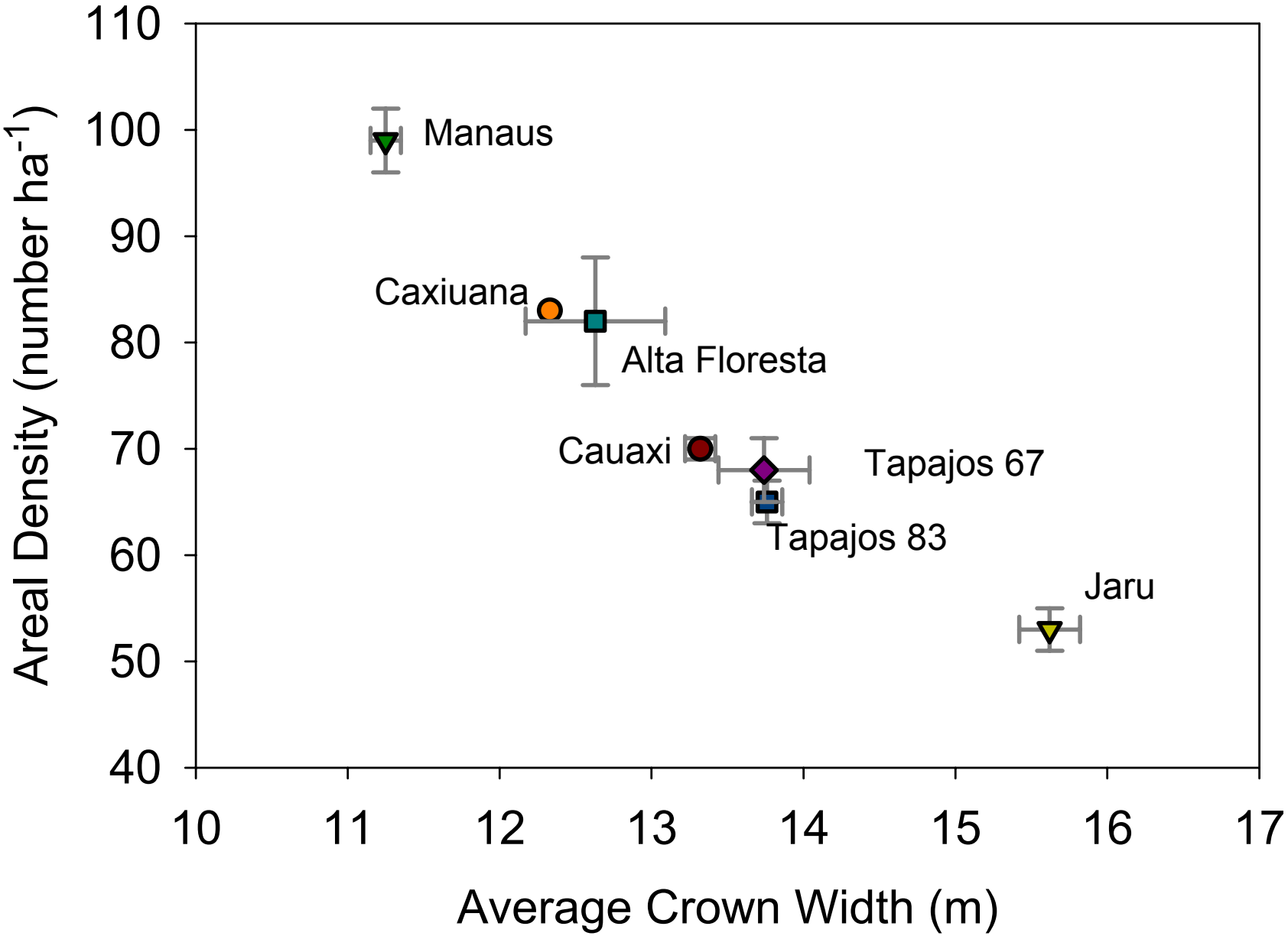


FIGURE 4. Seven IKONOS scenes were used to test the algorithm for undisturbed forest areas distributed across the Amazon region. The crown detection algorithm was conducted on 52 tiles of 1 km2 (1=Cauaxi – 14 (tiles), 2=Caxiuana – 1, 3=Jaru – 2, 4=Manaus – 9, 5=Alta Floresta – 11, 6=Tapajos 67 – 10, 7=Tapajos 83 – 5).


Areal Density (number ha-1)
110
100
90
80
70
60
50
40
10
11
12
13
14
15
16
17
Average Crown Width (m)


Areal Density (number ha-1)
110
100
90
80
70
60
50
40
10
11
12
13
14
15
16
17
Average Crown Width (m)
Manaus
Caxiuana
Alta Floresta
Cauaxi
Tapajos 67
Tapajos 83
Jaru

+ indicates a difference
- indicates no difference

Crown Width

	Jaru	Tapajos 83	Tapajos 67	Cauaxi	Alta Floresta	Caxiuana	Manaus
Jaru	-	+	+	+	+	+	+
Tapajos 83		-	-	-	-	-	+
Tapajos 67			-	-	+	-	+
Cauaxi				-	-	-	+
Alta Floresta					-	-	+
Caxiuana						-	-
Manaus							-

Figure 3. Comparisons between different LBA-ECO sites using ANOVAs that utilize the crown detection algorithm results for each site. All comparison pairs use Tukey-Kramer HSD with an alpha value of 0.05.

+ indicates a difference
- indicates no difference

Areal Density

	Manaus	Caxiuana	Alta Floresta	Cauaxi	Tapajos 83	Tapajos 67	Jaru
Manaus	-	-	+	+	+	+	+
Caxiuana		-	-	-	-	-	-
Alta Floresta			-	-	-	+	+
Cauaxi				-	-	-	-
Tapajos 83					-	-	-
Tapajos 67						-	-
Jaru							-

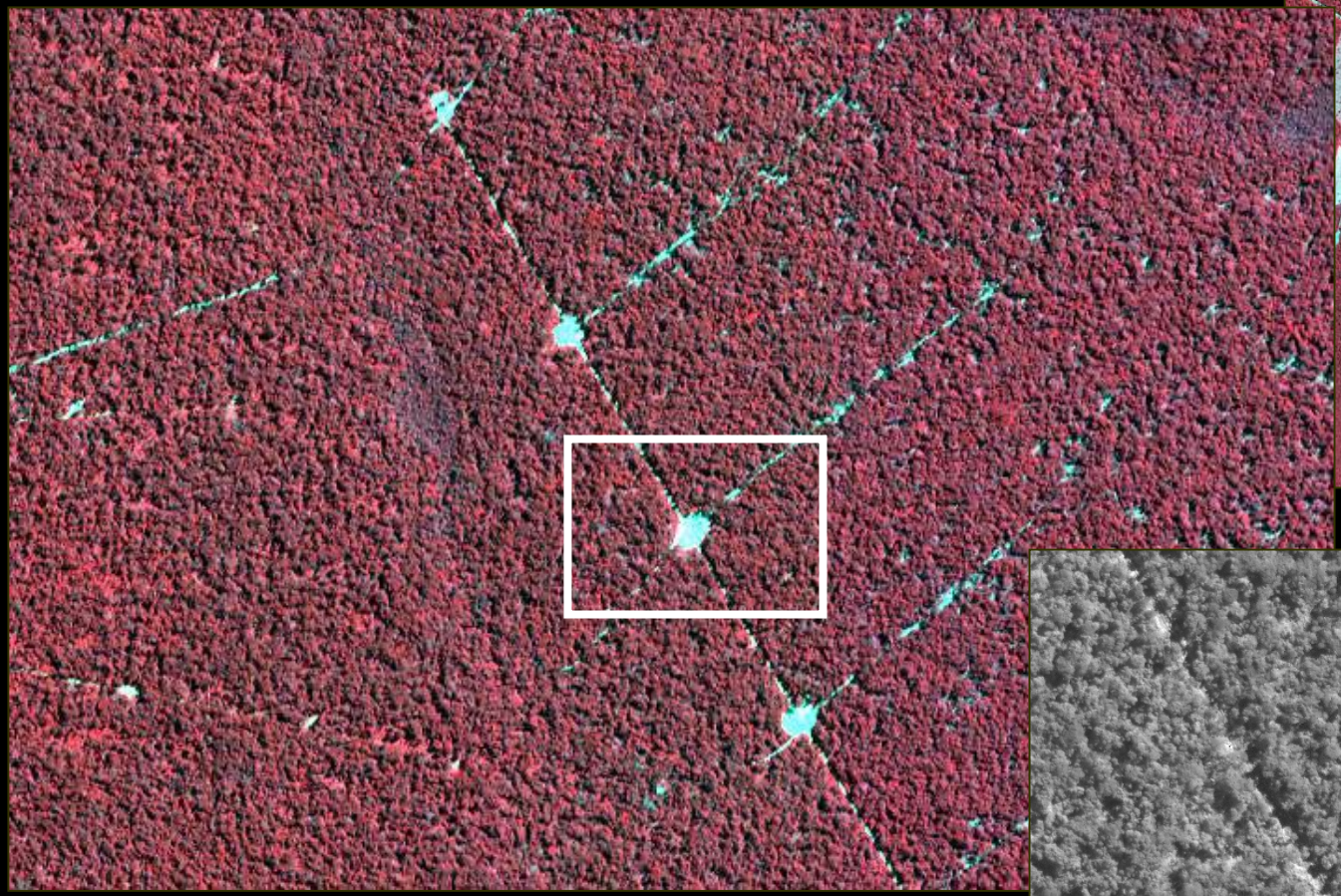
Figure 3. Comparisons between different LBA-ECO sites using ANOVAs that utilize the crown detection algorithm results for each site. All comparison pairs use Tukey-Kramer HSD with an alpha value of 0.05.

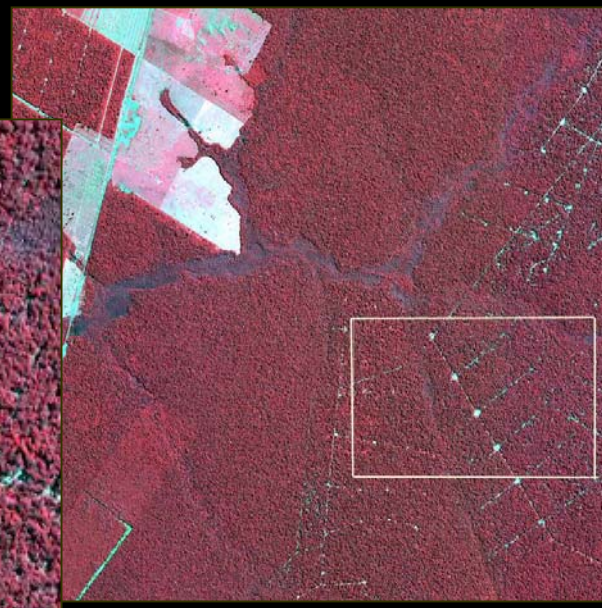
+ indicates a difference
- indicates no difference

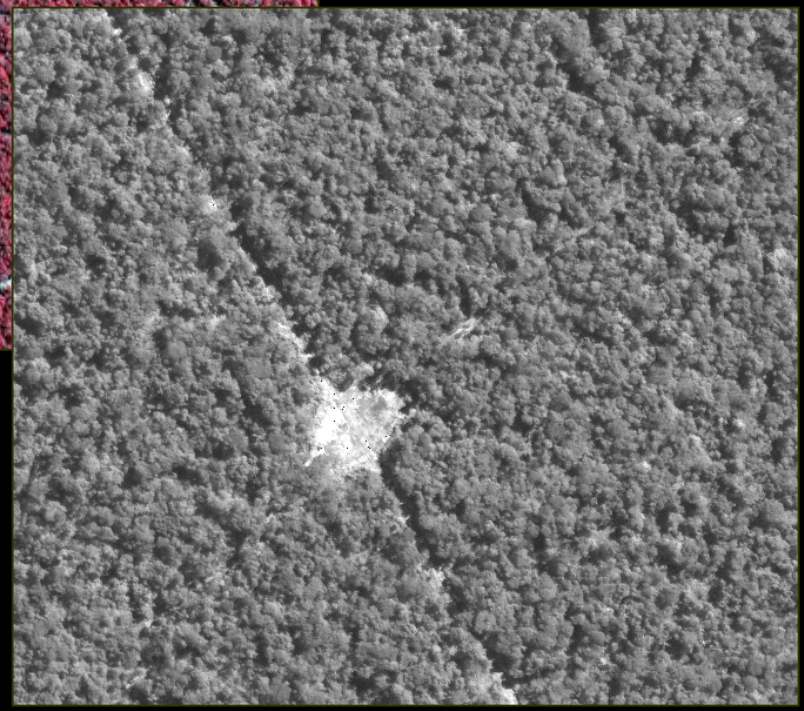
Biomass

	Caxiuana	Manaus	Alta Floresta	Jaru	Tapajos 83	Cauaxi	Tapajos 67
Caxiuana	-	-	-	-	-	-	-
Manaus		-	-	-	-	-	+
Alta Floresta			-	-	-	-	+
Jaru				-	-	-	-
Tapajos 83					-	-	-
Cauaxi						-	-
Tapajos 67							-

Figure 3. Comparisons between different LBA-ECO sites using ANOVAs that utilize the crown detection algorithm results for each site. All comparison pairs use Tukey-Kramer HSD with an alpha value of 0.05.







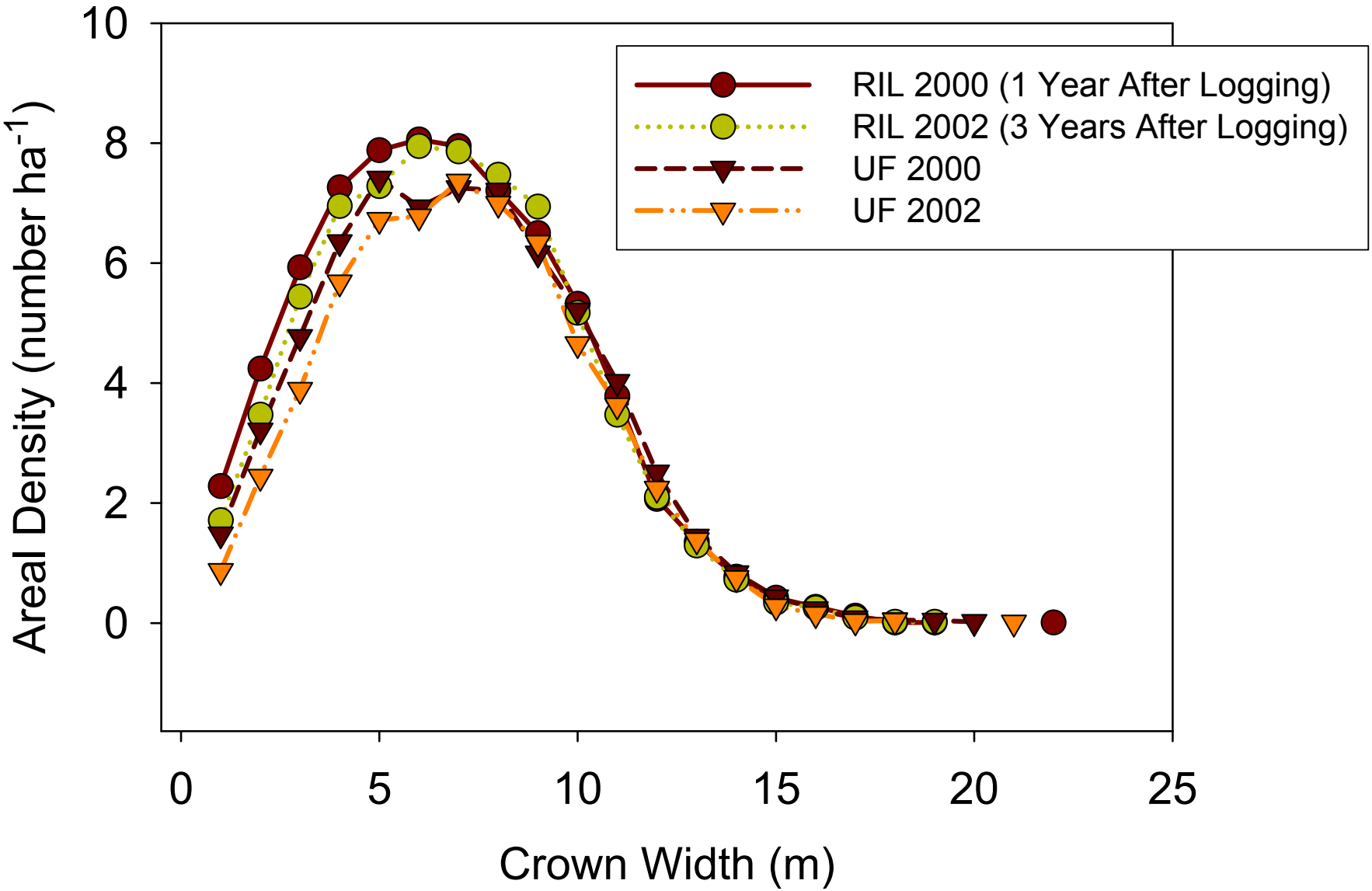


Figure 5. Comparison of Crown Width Distribution derived from an automated Crown detection algorithm. Two areas from two IKONOS images. (Logging occurred in 1999 at the RIL site).

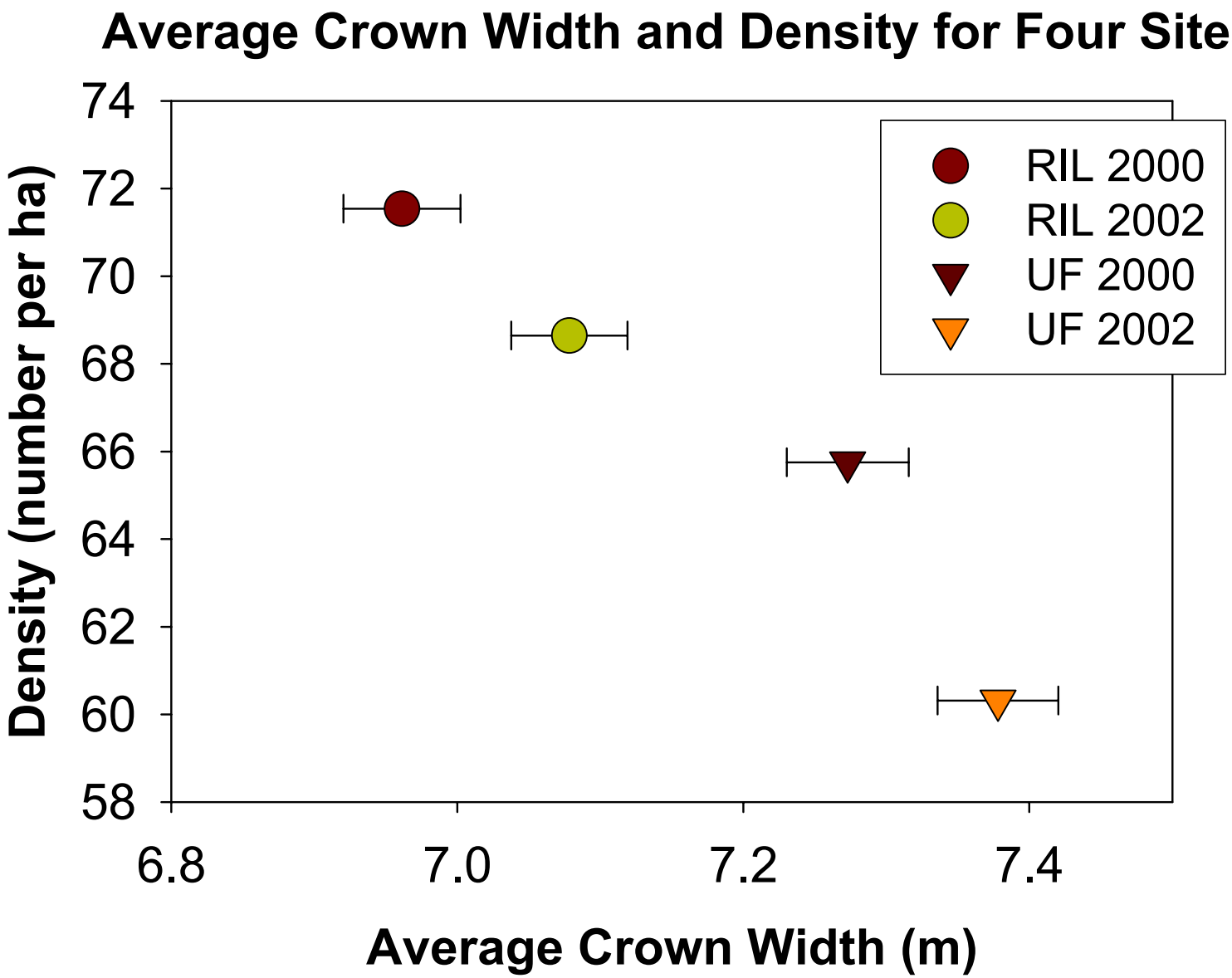
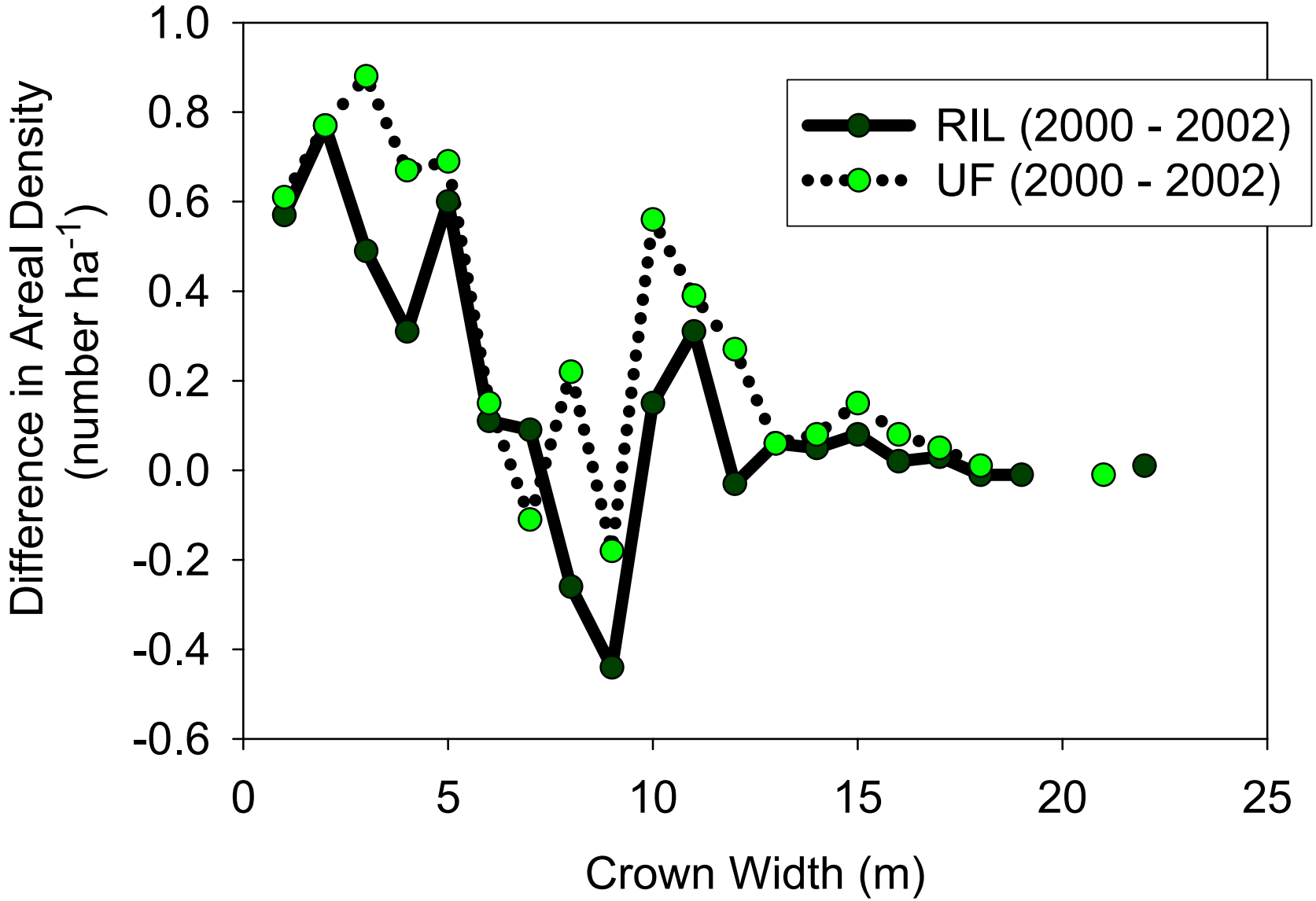


Figure 4. Comparison of Average Crown Width and Areal Density derived from an automated Crown detection algorithm. Two areas from two IKONOS images. (Logging occurred in 1999 at the RIL site).


1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Difference in Areal Density (number ha-1)
0
5
10
15
20
25
Crown Width (m)
RIL (2000 - 2002)
UF (2000 - 2002)

Future Work

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

Future Work

Other Areas and Other Platforms

- Quickbird Images
- Videography in Tapajos
- Aerial Photography

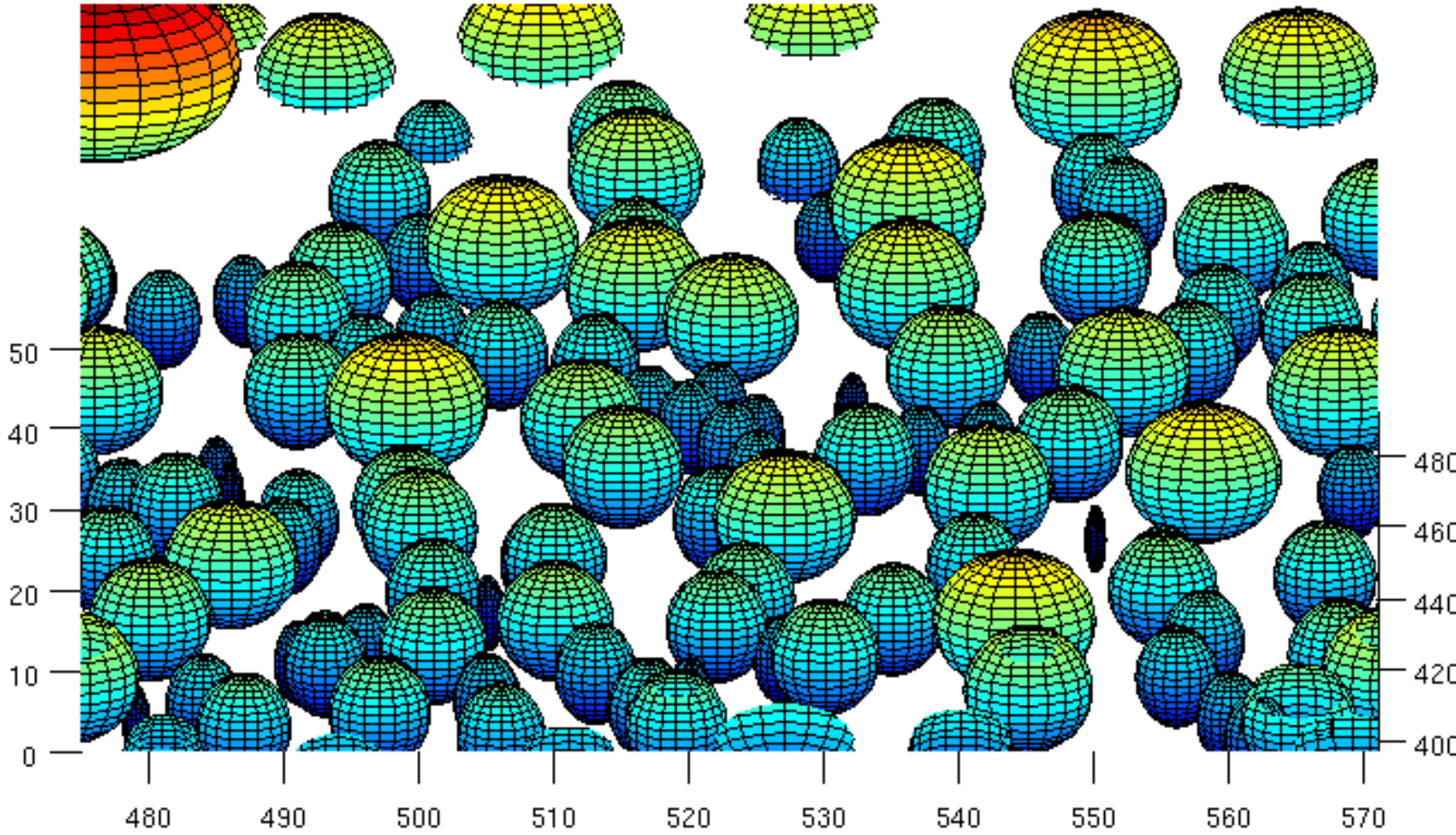
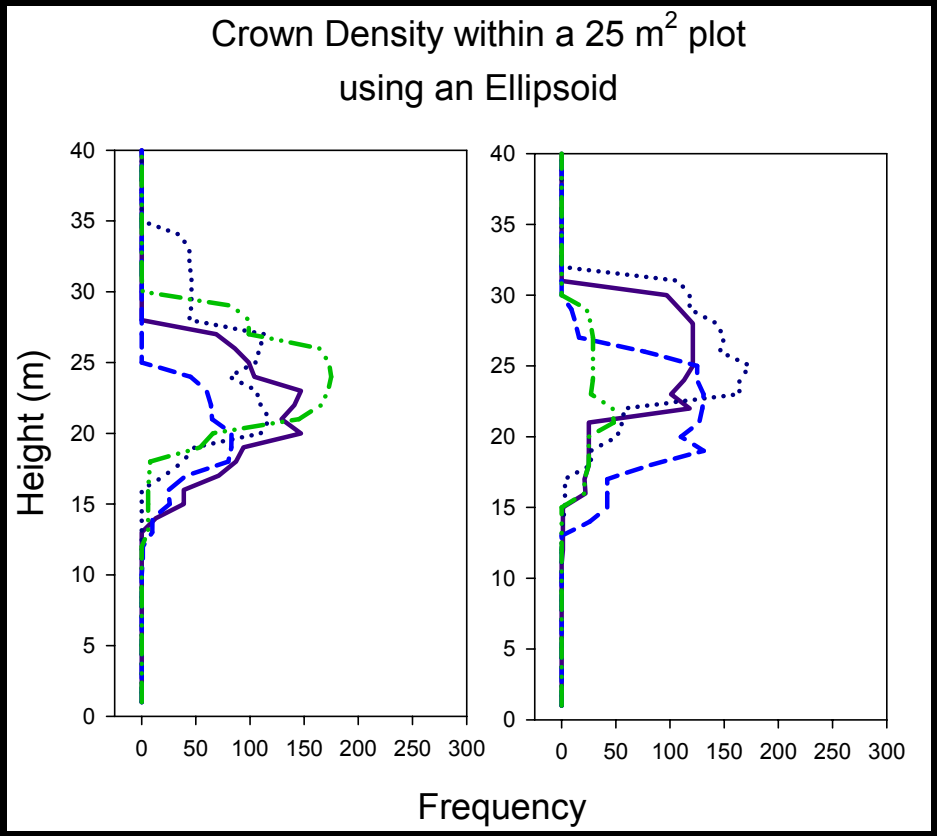
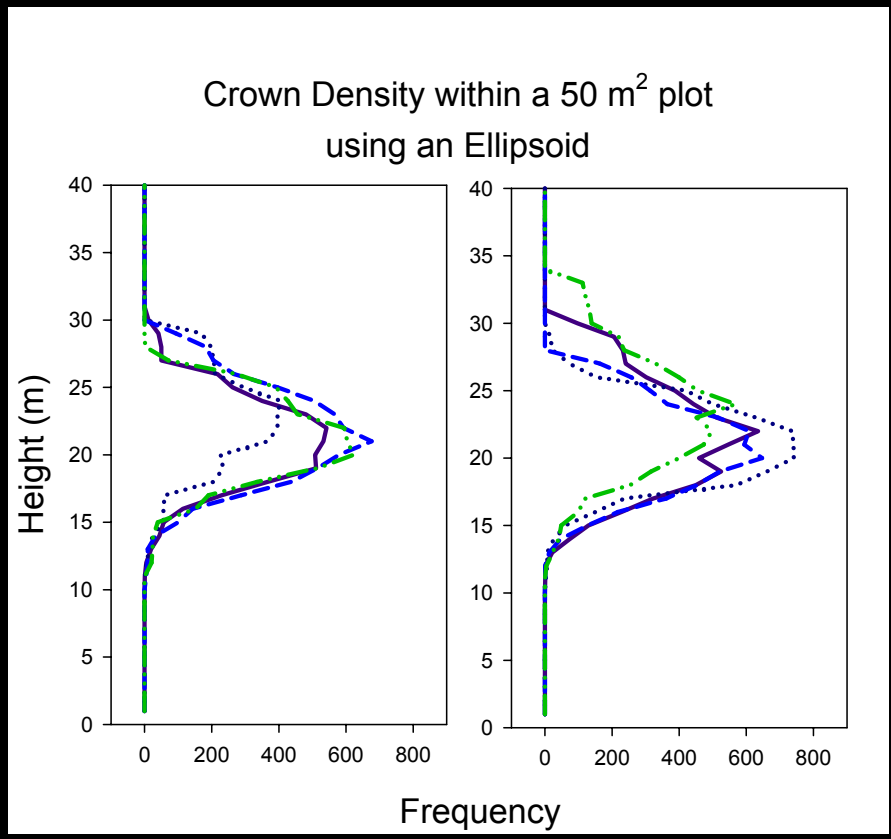


Figure 3. Example of crowns developed using a crown detection algorithm and allometric equations. Location of each crown in three-dimensions is used to calculate the canopy profile.





Figures 2. a-b. Synthetic canopy profiles generated using a crown edge detection algorithm and an allometric relationship between crown width and both tree height and height to the bottom of the canopy. Ellipsoids were generated in three-dimensional space and grided plots of 25 m^2 or 50 m^2 were used to estimate frequency of crown location in a vertical profile. Each color on the graph represents a randomly selected plot within the study area.

Site Name	Longitude	Latitude	IKONOS Tiles	Average Crown Width (m)		Average DBH (cm)		Above Biomass (Mg ha^{-1})		Areal Density (trees ha^{-1})	
				Mean	Std Error	Mean	Std Error	Mean	Std Error	Mean	Std Error
Cauaxi	-48.30000	-3.75500	14	13.32	0.1	56.4	0.4	266	2	70	1
Caxiuana	-51.45500	-1.75000	1	12.33		53.1		281		83	
Jaru	-61.93500	-10.08000	2	15.62	0.2	65.0	0.5	281	5	53	2
Manaus	-60.21000	-2.61000	9	11.25	0.1	49.3	0.5	279	2	99	3
Alta Floresta	-55.94000	-9.60000	11	12.63	0.46	54.2	1.1	281	6	82	6
Tapajos 67	-54.96000	-2.86000	10	13.76	0.1	57.9	0.5	258	3	65	2
Tapajos 83	-54.97500	-3.03000	5	13.74	0.3	58.0	0.8	275	5	68	3