LBA-ECO CD-37 Secondary Forest Biomass and Age Class, Rondonia, Brazil

Summary:

This data set provides stand age, forest formation, and land cover classification maps, and estimates of landscape-level above-ground live woody biomass (AGLB) for secondary forests in Rôndonia, Brazil. The Threshold Age Mapping Algorithm (TAMA) was applied to a densely spaced time series of Landsat images (1975 to 2003) to derive forest age. Forest type and land cover for 2003 were mapped with decision tree classification of three dates of Landsat imagery. The AGLB of the secondary forest was estimated by combining the forest classification map with coincident biomass estimates from the Geoscience Laser Altimeter System (GLAS).

This data set includes two compressed (*.zip) files which when expanded, contain a classified raster file in GeoTIFF format and one .xml file. There are also three comma-delimited (.csv) data files.

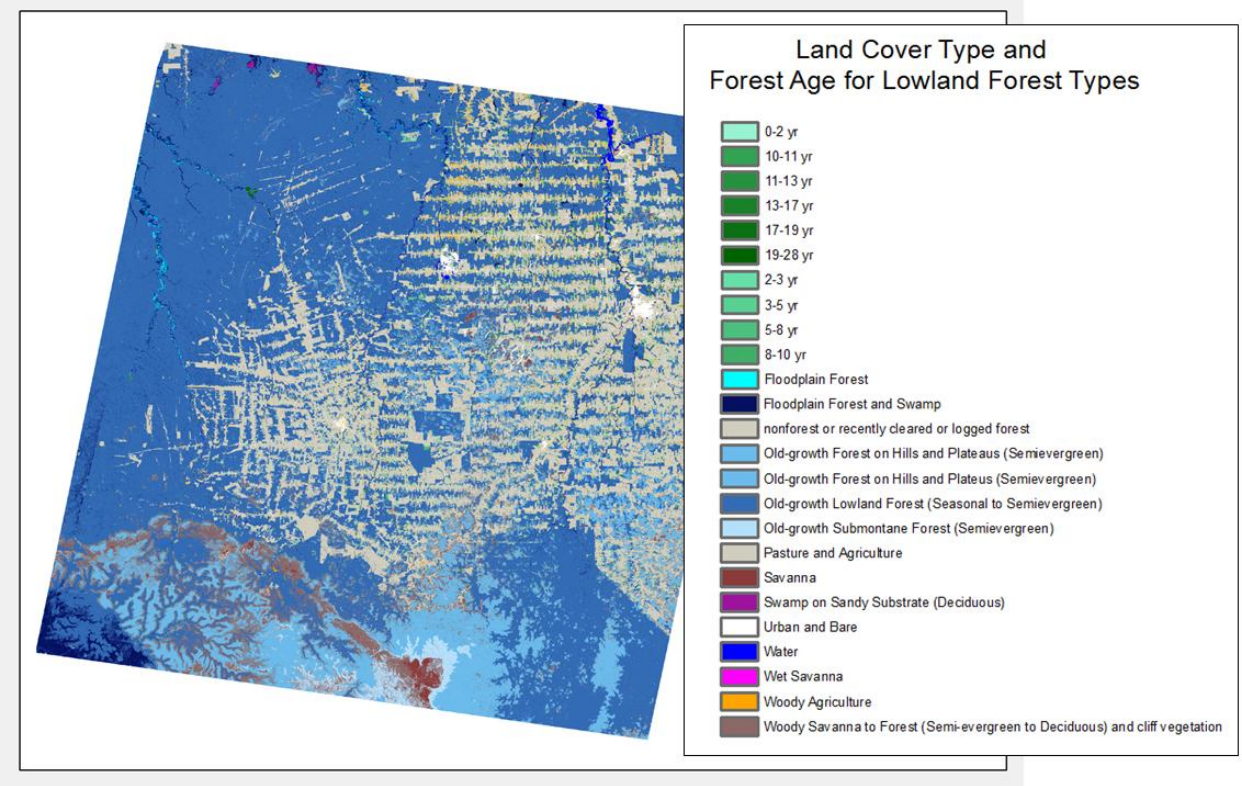

Figure 1. Land Cover and Forest Formation. A supervised decision tree classification was used to map land cover and forest type for 2003. TAMA was applied to a time series of 11 Landsat images to determine the age of lowland forests. A map of the age of those lowland forests was merged with the land cover and forest type map

Data Citation:

Cite this data set as follows:

Helmer, E.H., M.A. Lefsky, and D.A. Roberts. 2013. LBA-ECO CD-37 Secondary Forest Biomass and Age Class, Rondonia, Brazil. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA http://dx.doi.org/10.3334/ORNLDAAC/1145

The article that describes the data set should also be cited:

Helmer, Eileen H., Michael A. Lefsky, and Dar A. Roberts. "Biomass accumulation rates of Amazonian secondary forest and biomass of old-growth forests from Landsat time series and the Geoscience Laser Altimeter System." Journal of Applied Remote Sensing 3, no. 1 (2009): 033505-033505 http://dx.doi.org/10.1117/1.3082116

Implementation of the LBA Data and Publication Policy by Data Users:

The LBA Data and Publication Policy [http://daac.ornl.gov/LBA/lba_data_policy.html] is in effect for a period of five (5) years from the date of archiving and should be followed by data users who have obtained LBA data sets from the ORNL DAAC. Users who download LBA data in the five years after data have been archived must contact the investigators who collected the data, per provisions 6 and 7 in the Policy.

This data set was archived in February 2013. Users who download the data between February 2013 and January 2018 must comply with the LBA Data and Publication Policy.

Data users should use the Investigator contact information in this document to communicate with the data provider.

Data users should use the Data Set Citation and other applicable references provided in this document to acknowledge use of the data.

Table of Contents:

1. Data Set Overview:

Project: LBA (Large-Scale Biosphere-Atmosphere Experiment in the Amazon)

Activity: LBA-ECO

LBA Science Component: Carbon Dynamics

Team ID: CD-37 (Lefsky / Helmer / Roberts)

The investigators were Lefsky, Michael; Keller, Michael M. and Roberts, Dar A. You may contact Helmer, Eileen H (ehelmer@fs.fed.us).

LBA Data Set Inventory ID: CD37_Biomass_Landsat_GLAS

This data set provides stand age, forest formation, and land cover classification maps, and estimates of landscape-level above-ground live woody biomass (AGLB) for secondary forests in Rôndonia, Brazil. The Threshold Age Mapping Algorithm (TAMA) was applied to a densely spaced time series of Landsat images (1975 to 2003) to derive forest age. Forest type and land cover for 2003 were mapped with decision tree classification of three dates of Landsat imagery. The AGLB of the secondary forest was estimated by combining the forest classification map with coincident biomass estimates from the Geoscience Laser Altimeter System (GLAS).

2. Data Characteristics:

This data set includes two compressed (*.zip) files which when expanded, contain a classified raster file in GeoTIFF format and one .xml file. There are also three comma-delimited (.csv) data files:

File #1: **forest_type_age_combined.zip**: when expanded, contains **forest_type_age_combined.tif** and **forest_type_age_combined.aux.xml**

File #2: **sfage_all_auto1_filter_ar01msk_undisteq30.zip**: when expanded, contains **sfage_all_auto1_filter_ar01msk_undisteq30.tif** and **sfage_all_auto1_filter_ar01msk_undisteq30.aux.xml**

File #3: TAMA_Thresholds.csv

File #4: TAMA_Model_Checkpoints.csv

File #5: GLAS_Secondary_Forest.csv

Raster files

The information below applies to both image files (.tif):

- GeoTIFF file format
- Col x row = 7,881 x 7,368
- Cell size= 30 x 30 meters
- Pixel Type: unsigned integer, 8 bit

Coordinate System

- UTM_Zone_20_Southern_Hemisphere
- Projection: Transverse_Mercator
- false_easting: 500000.000000
- false_northing: 10000000.000000
- central_meridian: -63.000000

- scale_factor: 0.999600
- latitude_of_origin: 0.000000
- Linear Unit: Meter

Extent in meters

- Top 8990056
- Left 309462
- Right 545892
- Bottom 8769016

Corner Coordinates:

- Upper Left (309462.000, 8990056.000) (64d44' 2.02"W, 9d 7'56.41"S)
- Lower Left (309462.000, 8769016.000) (64d44'40.81"W, 11d 7'50.15"S)
- Upper Right (545892.000, 8990056.000) (62d34'56.36"W, 9d 8'10.44"S)
- Lower Right (545892.000, 8769016.000) (62d34'47.01"W, 11d 8' 7.33"S)

File 1: forest_type_age_combined.tif : This is the classification of forest formation and land cover which resulted from the application of TAMA to a time series of 11 Landsat images (not included in this data set). This raster image file includes a color legend indicating class information. There is one image for both forest-type and forest age.

The classes in this file are as follows:

Raster Value	Class Names
1	Recently cleared
3	0-1 yr
4	2-3 yr
5	3-5 yr
6	5-8 yr
7	8-10 yr
8	10-11 yr
9	11-13 yr
10	13-17 yr
11	17-10 yr
12	19-28 yr
13	Floodplain Forest
14	Floodplain Forest and Swamp
15	Old-growth Lowland Forest (Seasonal to Semi-evergreen)
16	Urban and Bare
17	Pasture and Agriculture
18	Woody Agriculture
19	Savanna
20	Woody Savanna to Forest (Semi-evergreen to Deciduous) and cliff vegetation
21	Woody Savanna to Forest (Semi-evergreen to Deciduous) and cliff vegetation
22	Old-growth Forest on Hills and Plateaus (Semi-evergreen)
23	Old-growth Forest on Hills and Plateaus (Semi-evergreen)

24	Old-growth Sub-montane Forest (Semi-evergreen)
25	Swamp on Sandy Substrate (Deciduous)
26	Wet Savanna
27	Water

File 2: sfage_all_auto1_filter_ar01msk_undisteq30.tif

This is a file of forest age class output from applying the Threshold Age Mapping Algorithm (TAMA). As mentioned in Helmer et al. (2009), the algorithm applies only to lowland forests. Hill and submontane old-growth forests, for example, are misclassified as older secondary forest in this file.

The classes in this file are as follows:

Number	Name	Age Class
1	nonfor03	Non-forest in 2003
2	A01-03	0-2 yr
3	B00-01	2-3 yr
4	E98-00	3-5 yr
5	F95-98	5-8 yr
6	G93-95	8-10 yr
7	H92-93	10-11 yr
8	I90-92	11-13 yr
9	J86-90	13-17 yr
10	K84-86	17-19 yr
11	L75-84	19-28 yr
30	lowl_og_forwetl	Lowland old-growth forest and swamp

File contents and organization of ASCII files (files 3-5):

File 3: TAMA_thresholds.csv

Column	Heading	Description
1	Image_year	Image year (yyyy)
2	Wetness_MSS	Minimum TM Wetness for forest (rescaled to 8 bits) or maximum value in the MSS red band (band 2)
3	Greenness_NDVI	Maximum TM Greenness for old forest (rescaled to 8 bits) or maximum NDVI for MSS (rescaled to 8 bits)

Example data records:

```
Image_year,Wetness_MSS,Greenness_NDVI
1975,36,174
1984,134,163
1986,168,176
...
1990,172,126
```

```
1992,161,120
1993,168,171
...
2000,190,132
2001,164,150
2003,188,115
```

File 4: TAMA_Model_Checkpoints.csv

Column	Heading	Units/format	Description
1	X_UTM		Sample coordinates in UTM
2	Y_UTM		Sample coordinates in UTM
3	Period		GLAS sampling period
4	Age_2003	years	Age of forest in 2003 reported in years
5	Height	meters	Forest height reported in meters
6	Biomass	Mg	Biomass of forest calculated from estimated height
7	Age_biomass	years	Age of forest based on calculated biomass
8	Age_total	years	Total age of forest calculated by adding column 4 and column 8
9	Notes		Notes on forest dynamics from images

Example data records:

```
X_UTM,Y_UTM,Period,Age_2003,Height,Biomass,Age_biomass,Age_total,Notes
492315.174,8934143.378,L2A,0.458,12.7,121.4,11.238,11.696,-9999
454902.903,8953933.546,L3A,1.417,41.4,414.37,3.786,5.202,logged only; not cleared
...
450754.584,8923454.324,L3A,1.417,18,174.83,14.595,16.012,-9999
488505.731,8959698.844,L3C,2.083,12.9,122.77,4,6.083,-9999
...
457142.487,8930535.823,L3E,2.833,11.1,104.24,8.25,11.083,-9999
505024.014,8906252.339,L3I,4.417,13.9,133.76,11.571,15.988,-9999
```

File 5: GLAS_Secondary_Forest.csv

Column	Heading	Units/format	Description
1	New_obs		Internal observation number
2	Obs		Internal observation number
3	Elev_DEM	m amsl	Elevation in meters above mean sea level from the SRTM digital elevation model
4	Time		UTC Time of GLAS waveform collection
5	Latitude	degrees	Degrees Latitude for GLAS waveform location. Negative values indicate S and positive values N
6	Longitude	degrees	Degrees Longitude for GLAS waveform location. Negative values indicate W and positive values E
7	X_UTM		Sample coordinates in UTM
8	Y_UTM		Sample coordinates in UTM
9	Elev_GLAS	m amsl	Ground elevation in meters above mean sea level as estimated from GLAS waveform
10	Period		GLAS collection period

11	Age_2003	years	Age of forest in 2003 reported in years
12	Height	m amsl	Forest height in meters above mean sea level
13	Height_ver	m amsl	Forest height in meters above mean sea level calculated from GLAS waveform using a processing algorithm (Lefsky et al., 2007)
14	Biomass	Mg/ha	Biomass in megagrams per hectare (Mg/ha) calculated from forest height
15	Pixels		Number of pixels of secondary forest in surrounding 5x5 window

Example data records:

```
New_obs,Obs,Elev_DEM,Time,Latitude,Longitude,X_UTM,Y_UTM,Elev_GLAS,
Period,Age_2003,Height,Height_GLAS,Biomass,Pixels
2649,35948,160.03,121950602.5,-9.642592,-63.07054,492315.174,8934143.378,168.809,
L2A,0.458,12.729,0.2,121.4,
...
25 6707,101748,159.11,153142560.3,-9.46336,-63.411322,454902.903,8953933.546,151.054,
L3A,1.417,41.364,0.2,414.4,
25 6835,101903,139.4,153142564.2,-9.704703,-63.444692,451274.241,8927245.183,
140.554,L3A,1.417,6.329,0.2,55.9,
...
25 11588,180753,0,185542976,-9.668608,-63.071218,492241.388,8931266.996,143.067,
L3D,2.5,0,0.2,-8.8,
25 15410,233786,145.85,204094343.6,-9.692295,-63.328121,464060.229,8928631.59,146.179,
L3F,3.083,2.705,0.2,18.8
..
```

Site boundaries: (All latitude and longitude given in degrees and fractions)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Rondonia (Rondonia)	-64.3889	-62.8926	-9.34191	-10.7769

Time period:

- The data set covers the period 1975/06/19 to 2003/05/20.
- Temporal Resolution: 11 individual Landsat images over the time period covered

Platform/Sensor/Parameters measured include:

- COMPUTER MODEL / ANALYSIS / FORESTS
- ICESAT / GLAS (GEOSCIENCE LASER ALTIMETER SYSTEM) / BIOMASS
- LANDSAT /LANDSAT TM / BIOMASS
- LANDSAT / LANDSAT MSS / BIOMASS

3. Data Application and Derivation:

TAMA is simple, fast, and self-calibrating. By not using between-date band or index differences or trends, it requires neither image normalization nor atmospheric correction. In addition, it uses an

approach to map forest cover for self-calibration that is novel to forest mapping with satellite imagery. It maps humid secondary forest that is difficult to distinguish from old-growth forest in single-date imagery. It does not assume that forest age equals time since disturbance, and it incorporates Landsat Multispectral Scanner (MSS) imagery. Variations on the work that we present here can be applied to other forested landscapes (Helmer et al., 2009).

4. Quality Assessment:

The map of forest age has an overall accuracy of 88%. The Kappa coefficient of agreement of 0.62 is generally considered good. The forest-age mapping algorithm mapped some of the land cleared land from 2000 to 2003 as secondary forest. Some of this land had dense vegetation or large amounts of slash in the fine-resolution imagery. Some of it was clearly also pasture or woody agriculture in later fine-resolution imagery from 2005. To ensure that the algorithm was accurately aging secondary forest younger than three years that was not recently cleared, we excluded recently cleared land from the error assessment of lowland forest age.

The final map of land cover and major forest types, which resulted from the two decision tree classifications and the editing, has an overall classification accuracy of 69% and a Kappa coefficient of agreement of 0.56 for the 14 classes, which is also considered good. Although overall accuracy was good, it reflects the fact that the error matrix merges secondary forest with lands cleared in the last three years, because, similar to the age-mapping algorithm, about one-third of the land that was cleared in the last three years was classified as secondary forest. Woody agriculture also showed confusion with secondary forest. Remaining errors included confusion between the following classes: pasture vs. savanna; secondary forest vs. semi-evergreen to deciduous woody savanna to forest; and forested wetlands vs. other classes. Other old-growth forest classes had users and producers accuracies ranging from 52% to 98%.

Currently TAMA exists as an algorithm that was implemented within different software rather than as a self-contained computer program (Helmer et al., 2009).

5. Data Acquisition Materials and Methods:

The study area extends over one Landsat scene in the Brazilian state of Rondonia, namely World Reference System 2, Path/Row 232/067 (10.1 deg S, 63.7 deg W). Forests in the study area are tropical and include broadleaf seasonal evergreen, semi-evergreen, and deciduous forests, forested wetlands, savannas, and woody savannas. Elevation in the study area ranges from river levels of 70 meters above sea level in lowlands in the north to about 1,100 m on the Serra dos Pacaas Novos. Annual rainfall ranges from 1,900 to 2,700 mm per year, with a wet season from November to April and a dry season from June to August (Culf et al., 1998, Roberts et al., 2002). Major soil types include Latosols, Podzolic soils, Lithosols and Terras Roxas Estruradas (in U.S. soil taxonomy, Oxisols, Ultisols, Entisols and Alfisols).

Landsat Images

Landsat imagery for the study included a previously assembled time series of MSS, Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) scenes dated from 1975 through 2000 (Roberts et al 2002). We coregistered additional images to this time series, from 1986, 2001, and 2003, to within < 0.5 pixels root mean square error, with nearest neighbor resampling. The data set has a pixel size of 30 m. The Landsat images are not provided with this data set.

TAMA and Biomass Estimation Steps

1) Forest age was mapped from the 11-image sequence of Landsat images with TAMA.

2) After TAMA was applied, the lowland forests were isolated by separately mapping land cover and oldgrowth forest types with two decision tree classifications of the Landsat imagery and topographic data.

3) The resulting land-cover and forest-type map allowed us to estimate AGLB of the different old-growth forest types with coincident GLAS data.

4) The age map from TAMA was combined with the land-cover and forest-type map by replacing all lands mapped as secondary forest in the land-cover and forest-type map with secondary forest age from the age map.

5) Forest age or type was extracted for each GLAS waveform from the combined map.

For more details on the TAMA classification process see Helmer et al. 2009.

Thresholds for mapping lowland forest age (Data File #3)

The TAMA maps the age of lowland humid tropical forest from a sequence of Landsat images. For the Landsat Path/Row of this study, TAMA is automatic.The algorithm finds and ages secondary forest, including post-agricultural secondary forest, heavily logged but not entirely cleared forest, and forest where recent river disturbance was stand-replacing. It classifies lightly logged forest as old-growth forest.

The first TAMA step maps forest for the most recent image in the time series, with near the minimum forest cover, which determines the minimum forest mask. General knowledge of land-use trends inthe region under study helps determine this date. The second step applies the minimum forest mask to all images in the time series to find the thresholds (Wetness_MSS and Greenness_NDVI) for forest and mature forest that are specific to each image date. See Helmer et al., 2009, for more details.

Forest biomass estimates at TAMA Model Reference Points (Data File #4)

Fine resolution biomass estimate reference data were derived from three pan-sharpened IKONOS images dated from 2002 and QuickBird images, dated from 2002 to 2005, that were viewable on Google Earth (http://earth.google.com). These data were used for an accuracy assessment of the land-cover and forest-type map and relied on a stratified random sample of about 50 pixels for each mapped class. All of these samples were only from the areas in the map covered by fine-resolution imagery dated within one yr of the image from 2003 (12% of the mapped area). We created a kml file of validation points, and loaded it into Google Earth to locate and identify the land cover or forest type of points viewable at fine-resolution only in Google Earth. See Helmer et al., 2009, for more details.

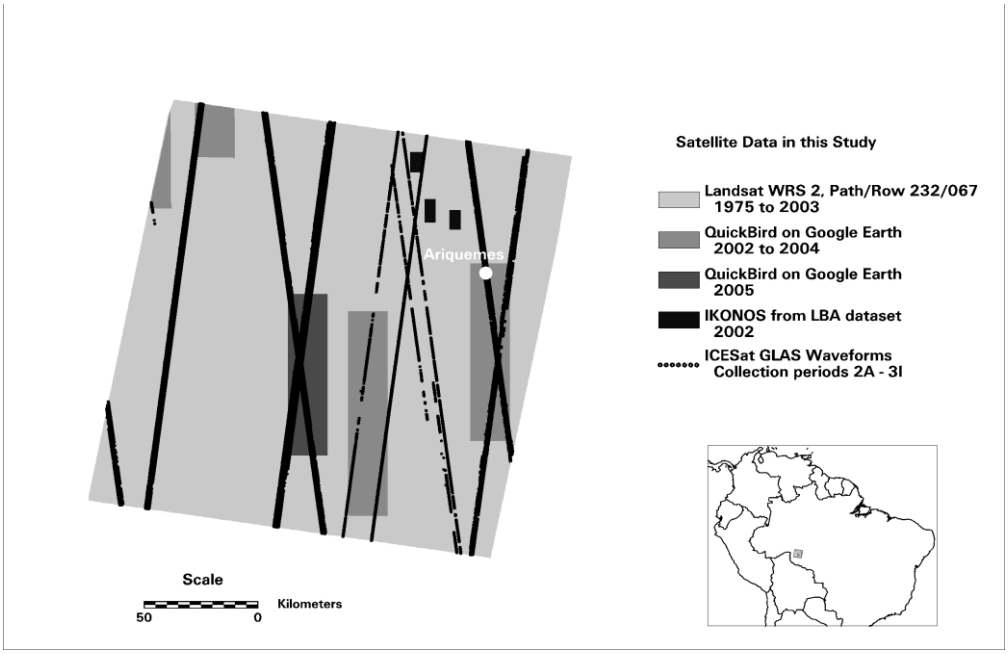

Figure 2. Fine-resolution imagery used for reference data covered 15% of Landsat Path/Row 232/067 and included 1) QuickBird imagery viewable on Google Earth, and 2) three areas of IKONOS imagery. The study area is located in southwestern Amazônia in Brazil, in the State of Rondônia. From Helmer et al., 2009.

Forest biomass estimates for coincident secondary forest and GLAS waveform locations (Data File #5)

The GLAS, onboard the Ice, Cloud, and land Elevation Satellite (ICESat), is a waveform sampling lidar sensor. Canopy height and above ground live biomass (AGLB) were estimated from GLAS waveforms for collection periods 2A through 3I, which extend from November 2003 through November 2007 using the following equation:

AGLB (Mg ha-1) = -8.84 + 10.23 GLAS Height

For a more complete description of the method used to process the data and to estimate canopy height from the GLAS data, please refer to Lefsky et al., 2007. Note that the equation above is an updated equation from the Lefsky et al., 2007 publication.

6. Data Access:

This data is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive Center:

Contact for Data Center Access Information:
E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

7. References:

Culf A.D., G. Fisch, J. Lean, and J. Polcher.1998. A comparison of Amazonian climate data with general circulation model simulations, J. Clim. 11, 2674-2773 [doi:10.1175/1520-0442(1998)011<2764:ACOACD>2.0.CO;2].

Helmer, E.H., M.A. Lefsky, and D.A. Roberts. 2009. Biomass accumulation rates of Amazonian secondary forest and biomass of old-growth forests from Landsat time series and the Geoscience Laser Altimeter System. Journal of Applied Remote Sensing, Vol.3 033505.

M. A. Lefsky, M. Keller, Y. Pang, P. B. D. Camargo, and M. O. Hunter, "Revised method for forest canopy height estimation from Geoscience Altimeter System waveforms," J. Appl. Remote Sens. 1, 1-18 (2007) [doi: 10.1117/1.2795724].

Roberts,D.A., I. Numata, K. Holmes, G. Batista, T. Krug, A. Monteiro, B. Powell, and O. A. Chadwick. 2002. Large area mapping of land-cover change in Rondonia using multitemporal spectral mixture analysis and decision tree classifiers, J. Geophys. Res. Atmos. 107, 8073 [doi:10.1029/2001JD000374].