

AfriSAR: Gridded Forest Biomass and Canopy Metrics Derived from LVIS, Gabon, 2016

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Documentation Revision Date: 2020-09-22

Dataset Version: 1

Summary

This dataset contains gridded forest characterization products derived from full-waveform lidar data acquired by NASA's airborne Land, Vegetation, and Ice Sensor (LVIS) instrument for five forested sites in Gabon, Africa, during the 2016 NASA-ESA AfriSAR campaign. The LVIS lidar instrument was flown over study sites in Lope, Mondah/Akanda, Pongara, Rabi, and Mabouni from February to March 2016. Derived canopy cover, canopy heights, bare ground elevation, plant area index (PAI), and foliage height diversity (FHD), and respective uncertainties are provided at a 25 m resolution for each of the five study sites. Aboveground biomass density (AGBD) and uncertainty were modeled at 50 m and 100 m resolutions for the Lope, Mondah, and Mabounie sites using field inventory data and waveform height and cover metrics. Lidar grid cell data collection statistics (i.e., number of shots and flight lines) and a data mask are also included. This research leverages high-quality forest inventory datasets collected during the AfriSAR campaign for one of the least studied and most unique forest ecosystems in the world.

There are 176 data files in GeoTIFF (.tif) format with this dataset.

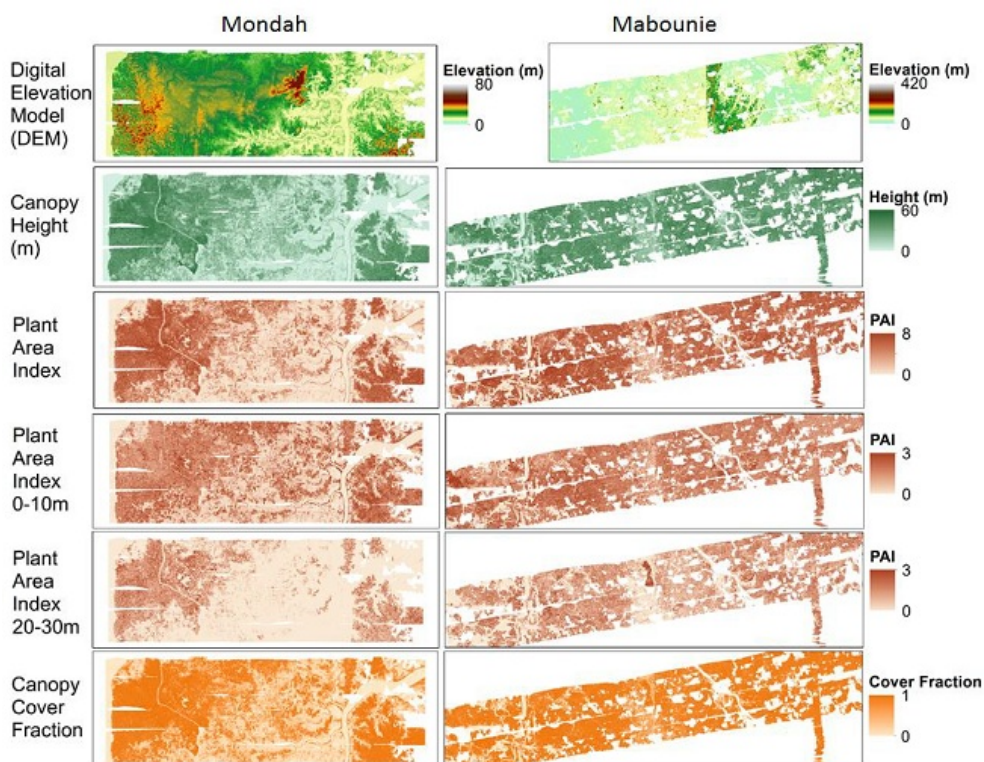


Figure 1. Gridded Land, Vegetation, and Ice Sensor (LVIS) instrument data products at 25 m spatial resolution over the Mondah Forest (left) and Mabounie (right) sites in Gabon. Note that the images labeled "DEM" are plotted from the bare ground elevation data files included in the dataset. Source: J. Armston

Citation

Armston, J., H. Tang, S. Hancock, S. Marselis, L. Duncanson, J. Kellner, M. Hofton, J.B. Blair, T. Fatoyinbo, and R.O. Dubayah. 2020. AfriSAR: Gridded Forest Biomass and Canopy Metrics Derived from LVIS, Gabon, 2016. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1775>

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1. Dataset Overview

This dataset contains gridded forest characterization products derived from full-waveform lidar data acquired by NASA's airborne Land, Vegetation, and Ice Sensor (LVIS) instrument for five forested sites in Gabon, Africa, during the 2016 NASA-ESA AfriSAR campaign. The LVIS lidar instrument was flown over study sites in Lope, Mondah/Akanda, Pongara, Rabi, and Mabounie from February to March 2016. Derived canopy cover, canopy heights, bare ground elevation, plant area index (PAI), and foliage height diversity (FHD), and respective uncertainties are provided at a 25 m resolution for each of the five study sites. Aboveground biomass density (AGBD) and uncertainty were modeled at 50 m and 100 m resolutions for the Lope, Mondah, and Mabounie sites using field inventory data and waveform height and cover metrics. Lidar grid cell data collection statistics (i.e., number of shots and flight lines) and a data mask are also included. This research leverages high-quality forest inventory datasets collected during the AfriSAR campaign for one of the least studied and most unique forest ecosystems in the world.

Project: AfriSAR

The AfriSAR mission was an airborne campaign that collected radar and field measurements of forests in Gabon, West Africa. The mission was a NASA collaboration with the European Space Agency (ESA) and the Gabonese Space Agency. During the 2016 AfriSAR campaign, NASA UAVSAR and LVIS instruments collected data that will be used to derive forest canopy height, structure, and topography. The AfriSAR data will help prepare for and calibrate current and upcoming spaceborne missions that aim to gauge the role of forests in Earth's carbon cycle.

Related Publication

Fatoyinbo, T., et al. 2020. The 2016 NASA AfriSAR Campaign: Airborne SAR and Lidar Measurements of Tropical Forest Structure and Biomass in Support of Future Space Missions. *In progress*

Related Datasets

Fatoyinbo, T., S.S. Saatchi, J. Armston, J. Poulsen, S. Marselis, N. Pinto, L. Duncanson, L.J.T. White, and K. Jeffery. 2018. AfriSAR: Mondah Forest Tree Species, Biophysical, and Biomass Data, Gabon, 2016. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1580>

Saatchi, S.S., J. Chave, N. Labriere, N. Barbier, M. Maxime-Rejou, A. Ferraz, and S. Tao. 2019. AfriSAR: Aboveground Biomass for Lope, Mabounie, Mondah, and Rabi Sites, Gabon. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1681>

Tang, H., J. Armston, S. Hancock, M. Hofton, J.B. Blair, T. Fatoyinbo, and R.O. Dubayah. 2018. AfriSAR: Canopy Cover and Vertical Profile Metrics Derived from LVIS, Gabon, 2016. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1591>

Acknowledgments

This work was funded by the NASA AfriSAR Mission (grant number NNX16AP74G).

2. Data Characteristics

Spatial Coverage: Lope, Mondah/Akanda, Pongara, Rabi, and Mabounie study sites in Gabon, Africa

Spatial Resolution: L3 LVIS-derived products provided at a 25 m resolution; modeled aboveground biomass is provided at 50 m and 100 m resolutions

Temporal Coverage: 2016-02-20 to 2016-03-08

Temporal Resolution: One-time measurements

Study Area: Latitudes and longitudes are provided in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Full extent	9.179286	12.02394	0.631722	-2.29494
Lope	11.39674	12.02394	-0.01559	-0.64224
Mabounie	9.935094	10.7425	-0.67959	-0.95097
Mondah/Akanda	9.269389	9.631119	0.631722	0.534436
Pongara	9.179286	9.995917	0.265536	0.004522
Rabi	9.594942	10.27658	-1.68464	-2.29494

Data File Information:

There are 176 data files in GeoTIFF (.tif) format. The files are named `lvis2_site_2016022020160308_level_variable_e32732_v0301_resolution.tif`, where

`lvis2` = instrument

`site` = sites; `mond` (Mondah/Akanda), `lope` (Lope), `mabo` (Mabounie), `rabi` (Rabi), `pong` (Pongara)

`2016022020160308` = date range of LVIS flightline acquisition

`level` = data product level; `l3a1`, `l3a2`, `l3b1`, `l3b2`, `l3c1`, `l3d1`, `l4a1`

`variable` = data product variable

`e32732` = map projection

`v0301` = processing version

Table 1. File names and descriptions for each data product level.

File Names	Description	Number of Files	Resolution
<p>Ivis2_site_2016022020160308_13a1_variable_e32732_v0301_r025m.tif</p> <p>Ivis2_site_2016022020160308_13a2_variable_e32732_v0301_r025m.tif</p>	<p>product = 13a1 is the mean at the respective height (i.e. variable)</p> <p>product = 13a2 is the corresponding standard deviation</p> <p>variable = 8 relative heights (RH) in meters above ground level (X): RH25, RH50, RH75, RH90, RH95, RH98, RH99, RH100</p>	<p>8 variable files for product = 13a1, 1 file for each of 5 site; 40 files total</p> <p>8 variable files for product = 13a2, 1 file for each of 5 site; 40 files total</p>	25 m
<p>Ivis2_site_2016022020160308_13b1_variable_e32732_v0301_r025m.tif</p> <p>Ivis2_site_2016022020160308_13b2_variable_e32732_v0301_r025m.tif</p>	<p>product = 13b1 is the mean of the respective canopy metric (i.e. variable)</p> <p>product = 13b2 is the corresponding standard deviation</p> <p>variable = 7 canopy metrics: canopy_cover (fractions); foliage_height_diversity (unitless); PAI_0-10m, PAI_10-20m, PAI_20-30m, PAI_above_30m, and total_PAI (square meters per square meters)</p>	<p>7 variable files for product = 13b1, 1 file for each of 5 site; 35 files total</p> <p>7 variable files for product = 13b2, 1 file for each of 5 site; 35 files total</p>	25 m
<p>Ivis2_site_2016022020160308_13c1_ground_elev_e32732_v0301_r025m.tif</p>	<p>product = 13c1 and variable = gound_elev is bare ground elevation in meters above mean sea level</p>	<p>1 variable files for product = 13c1 and variable = gound_elev, 1 file for each of 5 site; 5 files total</p>	25 m
<p>Ivis2_site_2016022020160308_13d1_variable_e32732_v0301_r025m.tif</p>	<p>product = 13d1 is lidar grid cell statistics and data mask</p> <p>variable = 3 lidar metrics: flightlines (number of flight lines), shots (number of lidar shots), valid_data_mask (1 = good pixel, 0 = no data)</p>	<p>3 variable files for product = 13d1, 1 file for each of 5 site; 15 files total</p>	25 m
<p>Ivis2_site_2016022020160308_14a1_agb_e32732_v0301_resolution.tif</p>	<p>product = 14a1 and variable = agb is gridded modeled aboveground biomass and uncertainty in megagrams per hectare</p> <p>resolution = 50 m (0.25 ha), 100 m (1 ha) spatial resolutions</p> <p>there are 4 bands: Band 1. mean AGBD Band 2. standard deviation of the mean AGBD Band 3. lower 1 sigma credible interval Band 4. upper 1 sigma credible interval</p>	<p>2 resolution files for product = 14a1 and variable = agb, 1 file for each of the sites Lope, Mabounie, Mondah/Akanda; 6 files total</p>	50 m, 100 m

Data File Details

The projection is "WGS 84 / UTM zone 32S", EPSG 32732, and the no data value is -9999.

L3 products have one data band per file and L4 product has 4 bands per file.

3. Application and Derivation

AfriSAR presents a unique opportunity to test refined methods for retrieval of canopy height and vertical profile metrics in high aboveground biomass rainforests (up to 600 Mg/ha) with dense canopies (>90% cover), where the greatest uncertainty exists. This research leverages high-quality forest inventory datasets collected through the AfriSAR campaign for one of the least studied and unique forest ecosystems in the world.

4. Quality Assessment

Only good quality LVIS shots dictated by quality flags are included in original LVIS footprint data, depending largely on whether the ground was reached by the lidar waveform. There was no temporal discrepancy between field and lidar data for the calibration of the biomass data. Quality Assurance and Quality Control (QAQC) were applied to field data. Biomass estimates were compared to those from Labriere et al. (2018). Additional information on quality assurance can be found in Fatoyinbo et al. (2020).

Known Problems

For all gridded products, cloud cover resulted in lidar data gaps. There are also gaps between flight lines, where the flight lines were not exactly adjacent resulting in missing values.

For the gridded biomass products, there is inherent uncertainty in ground estimates of aboveground biomass (i.e., field estimates) propagated through to the gridded biomass products. Moreover, geolocation uncertainty of the field data resulted in poorer alignment between the field plots and the LVIS lidar data. Both these uncertainties propagated through in the gridded biomass products.

These known problems could limit the data's use (e.g., uncertainty, sampling problems, blanks, QC samples)

5. Data Acquisition, Materials, and Methods

Study Area

Gridded products were derived from full-waveform lidar data acquired by NASA's LVIS instrument for the Lope, Mondah/Akanda, Pongara, Rabi, and Mabounie study sites in Gabon, Africa.

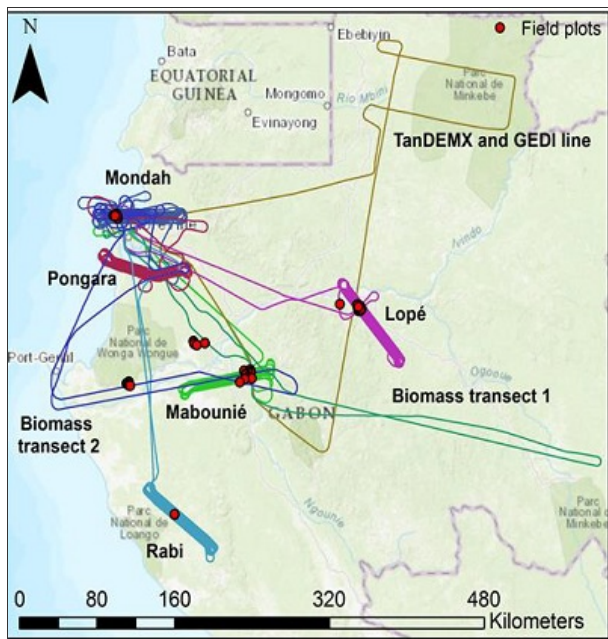


Figure 2. Locations of AfriSAR LVIS acquisitions and field data sites.

NASA's Airborne Land, Vegetation, and Ice Sensor (LVIS) Instrument

LVIS is an airborne, wide-swath imaging laser altimeter system that is flown over target areas to collect data on surface topography and 3D structure. Utilizing a system that includes a 1064 nm wavelength laser and three detectors, the entire time history of the outgoing and return pulses are digitized, allowing unambiguous determination of range and return pulse structure. Combined with aircraft position and attitude knowledge, the sensor produces topographic maps with dm accuracy and vertical height and structure measurements of overflown terrain (e.g., vegetation and ice).

Data Collection

LVIS was flown in Gabon from February to March 2016 on the NASA Langley King Air B-200 at an altitude of 7.3 km. Dates and locations of individual flights are shown in Table 3.

Table 3. LVIS acquisition sites and dates.

Site	Date in 2016	Reported in this Dataset?
Mabounié	February 20	Yes
TanDEM-X transect	February 22	No
GEDI crossover transect	February 22	No
Biomass-1 transect	February 23	No
Lopé	March 2	Yes
Pongara	March 4	Yes
Rabi	March 7	Yes
Mondah/Akanda	March 4	Yes
Mondah/Akanda	March 8	Yes
Biomass-2 Transect	March 8	No

Data Product Derivation

[Relative Height Metric and Bare Earth Elevation Grids](#)

LVIS 25 m x 25 m (0.0625 ha) spatial resolution relative height metric and bare earth elevation grids were generated from the footprint elevation and height metrics. The bare earth elevation or Digital Elevation Model (DEM) interpolation approach used the natural neighbor algorithm, which finds the nearest subset of input points to an interpolation point and weights them based on the proportion of overlap between the polygon defined by a Voronoi diagram around the interpolation point and one based on the input points only (Sibson, 1981).

Canopy Cover and Vertical Profile Metric Grids

LVIS 25 m x 25 m (0.0625 ha) spatial resolution canopy cover and vertical profile metric grids were generated from the footprint canopy cover and vertical profile metrics including total canopy cover, foliage height diversity, total plant area index (PAI), and PAI in height intervals of 0-10 m, 10-20 m, 20-30 m, and >30 m. The gridded products were derived by aggregation of all shots falling within individual cells according to their ground location and calculating the mean and standard deviation of values.

Foliage height diversity (FHD) is a canopy structural index that describes the vertical heterogeneity of foliage profile (MacArthur and Horn, 1969). It is unitless.

Aboveground Biomass Density

Aboveground biomass density (AGBD) and uncertainty were modeled for the Lope, Mondah/Akanda, and Mabounie sites using field inventory data and waveform height and cover metrics, combined in a non-linear Bayesian modelling framework to predict aboveground biomass density and uncertainty at 0.25 ha and 1 ha spatial resolution. A model that follows the functional form of the scaling equations used to derive mass from individual tree structure was used in this study to model AGBD at the plot level:

$$\text{AGBD (Mg ha}^{-1}\text{)} = H \times \text{SBA} \times \text{WSGc} \quad (1)$$

Where AGBD is Aboveground Biomass Density, H is the canopy top height and WSG is the wood specific gravity. RH98 was used for the canopy top height (H) since this is less sensitive to noise (Hancock et al., 2019). However, this model is also parameterized in terms of stand basal area (SBA) and wood specific gravity (WSG), neither of which are directly measured by the lidar waveforms. Therefore, to model SBA in this study, a linear model was developed parameterized by cover and height for prediction from lidar measurements:

$$\text{SBA (m}^2 \text{ ha}^{-1}\text{)} = \text{RH90} \times \text{CCz} = \text{Hmax} \quad (2)$$

Where SBA is the Stand Basal Area Density, and CCz = Hmax is canopy cover at the top of the canopy (i.e., total cover). Since spatially explicit estimates of WSG are not available at 1 ha spatial resolution, regional WSG values defined by Chave et al. (2009) were used and model performance was tested with and without its inclusion. Models were independently developed at spatial resolutions of 0.25 ha and 1 ha, for which we had in situ AGBD data that could be co-located with waveform footprints with relative geolocation errors of <5%. Specification of these models required explicit treatment of heteroscedasticity and the non-normal error distribution of the response (AGBD). This was achieved through the use of a Generalized Linear Model (GLM), selecting a Gamma distribution for modelling the continuous, non-negative, and positive-skewed AGBD data, where the variance is proportional to the mean squared. Estimation of model parameters was undertaken in a generalized non-linear Bayesian framework using R software. Posterior predictive distributions provided realistic per-pixel estimates of uncertainty in the form of 1 sigma credible intervals. Model performance was assessed by leave-one-out (LOO) cross-validation.

Data Sources

Gridded canopy cover metrics were generated from the footprint-level metrics (Tang et al., 2018). Details on field data used for the calibration of the biomass models are available in Fatoyinbo et al. (2018). Other field data used for the calibration of the models are provided by N. Labrière et al. (2018).

6. Data Access

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

[AfriSAR: Gridded Forest Biomass and Canopy Metrics Derived from LVIS, Gabon, 2016](#)

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

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