CMS: Aboveground Biomass for Mangrove Forest, Zambezi River Delta, Mozambique

Get Data

Documentation Revision Date: 2017-08-25

Data Set Version: 1

Summary

This dataset provides several estimates of aboveground biomass from various regressions and allometries for mangrove forest in the Zambezi River Delta, Mozambique. Plot level estimates of aboveground biomass are based on extensive tree biophysical measurements from field campaigns conducted in September and October of 2012 and 2013. Aboveground biomass estimates for the larger area of mangrove coverage within the delta are based on (1) the plot level data and (2) canopy structure data derived from airborne LiDAR surveys in 2014. The high-resolution canopy height model for the delta region derived from the airborne LiDAR data is also included.

This dataset contains seven data files in GeoTIFF format (.tif) and one file in comma-delimited text (.csv) format.

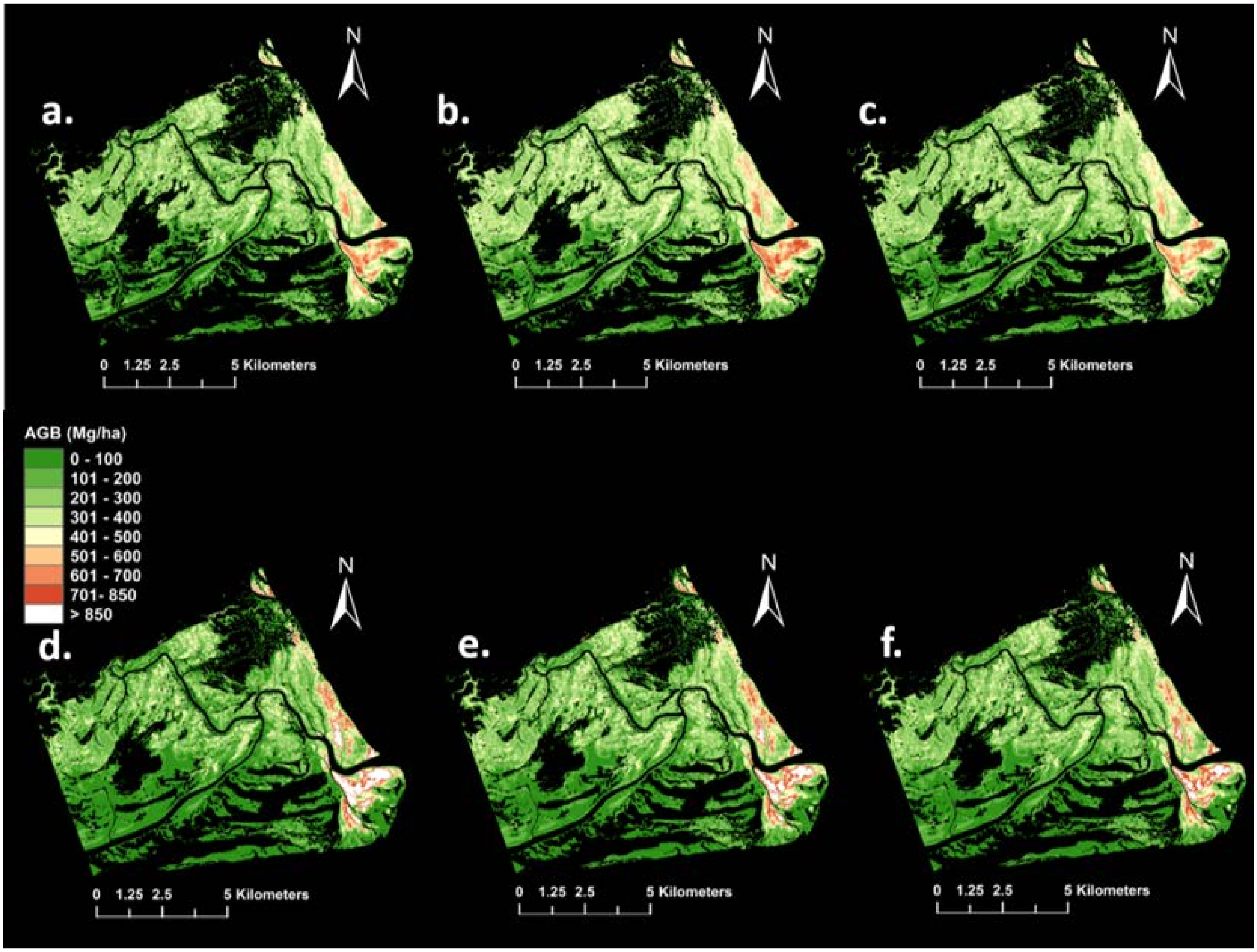

Figure 1. Zambezi Delta mangrove AGB maps derived from different allometric models. a) Chave linear, b) Komiyama linear, c) Njana linear, d) Chave power, e) Komiyama power, f) Njana power; from Fatoyinbo et al. (in review)

Citation

Fatoyinbo, T., E. Feliciano, D. Lagomasino, S. Lee, and C. Trettin. 2017. CMS: Aboveground Biomass for Mangrove Forest, Zambezi River Delta, Mozambique. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1522

Table of Contents

1. Data Set Overview

This dataset provides several estimates of aboveground biomass (AGB) from various regressions and allometries for mangrove forest in the Zambezi River Delta, Mozambique. Plot level estimates of AGB are based on extensive tree biophysical measurements from field campaigns conducted in September and October of 2012 and 2013. AGB estimates for the larger area of mangrove coverage within the delta are based on (1) the plot level data and (2) canopy structure data derived from airborne LiDAR surveys in 2014. The high-resolution canopy height model for the delta region derived from the airborne LiDAR data is also included.

Project: Carbon Monitoring System

The NASA Carbon Monitoring System (CMS) is designed to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes. The System will use the full range of NASA satellite observations and modeling/analysis capabilities to establish the accuracy, quantitative uncertainties, and utility of products for supporting national and international policy, regulatory, and management activities. CMS will maintain a global emphasis while providing finer scale regional information, utilizing space-based and surface-based data and will rapidly initiate generation and distribution of products both for user evaluation and to inform near-term policy development and planning.

Related Datasets:

Lagomasino, D., T. Fatoyinbo, S. Lee, E. Feliciano, M. Simard, and C. Trettin. 2016. CMS: Mangrove Canopy Height Estimates from Remote Imagery, Zambezi Delta, Mozambique. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1357

Fatoyinbo, T., and C. Trettin. 2017. CMS: LiDAR Data for Mangrove Forests in the Zambezi River Delta, Mozambique, 2014. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1521

Acknowledgements:

This data collection was funded through CMS Project grant number 14-CMS14-0028.

2. Data Characteristics

Spatial Coverage: Mangrove forested land of the Zambezi River Delta, Mozambique

Spatial Resolution: 1 meter

Temporal Coverage: Field measurements were made in September and October of 2012 and 2013. LiDAR measurements were taken on a single day: 20140505

Temporal Resolution: Seasonal

Study Area (all latitudes and longitudes given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Zambezi River Delta, Mozambique	36.1489	36.2925	-18.7866	-18.8987

Data File Information

There are seven data files in GeoTIFF format (.tif) -- six files of LiDAR-derived biomass estimates and one with the canopy height model (CHM) generated from airborne LiDAR data collected in May 2014 (Fatoyinbo et al., in review). There is one comma-delimited file (.csv) with selected field plot biomass metrics and estimates collected during field campaigns in September and October of 2012 and 2013 (Stringer et al. 2015, Trettin et al. 2015).

Table 1. Filenames, units, and descriptions for files included in this dataset

Filename	Units	Description
chave_linear_agb.tif	Mg/ha	AGB based on Chave et al. (2005) linear allometry
chave_power_agb.tif	Mg/ha	AGB based on Chave et al. (2005) power allometry
komiyama_linear_agb.tif	Mg/ha	AGB on Komiyama et al. (2005) linear allometry
komiyama_power_agb.tif	Mg/ha	AGB based on Komiyama et al. (2005) power allometry
njana_linear_agb.tif	Mg/ha	AGB based on Njana et al. (2015) linear allometry
njana_power_agb.tif * **	**Mg/ha**	**AGB based on Njana et al. (2015) power allometry**
chm_lidar_1m.tif	(m)	CHM generated from airborne LiDAR data
zambezi_plots_height_biomass_metrics.csv		Plot level H100, Lorey's height, and AGB measurements

***The dataset authors advise that the Njana Power-based AGB map (njana_power_agb.tif) provides the most accurate estimates of AGB for this region as it is based on an allometric equation specific to East African mangrove forest, takes into account tree height, and has the highest range of input diameter at breast height and height measurements.

Spatial Data Files

<u>Spatial Data Properties</u>

Spatial Representation Type: Raster
Pixel Depth: 16 bit int (AGB); 32 bit float (CHM)
Pixel Type: byte

Compression Type: LZW
Number of Bands: 1
Raster Format: TIFF
No Data Value: -9999
Scale Factor: 1

Spatial Reference Properties

WGS 84 / UTM 36S
Authority: Custom

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 10000000.0
central_meridian: 33.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
  Semimajor Axis: 6378137.0
  Semiminor Axis: 6356752.314245179
  Inverse Flattening: 298.257223563

Tabular Data File

The CSV data file (*zambezi_plots_height_biomass_metrics.csv*) provides measurements of field H100, Lorey's height (LH; see Section 5), LiDAR H100 (2014), and AGB derived from the three allometries for plots that fall within the airborne survey coverage. Columns names, units, and descriptions are given in Table 2.

Table 2. Column names, units, and descriptions for CSV data in *zambezi_plots_height_biomass_metrics.csv*

Column Name	Units	Description
plot		Field plot identifier
field_h100	m	Average height of the two tallest trees within the plot measured using a hypsometer
lidar_h100	m	Average height of the 100 tallest trees in the hectare containing the plot measured from the LiDAR data
field_loreys_height	m	Lorey's mean weighted height (LH) calculated for each plot
chave_agb		Field AGB based on Chave et al. (2005) allometry
komiyama_agb		Field AGB based on Komiyama et al. (2005) allometry
njana_agb		Field AGB based on Njana et al. (2015) allometry

3. Application and Derivation

This dataset provides aboveground biomass estimates of tall mangrove forests in the Zambezi Delta, Mozambique. Mangroves are ecologically and economically important forested wetlands with the highest carbon density of all terrestrial ecosystems. Because of their large carbon stocks and importance as a coastal buffer, their protection and restoration has been proposed as effective mitigation strategy for climate change and coastline loss.

4. Quality Assessment

Height metrics

Comparison of field and LiDAR height metrics showed that the airborne survey data was highly correlated with field estimates of forest canopy height at the plot level across the entire range of sampled canopy heights. The strongest correlation between field and airborne survey metrics were found between LiDAR H100, LH, and Field H100, with 93% accuracy prediction between the airborne and field survey metrics. The root mean square error for the LiDAR H100 and Field H100 comparison was of 1.7 m and 1.4 m for the LiDAR H100 versus the LH comparison.

Aboveground biomass

A summary of the LiDAR-based AGB predictive models equations and their respective correlation coefficients can be found in Table 3. In general, the LiDAR-based regression models performed equally or better in estimating AGB as the field height measurements in terms of R^2.

Table 3. Regressions models based on AGB and LiDAR H100.

Equation	R^2	RMSE (Mg/ha^{-1})	RMSE (%)	Allometry
Linear				
AGB = 32.27 * (LiDAR H100) – 312.84	0.85	78	24	Chave
AGB = 31.45 * (LiDAR H100) – 254.81	0.82	83	23	Komiyama
AGB = 28.02 * (LiDAR H100) – 217.2	0.80	80	24	Njana
Power				
AGB = 0.01 * $(\text{LiDAR H100})^{3.46}$	0.88	119	33	Chave
AGB = 0.07 * $(\text{LiDAR H100})^{2.83}$	0.86	135	33	Komiyama
AGB = 0.10 * $(\text{LiDAR H100})^{2.7}$	0.85	122	33	Njana

5. Data Acquisition, Materials, and Methods

Site Description

The Zambezi River sheds water from a 1,570,000 km^2 area encompassing eight African countries and eventually discharges into the Indian Ocean via the Zambezi Delta. The wet season occurs from April to October with approximately 1,000 to 1,400 mm annual rainfall.

Plot-Level Canopy Characteristics

Field sampling was conducted over two seasons in September and October of 2012 and 2013. Field-based canopy height and carbon stock estimates were inventoried using a stratified random sampling design that took into account forest canopy height classes determined from the Mozambique mangrove canopy height data product derived from SRTM and GLAS data (Fatoyinbo et al., 2008). The forest was separated into 5 height classes and five sub-plots were used as the basis for measurements and sampling within each 0.52 ha plot to characterize above and belowground biomass carbon pools. Field H100 and A nested sampling approach was used to measure tree diameter at breast height (DBH) and height within each subplot, with trees > 5 cm measured on the entire sub-plot and trees < 5 cm measured on a 2-m radius area.

Field H100 height and Lorey's mean weighted height (LH) were calculated within each plot as a basis for comparison with the LiDAR height measurements used to generate biomass estimates. H100 represents the height of the 100 tallest trees in a given hectare.

- Field H100 was calculated from the field data using the average of the two tallest trees for each sub-plot.
- LH, defined as mean height weighted by basal area, was estimated using individual trees greater than 5 cm, calculated as:

$$LH(m) = \frac{\sum g_i * h(m)_i}{\sum g_i}$$

where h_i is the height in meters for each tree and g_i is the basal area in square meters for each tree.

The H100 and LH measurements are provided for each plot in the CSV data file (*zambezi_plots_height_biomass_metrics.csv*).

Additional details regarding the mangrove field inventory can be found in Stringer et al. (2015) and Trettin et al. (2015). Field plot locations are depicted in Figure 2.

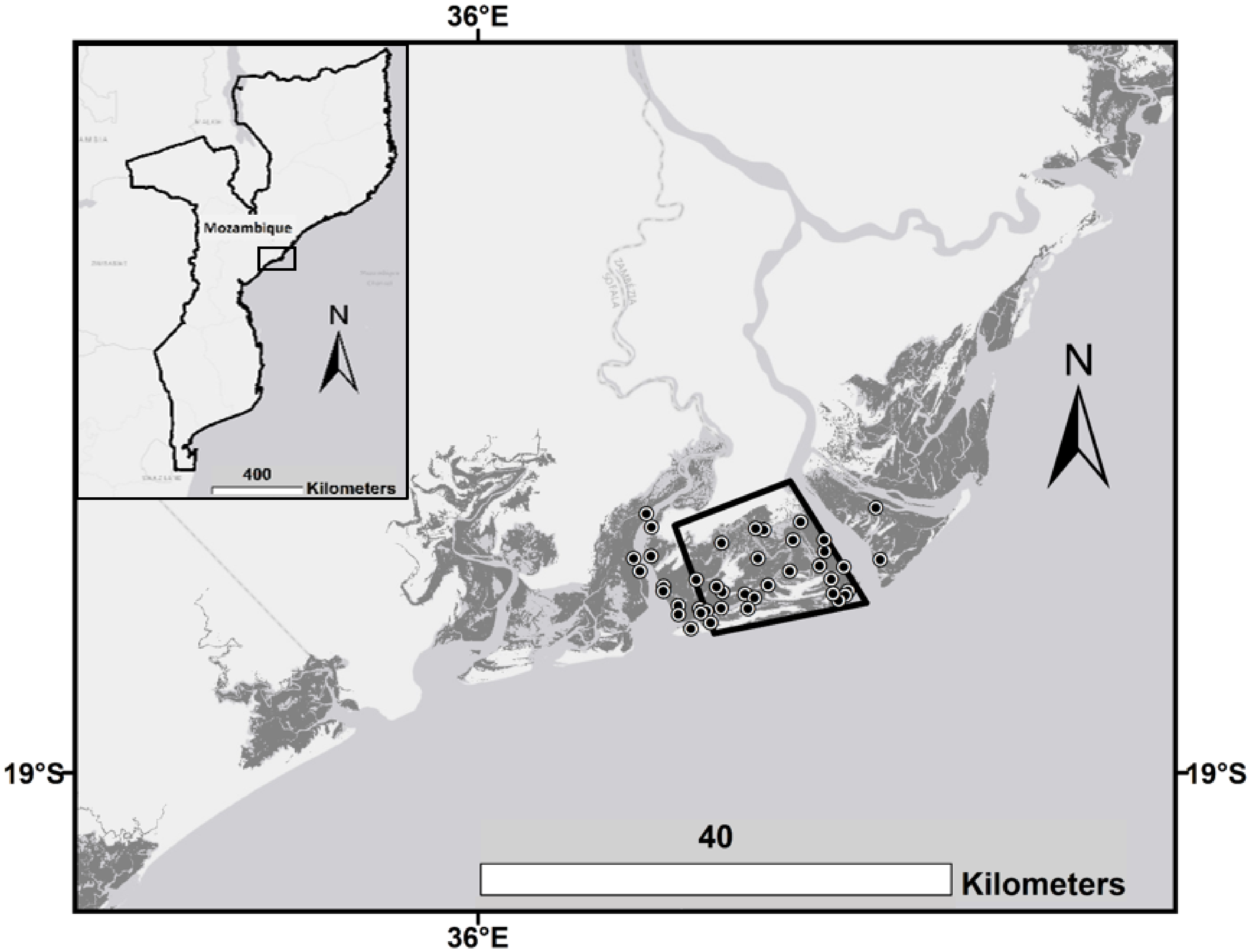

Figure 2. Study area along Zambezi Delta showing plot locations and ALS survey outline. Mangrove canopy cover mapped by Shapiro et al. (2015) is marked in dark gray, from Fatoyinbo et al. (in review)

Airborne LiDAR Data

To compare, enhance, and validate spaceborne-based assessments, airborne LiDAR data were acquired 5 May 2014 by Land Resources International (Pietermaritzburg, South Africa). The airborne survey comprised an approximate area of 115 km^2 in the Zambezi Delta region, Mozambique, with a point density that ranged between 5 - 7 points per m2 (Lagomasino et al., 2016).

- The LiDAR data were used to generate the high resolution (1m) CHM included in this dataset.
- The LiDAR data files are available as a related dataset listed above in the Dataset Overview section.

Aboveground Biomass Calculation

Total aboveground biomass (AGB) was estimated using the generalized Komiyama et al. (2005) mangrove allometry, the pantropical Chave et al. (2005) allometry, and the site-specific Njana et al. (2015) allometry derived for Tanzania as there is no site-specific published allometry for the Zambezi region.

Komiyama’s generalized mangrove AGB equation was derived using DBH and wood density as parameters and is given by:

$$AGB_K = 0.251 * \rho * D^{2.46}$$

where AGB_K is above-ground biomass in kg per tree, ρ is wood density in $g*cm^{-3}$ and *D* is DBH in cm. This equation has a standard AGB error of 8.5% and was generated for mangrove stands with a measured DBH up to 49 cm (Komiyama et al., 2005).

The generalized pantropical Chave et al. (2005) equation for moist mangrove forests is given by:

$$AGB_C = 0.0509 * \rho * D^2 * H$$

The Chave et al. (2005) allometry reduces the standard error (12.5%) by incorporating tree height information and was generated for mangrove stands up to 42 cm DBH.

The Njana et al. (2015) equation incorporates height, DBH, and wood density and is given by:

$$AGB_N = 0.353 * \rho^{1.13} * D^{2.08} * H^{0.29}$$

This model was developed for quantification of tree AGB and BGB for *Avicennia marina*, *Sonneratia alba*, and *Rhizophora mucronata*, which are dominant mangrove species in East Africa. The standard error for this equation was less than 10%, with a range of DBH up to 70.5 cm, and maximum height of 32.2 m.

The dataset authors advise that the Njana Power-based AGB map (njana_power_agb.tif) provides the most accurate estimates of AGB for this region as it is based on an allometric equation specific to East African mangrove forest, takes into account tree height, and has the highest range of input diameter at breast height and height measurements.

6. Data Access

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

CMS: Aboveground Biomass for Mangrove Forest, Zambezi River Delta, Mozambique

Contact for Data Center Access Information:

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

7. References

Chave, J., C. Andalo, S. Brown, M.A. Cairns, J.Q. Chambers, D. Eamus, H. Folster, F. Fromard, N. Higuchi, T. Kira, J.P. Lescure, B.W. Nelson, H. Ogawa, H. Puig, B. Riera, and T. Yamakura. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia,* 145**,** 87-99. https://doi.org/10.1007/s00442-005-0100-x

Fatoyinbo, T.E., M. Simard, R.A. Washington-Allen, H.H. Shugart. 2008. Landscape-scale extent, height, biomass, and carbon estimation of Mozambique's mangrove forests with Landsat ETM+ and Shuttle Radar Topography Mission elevation data. *Journal of Geophysical Research-Biogeosciences,* 113. https://doi.org/10.1029/2007JG000551

Fatoyinbo, T.E., E.A. Feliciano, D. Lagomasino, S.K. Lee, C. Trettin. Estimating mangrove aboveground biomass from airborne LiDAR data: A case study from the Zambezi River Delta. *Environmental Research Letters*. In Review.

Komiyama, A., S. Poungparn, and S. Kato. 2005. Common allometric equations for estimating the tree weight of mangroves. *Journal of Tropical Ecology,* 21**,** 471-477. https://doi.org/10.1017/S0266467405002476

Lagomasino, D., T. Fatoyinbo, S. Lee, L. Feliciano, C.C. Trettin, and M.A. Simard. 2016. Comparison of Mangrove Canopy Height Using Multiple Independent Measurements from Land, Air, and Space. *Remote Sens. 8*(4), 327; https://doi.org/10.3390/rs8040327

Njana, M.A., O.M. Bollandsås, T. Eid, E. Zahabu, and R.E. Malimbwi. 2015. Above- and belowground tree biomass models for three mangrove species in Tanzania: a nonlinear mixed effects modelling approach. *Annals of Forest Science***,** 1-17. https://doi.org/10.1007/s13595-015-0524-3

Shapiro, A.C., C.C. Trettin, H. Küchly, S. Alavinapanah, and S. Bandeira. 2015. The Mangroves of the Zambezi Delta: Increase in Extent Observed via Satellite from 1994 to 2013. *Remote Sensing,* 7**,** 16504-16518. https://dx.doi.org/10.3390/rs71215838

Stringer, C.E., C.C. Trettin, S.J. Zarnoch, and W. Tang. 2015. Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. *Forest Ecology and Management,* 354**,** 139-148. https://dx.doi.org/10.1016/j.foreco.2015.06.027

Trettin, C.C., C.E. Stringer, and S.J. Zarnoch. 2015. Composition, biomass and structure of mangroves within the Zambezi River Delta. *Wetlands Ecology and Management***,** 1-14. https://dx.doi.org/10.1007/s11273-015-9465-8

Land - Water Checker