

Data and code underlying the publication:

Estimating canopy height and aboveground biomass in tropical mangrove restoration areas through multisource remote sensing

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The dataset covers two long-term mangrove restoration areas in Bali Province, Indonesia, namely Budeng-Perancak (BP) and Tahura Ngurah Rai (TA). Field observation data of canopy height (CH) and aboveground biomass (AGB) were gathered in 2024 through plot-level data collection and UAV-LiDAR flight campaigns. The R code provides the regression machine learning model development for estimating canopy height and aboveground biomass using multisource remote sensing approach. For more information, please refer to the respective publication.

The dataset consists of three individual data:

- **Data 1.** Plot-level field observations of canopy height and aboveground biomass vector dataset
- **Data 2.** Dataset of plot-level UAV-LiDAR point clouds in Budeng-Perancak mangrove restoration area
- **Data 3.** 15-m spatial resolution reference raster dataset of canopy height and aboveground biomass in Budeng-Perancak

described in the following in more detail.

Data 1. Plot-level field observations of canopy height and aboveground biomass vector dataset

Plot_level_CH_AGB.shp / .shx / .dbf / .prj

This data includes the plot-level aggregated canopy height (Height_q95) and aboveground biomass (AGB_Chave) of individual trees in 117 field circular plots of 10-m radius (Table 1). The plots (Site) is classified further by mangrove type (Type) into 'Under restoration' for any planted mangroves in formerly forested areas and 'Non-restoration' for undisturbed mangroves that were never converted to other land use including old-growth forests and recent natural mangrove growth. Mangrove forest development stage (Age) represents forest development range of '(1-10)', '(10-20)', '(>20)' years, determined by previous literatures and expert knowledge. The unit for canopy height data is meter (m) and for aboveground biomass is Megagram per hectares (Mg ha⁻¹). The plot-based height at 95th percentile metric of all individual trees within a plot (RH95_{Plot}) was calculated to represent the canopy height. The aboveground biomass of each individual mangrove tree was estimated using the generalized pantropical tree allometric equation with species-specific wood density (Chave et al., 2014). This was summed, converted from kg to Mg for all trees within a plot and area normalized to Mg ha⁻¹

Table 1. Summary of the information concerning the plot-level canopy height and aboveground biomass provided in Data 1

Data columns	Location, Site, Type, Age, Height_q95, AGB_Chave
Number of observations	117 sites; Budeng Perancak: BP1-53 Tahura Ngurah Rai: TA1-64
Unit	year (Age), meter (Height_q95), Mg.ha ⁻¹ (AGB_Chave)
Temporal coverage	08 May – 02 July 2024
Spatial coverage	Budeng Perancak: xmin: 237879.5, xmax: 239168, ymin : 9070830, ymax: 9072833 Tahura Ngurah Rai: xmin: 299213.9, xmax: 305388.7, ymin: 9027769, ymax: 9036145
Projected coordinate system	WGS 84 / UTM zone 50S
Spatial reference	EPSG 32750

Data 2. Dataset of plot-level UAV-LiDAR point clouds in Budeng-Perancak mangrove restoration area

- A.Early-stage non-restoration.las*
- B.Early-stage restoration.las*
- C.Nypa mangroves.las*
- D.Late-stage restoration.las*
- E.Late-stage non-restoration.las*

This point cloud dataset consists of five representative plots of different forest development stages in tropical mangrove restoration area, which is normalized and classified into ground and non-ground, which (Table 2). These point clouds can be used to reproduce Figure 3 in the Results section of the respective publication.

Table 2. Summary of the information concerning the plot-level UAV-LiDAR point clouds provided in Data 2

UAV-LiDAR specification	DJI Matrice 300 RTK – DJI Zenmuse L1
Plot size	Circular plot with 10-m radius
Temporal coverage	18 – 23 May 2024
Spatial coverage (xmin, xmax, ymin, ymax)	<p>A.Early-stage non-restoration 238594.2274, 238614.2153, 9072813.0698, 9072833.0682</p> <p>B.Early-stage restoration 238752.0843, 238772.0542, 9072388.6152, 9072408.6004</p> <p>C.<i>Nypa</i> mangroves 238320.9343, 238340.6374, 9073006.71, 9073026.529</p> <p>D.Late-stage restoration 238706.4184, 238726.3965, 9072499.5644, 9072519.4954</p> <p>E.Late-stage non-restoration 238726.2912, 238746.2874, 9071268.1721, 9071288.1459</p>
Point cloud density	<p>A.Early-stage non-restoration: 1109.97 points/m²</p> <p>B.Early-stage restoration: 382.01 points/m²</p> <p>C.<i>Nypa</i> mangroves: 111.82 points/m²</p> <p>D.Late-stage restoration: 382.01 points/m²</p> <p>E.Late-stage non-restoration: 748.73 points/m²</p>
Projected coordinate system	WGS 84 / UTM zone 50S
Spatial reference	EPSG 32750

Data 3. 15-m spatial resolution reference raster dataset of canopy height and aboveground biomass in Budeng-Perancak

CH_AGB_15m.tif

This data is generated based on regression models between field observations (Plot_level_CH_AGB.shp / .shx / .dbf / .prj) and UAV-LiDAR metric of 95th percentile of relative height metric (RH95). The unit for canopy height data is meter (m) and for aboveground biomass is Megagram per hectares (Mg ha⁻¹). The spatial resolution of this data is following the approximate area size of a field plot, which is 15 m. Linear regression between plot-based 95th percentile relative height and LiDAR-derived 95th percentile relative height was used to produce plot-aggregated canopy height (CH) model, as follows:

$$CH_{LiDAR} = -1.96 + 1.09 RH95_{Plot}$$

The relationship between LiDAR plot-aggregated canopy height model and plot-based aboveground biomass (AGB) observations was established using a power law model (Asner and Mascaro, 2014; Mandal et al., 2024; Meyer et al., 2019). The model coefficients *a* and *b* were fitted with plot-based AGB to predict AGB outside of plots, resulting in:

$$AGB = 4.65 \times CH_{LiDAR}^{1.48}$$

Table 3. Summary of the information concerning the reference raster dataset provided in Data 3

Layers	Canopy height: Height.q95, Aboveground biomass: AGB.Chave
Unit	meter (Height.q95), Mg.ha ⁻¹ (AGB.Chave)
Spatial resolution	15 meter
Number of observations	7,522
Spatial coverage	xmin: 235995, xmax: 241200, ymin: 9069795, ymax: 9073905
Projected coordinate system	WGS 84 / UTM zone 50S
Spatial reference	EPSG 32750

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