Biodiversity and Climate Change Project - BIOCLIME

Survey of biomass, carbon stocks, biodiversity, and assessment of the historic fire regime for integration into a forest monitoring system in South Sumatra, Indonesia.

Project number: 12.9013.9-001.00

Work Package 3
Aboveground biomass and tree community composition modelling

Final Report

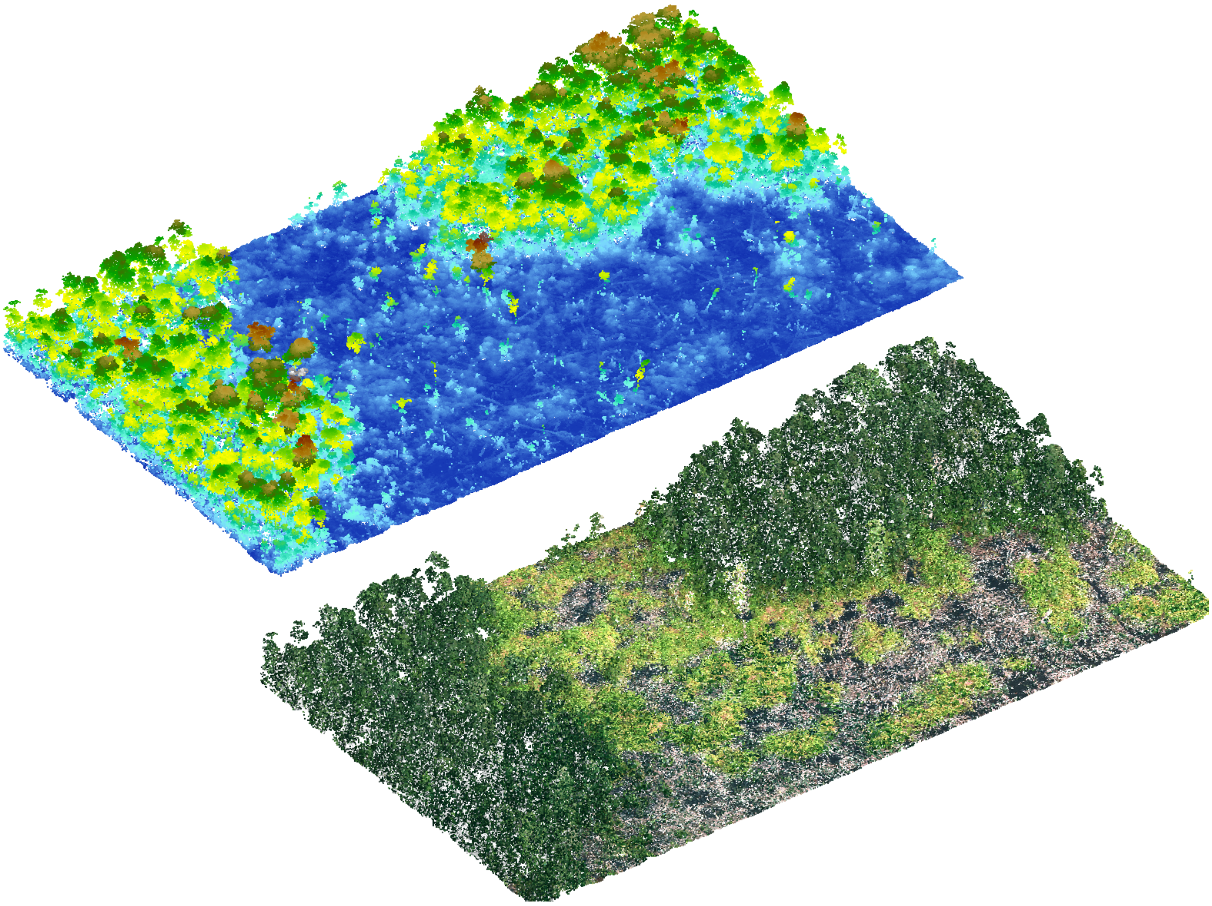

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Table of Content

1. Introduction

With the Biodiversity and Climate Change Project (BIOCLIME), Germany supports Indonesia's efforts to reduce greenhouse gas emissions from the forestry sector, to conserve forest biodiversity of High Value Forest Ecosystems, maintain their Carbon stock storage capacities and to implement sustainable forest management for the benefit of the people. Germany's immediate contribution will focus on supporting the Province of South Sumatra to develop and implement a conservation and management concept to lower emissions from its forests, contributing to the GHG emission reduction goal Indonesia has committed itself until 2020.

One of the important steps to improve land-use planning, forest management and protection of nature is to base the planning and management of natural resources on accurate, reliable and consistent geographic information. In order to generate and analyze this information, a multi-purpose monitoring system is required.

This system will provide a variety of information layers of different temporal and geographic scales:

- Information on actual land-use and the dynamics of land-use changes during the past decades is considered a key component of such a system. For South Sumatra, this data is already available from a previous assessment by the World Agroforestry Center (ICRAF).
- Accurate current information on forest types and forest status, in particular in terms of aboveground biomass, carbon stock and biodiversity, derived from a combination of remote sensing and field techniques.
- Accurate information of the historic fire regime in the study area. Fire is considered one of the key drivers shaping the landscape and influencing land cover change, biodiversity and carbon stocks. This information must be derived from historic satellite imagery.
- Indicators for biodiversity in different forest ecosystems and degradation stages.

The objective of the work conducted by Remote Sensing Solutions GmbH (RSS) was to support the goals of the BIOCLIME project by providing the required information on land use dynamics, forest types and status, biomass and biodiversity and the historic fire regime. The conducted work is based on a wide variety of remote sensing systems and analysis techniques, which were jointly implemented within the project, in order to produce a reliable information base able to fulfil the project's and the partners' requirements on the multi-purpose monitoring system.

This report presents the results of Work Package 3 (WP 3): Aboveground biomass and tree community composition modelling. The main objectives of WP 3 were:

- Filtering of the LiDAR 3D point clouds (provided by the project) into vegetation and non-vegetation points.
- Derive Digital Surface Models (DSM), Digital Terrain Models (DTM) and Canopy Height Models (CHM) from the airborne LiDAR data.
- Advice BIOCLIME in the collection of forest inventory data to calibrate the LiDAR derived aboveground biomass model.
- Derive an aboveground biomass model from the airborne LiDAR data (provided by the project) in combination with forest inventory data (provided by the project).
- Deduce local aboveground biomass values for different vegetation classes from this LiDAR based aboveground biomass model.

- Derive a tree a community composition model of Lowland Dipterocarp Forest at various degradation stages from LiDAR data (provided by the project) in combination with tree species/genera diversity data collected in the field (provided by the project).

Figure 1 shows the flowchart of the activities carried out in Work Package 3 (WP 3).

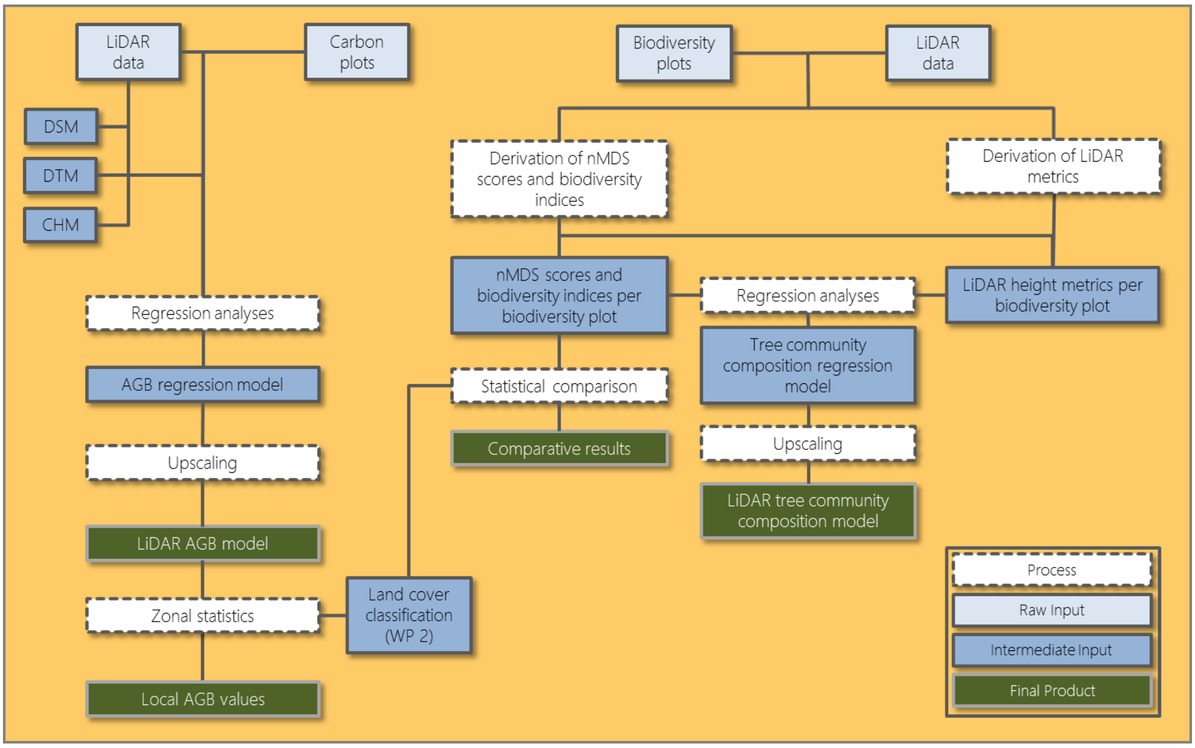

Figure 1: Flow chart of the activities carried out in Work Package 3 (WP 3): Aboveground biomass and tree community composition modelling.

2. Carbon and biodiversity plots

2.1. Inventory design

115 plots forest inventory plots were recorded within the four districts of Banyuasin, Musi Banyasin, Musi Rawas Utara and Musi Rawas. All these districts are located in the province of South Sumatra. The planning and collection of these so called carbon inventory plots was conducted by scientists of the Bogor Agricultural University (IPB) and BIOCLIME. The distribution of these carbon inventory plots is based on a systematic sampling design. In order, to assure that statistically enough carbon inventory plots are located within the airborne LiDAR transects to generate the LiDAR based aboveground biomass model (see Chapter 4 LiDAR based aboveground biomass model) some of these 115 plots where spatially shifted into the nearest LiDAR transect, consequently now not fitting into the systematic sampling design anymore. In natural forests a nested rectangular plot design was chosen. Figure 2 displays the layout of such a nested rectangular plot and which Diameter at Breast Height (DBH) ranges were measured in which subplot. In plantations a circular plot design was applied, where the size of the

circle depended on the age of the plantation (age of plantation < four years: radius = 7.98 m, area = 0.02 ha; age of plantation ≥ four years: radius = 11.29 m, area = 0.04 ha). Figure 3 shows the layouts of these circular plots. The determination of these plot sizes (nested rectangular and circular) and diameter thresholds is based on experiences from previous field inventories in Indonesia.

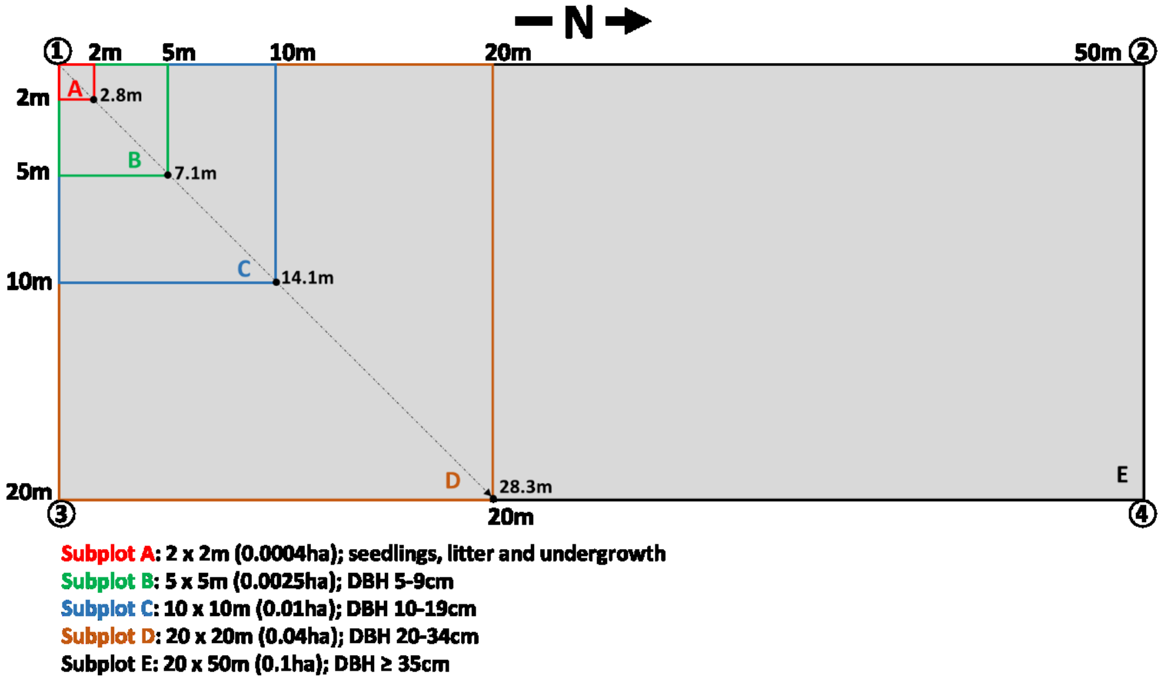

Figure 2: Layout of a rectangular nested carbon plot located in natural forests. Diameter at Breast Height (DBH) ranges in cm measured within the different rectangular nests (A, B, C, D and E) and the spatial orientation (N = North) are also given.

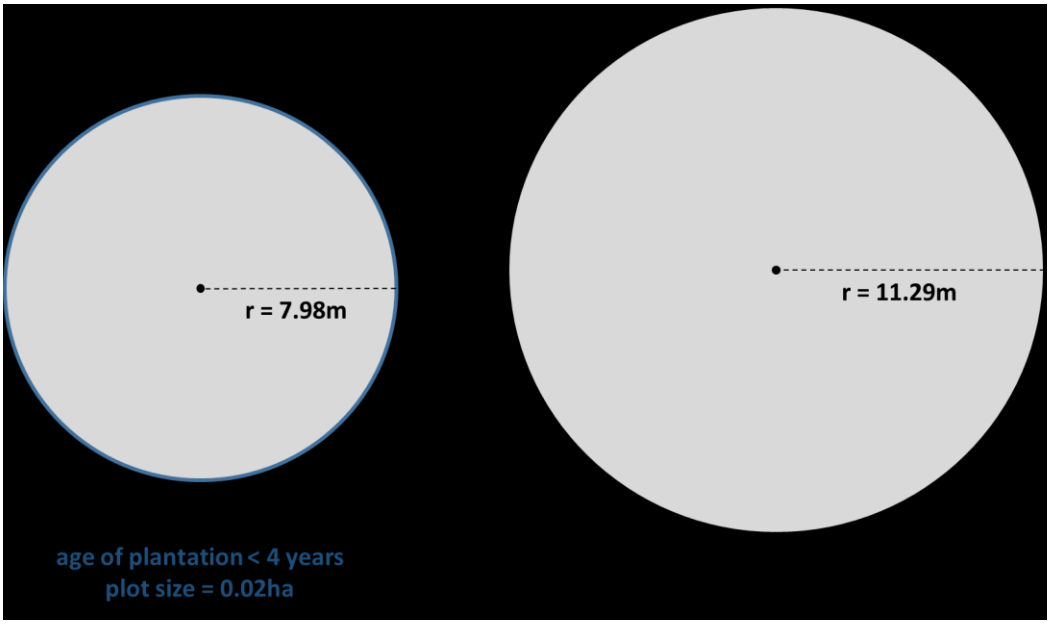

Figure 3: Layout of a circular plots in plantations. If the plantation is younger than four years a radius (r) of 7.98 m (plot size = 0.02 ha) is used and if the plantation is 4 years or older a radius of 11.29 m (plot size = 0.04 ha). Within these circular plots all trees with a Diameter at Breast Height (DBH) of more than 5 cm were measured.

For all "in" trees within the carbon plots following parameters where recoded (an "in" tree was defined as a tree where the center of the stem at DBH is within the boundaries of the respective (sub)plot):

- **Diameter at Breast Height** (DBH) at 1.3 m above the ground (in centimeter)
- **Total tree height** (in meter) measured with a Haga instrument or a Suunto clinometer
- **Tree species** (scientific names in Latin): All "in" trees were identified up to the species level by a trained botanist. This was necessary to determine wood densities. Ideally it would be good to have an identification up to the species level as wood density can strongly vary within genus level. If it was not possible to identify up to the species level it was at least tried to record the genus or the family.
- **Four dead wood classes** (for the aboveground biomass estimates all dead trees were excluded):
    - 1 = many branches and twigs but without leaves
    - 2=large branches are still there but without a branch / small twigs and leaves
    - 3=almost no branches / twigs but still there are rods that may be broken
    - 4=just a broken rod topped resemble stumps

Additionally, to the carbon plots 59 so called biodiversity plots were recorded. The layout of these biodiversity plots is shown in Figure 4. The spatial locations of these biodiversity plots are exactly the same as the ones of the respective carbon plot.

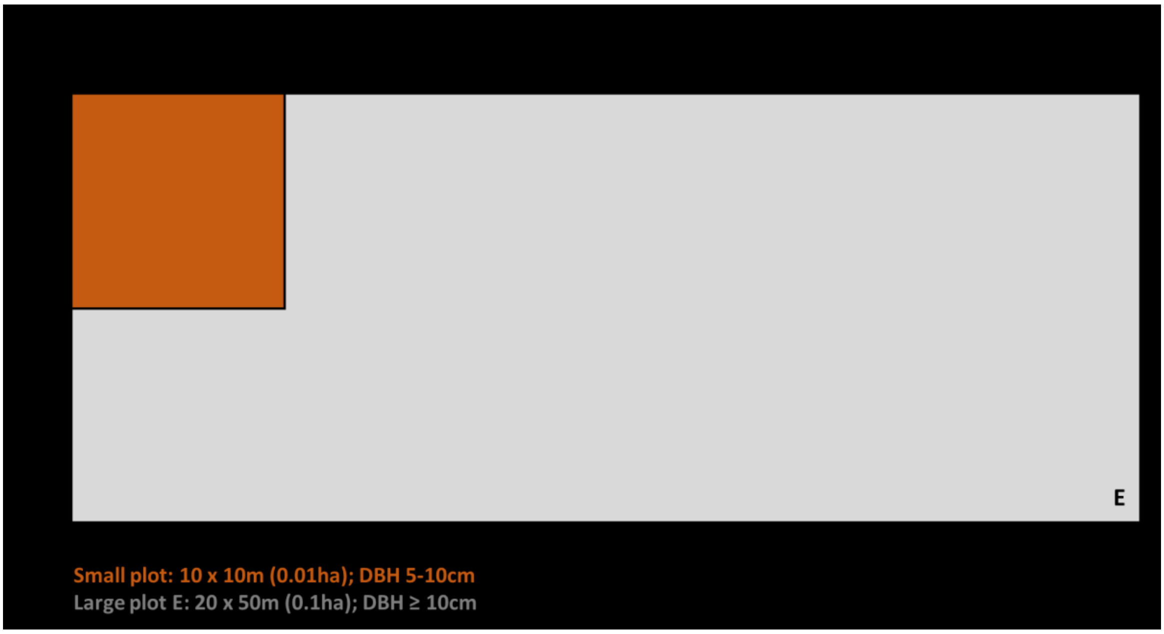

Figure 4: Layout of a biodiversity plot. Diameter at Breast Height (DBH) ranges in cm measured within the small and large plot and the spatial orientation (N = North) are also given.

For all "in" trees within the biodiversity plots following parameters where recoded (here also an "in" tree was defined as a tree where the center of the stem at DBH is within the boundaries of the respective (sub)plot):

- Diameter at Breast Height (DBH) at 1.3 m above the ground (in centimeter)
- Tree species (scientific names in Latin): All "in" trees were identified up to the species level by a trained botanist. This was necessary to determine wood densities. If it was not possible to identify up to the species level it was at least tried to record the genus or the family.

Table 1 gives an overview on how many carbon and biodiversity plots were recorded and whether they are located within LiDAR transects or not. As can be seen in Table *1*, six plots were recorded after the fires of 2015. These plots have to be treated with care, as the LiDAR data was recorded before the fires of 2015.

Table 1: Overview carbon and biodiversity plots recorded and whether they are located within LiDAR transects or not.

Carbon plots	Biodiversity plots	Amount plots	Amount plots within LiDAR transects
X		56 (54[1])	17 (15[1])
X	X	59 (55[1])	49 (45[1])
	Sum	**115 (109[1])**	**66 (60[1])**

[1] Amount of plots after subtracting plots that were recorded after the fires of 2015

Figure 5 displays the location of the recorded carbon and biodiversity plots within the four districts of Banyuasin, Musi Banyasin, Musi Rawas Utara and Musi Rawas. It also shows which of these carbon and biodiversity plots are located within a LiDAR transect.

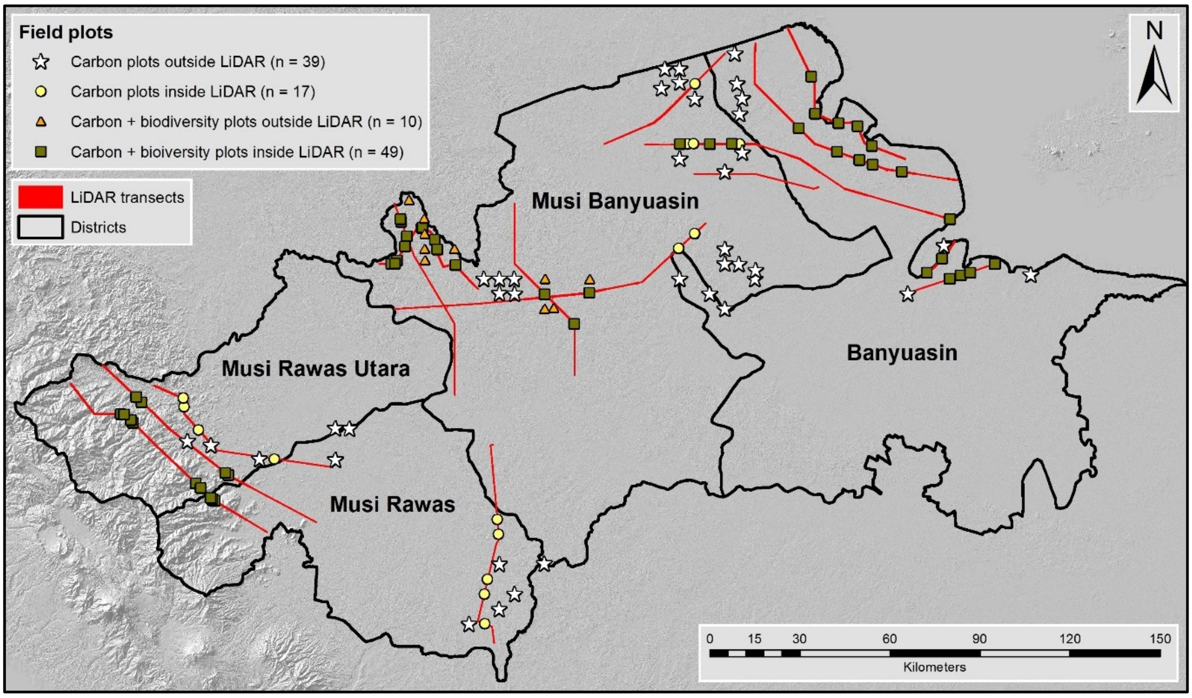

Figure 5: Location of all recorded carbon and biodiversity plots within the four districts of Banyuasin, Musi Banyasin, Musi Rawas Utara and Musi Rawas. Also shown is which of these carbon and biodiversity plots are located within a LiDAR transect.

Table 2 displays the amount of plots per forest type / land cover classes based on the classes at plot location from the land cover classification derived in Work Package 2 (WP 2; year 2013-2015; Spot-6 and RapidEye). Also shown is the amount of plots for the respective BAPLAN class. Due to missing classification (e.g. clouds) 22 plots were attributed with no data.

Table 2: Overview on the amount of plots based on the classes from land cover classification derived in Work Package 2 (WP 2; year 2013-2015; Spot-6 and RapidEye) present at plot location and after translation into the BBAPLAN forest type / land cover classes. Due to missing classification (e.g. clouds) 22 plots were attributed with no data. Also given are the respective BAPLAN and BAPLAN enhanced codes.

Forest type / land cover classification[1]	BAPLAN enhanced code[2]	Amount plots	Forest type / land cover BAPLAN[3]	BAPLAN code	Amount plots
High-density Lowland Dipterocarp Forest	2001-1	3	Primary Dryland Forest (Hutan Lahan Kering Primer)	2001	3
Medium-Density Lowland Dipterocarp Forest	2002-1	26	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	2002	39
Low-density Lowland Dipterocarp Forest	2002-2	13			
High-density Peat Swamp Forest	2005-1	9	Primary Swamp Forest (Hutan Rawa Primer)	2005	9
Low-density Peat Swamp Forest	20051-1	7	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	20051	8
Low-density Freshwater Swamp Forest	20051-6	1			
Mangrove 1	2004-1	16	Primary Mangrove Forest (Hutan Mangrove Primer)	2004	17
Mangrove 2	2004-2	1			
Young Mangrove	2007-2	3	Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	9999	3
Dryland Agriculture mixed with Scrub	20092-1	4	Mixed Dryland Agriculture / Mixed Garden (Pertanian Lehan Kering Campur Semak / Kebun Campur)	20092	4
Rubber	2010-3	1	Tree Crop Plantation (Perkebunan / Kebun)	2010	1
Acacia Plantation	2006-1	3	Plantation Forest (Hutan Tanaman)	2006	5
Industrial Forest	2006-2	2			
Dryland Agriculture	20091	1	Dryland Agriculture (Pertanian Lahan Kering)	20091	1
Bare Area	2014	1	Open Land (Tanah Terbuka)	2014	1
Road	2012-2	2	Settlement / Developed Land (Pemukiman / Lahan Terbangun)	2012	2
NoData[4]	-	22	NoData[4]	-	22
	Sum	**115**		**Sum**	**115**

[1] Dominant forest type/land cover at plot location based on the land cover classification derived in WP 2 (year 2013-2015; Spot-6 and RapidEye)
[2] The enhanced BAPLAN code is derived from the BAPLAN code adjusted to the forest types/land covers from the land cover classification (WP 2)
[3] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[4] Plots where at plot location no classification was available

Appendix A (Overview field plots) gives a detailed overview of all the 115 recorded plots. An in-depth explanation of the inventory design and collection is provided in the BIOCLIME GIZ Final Report: Panduan Survei Cadangan Karbon dan Keanekaragaman Hayati di Sumatera Selatan (Rusolono *et al.* 2015).

2.2. *Aboveground biomass calculations*

First the species-specific wood densities for the recorded trees were derived based on the Latin scientific names and an established wood density database (Zanne *et al.* 2009). Where there was more than one record on wood density per species within the wood density database an average of these species records was attributed. If a tree could not be identified or only identified to the genus or family level or the common name an average wood density of 0.57 g/cm^3 for South East Asia (tropical) trees from this data base was attributed. This average wood density was also attributed when the species was not recorded in the wood density data base. Table 3 displays the absolute numbers and percentage of trees within the carbon plots where the species could be identified, where only genus, family, common name was known and unidentified trees.

Table 3: Absolute and percentage of tree identification (species, only genus, only family, only common name and unidentified) within the carbon plots.

	All trees recorded	Species identified	Only genus identified	Only family identified	Only common name	Unidentified
Absolute number	2038	1105	272	18	605	38
Percent (%)	100%	54%	13%	1%	30%	2%

Next, for trees where absolute tree height was not measured a tree height model was derived based on DBH. Trees with a slenderness (absolute tree height divided by DBH) smaller than 0.2 or bigger than 2.0 where not included in the model development as they are rather unrealistic and indicate possible wrong measurements in the field, especially of absolute tree height. Finally, 1,851 tree height measurements were used as input to the model development. Three different models were tested. Table 4 displays these three models and the model results. Model 3 was finally used to calculate missing total tree heights from DBH as it had the lowest Residual Standard Error (*RSE*), Root Mean Square Error (*RMSE*), Akaike Information Criterion (*AIC*) and the highest r^2. The *AIC* is a measure of the relative quality of statistical models for given a set of data, so that *AIC* provides a means for model selection (the lower the "better" the model).

Table 4: Overview of the three different model tested to estimate total tree height from DBH for trees with missing tree height measurements. Model 3 was finally selected as it had the lowest Residual Standard Error (RSE), Root Mean Square Error (RMSE), Akaike Information Criterion (AIC) and the highest r^2 (all shown in bold).

	Model 1	**Model 2**	**Model 3**
Equation	H_{est}=a*D^b	H_{est}=a-b*exp(-cD)	H_{est}=a*(1-exp(-b*D^c))
Source	Exponential function	Benin *et al.* (2012)	Yang et al. (1978); Bailey (1979)
a	2.795	40.798	60.654
b	0.575	37.995	0.035
c	-	0.020	0.715
n	1,851	1,851	1,851
RSE	4.519	4.523	**4.493**
RMSE	4.517	4.519	**4.489**
r²	0.729	0.729	**0.732**
AIC	10,840.95	10,848.66	**10,824.31**

H_{est} = total tree height (m), *D* = diameter at breast height (in cm), *n* = amount of tree height measurements as input for the model, *RSE* = residual standard error, *RMSE* = Root mean square error, *AIC* = Akaike information criterion

Figure 6 displays the scatter plot and the curve of the final tree height regression model. Also shown are the results of the model.

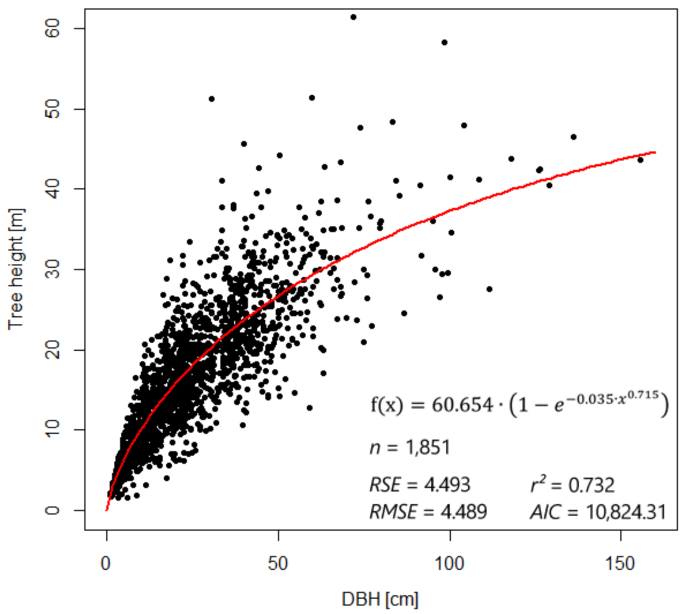

Figure 6: Final model chosen (see Table xx) to estimate total tree height from DBH for trees with missing tree height measurements. Also shown are: Amount of tree height measurements as input for the model (*n*), Residual Standard Error (*RSE*), Root Mean Square Error (*RMSE*), Akaike Information Criterion (*AIC*) and r^2.

Finally, to estimate aboveground biomass per tree (palm) three different allometric equations, depending on the tree (palm) type, were applied. Table 5 displays the allometric equations used for the different tree (palm) types.

Table 5: Allometric equations used to estimate above ground biomass depending on the tree (palm) type.

	Mangrove trees	Oil palms	All other trees
Allometric equation	Moist mangrove forest stands $AGB_{est}=\exp(-2.977+\ln(pD^2H))$	$AGB_{est}=71.797*H-7.0872$	Best fit pantropical model $AGB_{est}=0.0673*(pD^2H)^{0.976}$
Source	Chave *et al.* 2005	Asari *et al.* 2013	Chave *et al.* 2014

AGB_{est} = estimated aboveground biomass, p = wood specific density (in g/cm^3), D = diameter at breast height (in cm) and H = total tree (palm) height (in m)

The aboveground biomass estimates per tree were summed up per plot and then expanded to one hectare to get aboveground biomass estimates per hectare. Aboveground biomass estimates per plot in tons per hectare (t/ha) for the carbon plots are shown in Appendix A. Table 6 summarizes the aboveground biomass estimates for the forest type / land cover classes based on the satellite imagery classification from Work Package 2 (WP 2) and Table 7 summarizes the BAPLAN forest type / land cover classes. Aboveground biomass estimates for the biodiversity plots were calculated the same way as described above. Aboveground biomass estimates per plot in tons per hectare (t/ha) for the biodiversity plots are shown in Appendix B.

Table 6: Statistical results for the aboveground biomass estimates for the different forest type / land cover classes based on the satellite imagery classification from Work Package 2 (WP 2).

Forest type / land cover classification[1]	Amount plots	Min AGB (t/ha)[2]	Max AGB (t/ha)[3]	Mean AGB (t/ha)[4]
High-density Lowland Dipterocarp Forest	3	289.3	375.4	322.5 ±46.3
Medium-Density Lowland Dipterocarp Forest	26	6.0	903.6	305.6 ±204.6
Low-density Lowland Dipterocarp Forest	13	24.2	426.5	181.4 ±140.2
High-density Peat Swamp Forest	9	0.0	503.1	275.8 ±174.3
Low-density Peat Swamp Forest	7	0.0	169.1	70.4 ±71.5
Low-density Freshwater Swamp Forest	1	155.5	155.5	155.5 ±0.0
Mangrove 1	16	35.7	541.1	238.1 ±132.0
Mangrove 2[5]	1	364.4	364.4	364.4 ±0.0
Young Mangrove	3	125.7	234.7	170.3 ±57.1
Dryland Agriculture mixed with Scrub	4	16.0	61.9	39.5 ±24.7
Rubber	1	99.3	99.3	99.3 ±0.0
Acacia Plantation	3	91.3	203.8	145.4 ±56.4
Industrial Forest	2	10.5	65.8	38.2 ±39.1
Dryland Agriculture	1	2.3	2.3	2.3 ±0.0
Bare Area[6]	1	123.5	123.5	123.5 ±0.0
Road[7]	2	0.3	138.8	69.5 ±97.9
NoData[8]	22	0.2	406.5	86.1 ±88.3
Sum	**115**			

[1] Forest type/land cover class BAPLAN classification system (in brackets Bahasa Indonesia)
[2] Minimum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[3] Maximum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[4] Mean aboveground biomass (AGB) in tons per hectare for the forest type/land cover class (± standard deviation)
[5] Very high aboveground biomass (AGB) due to only one plot (not representative)
[6] AGB too high. Only one plot where bare area is mixed with high density peat swamp forest (not representative)
[7] AGB too high. Only two plots and one plot mixed with Low-density Lowland Dipterocarp Forest (not representative)
[8] Plots where at plot location no classification was available

Table 7: Statistical results for the aboveground biomass estimates for the different forest type / land cover classes based on BAPLAN.

Forest type / land cover BAPLAN[1]	Amount plots	Min AGB (t/ha)[2]	Max AGB (t/ha)[3]	Mean AGB (t/ha)[4]
Primary Dryland Forest (Hutan Lahan Kering Primer)	3	289.3	375.4	322.5 ±46.3
Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bekas Tebangan)	39	6.0	903.6	264.2 ±193.1
Primary Swamp Forest (Hutan Rawa Primer)	9	0.0	503.1	275.8 ±174.3
Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bekas Tebangan)	8	0.0	169.1	81.1 ±72.7
Primary Mangrove Forest (Hutan Mangrove Primer)	17	35.7	541.1	245.5 ±131.4
Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	3	125.7	234.7	170.3 ±57.1
Mixed Dryland Agriculture / Mixed Garden (Pertanian Lahan Kering Campur Semak / Kebun Campur)	4	16.0	61.9	39.5 ±24.7
Tree Crop Plantation (Perkebunan / Kebun)	1	99.3	99.3	99.3 ±0.0
Plantation Forest (Hutan Tanaman)	5	10.5	203.8	102.5 ±73.6
Dryland Agriculture (Pertanian Lahan Kering)	1	2.3	2.3	2.3 ±0.0
Open Land[5] (Tanah Terbuka)	1	123.5	123.5	123.5 ±0.0
Settlement / Developed Land[6] (Pemukiman / Lahan Terbangun)	2	0.3	138.8	69.5 ±97.9
NoData[7]	22	0.2	406.5	86.1 ±88.3
Sum	**115**			

[1] Forest type/land cover class BAPLAN classification system (in brackets Bahasa Indonesia)
[2] Minimum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[3] Maximum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[4] Mean aboveground biomass (AGB) in tons per hectare for the forest type/land cover class (± standard deviation)
[5] AGB too high. Only one plot where bare area is mixed with high density peat swamp forest (not representative)
[6] AGB too high. Only two plots and one plot mixed with Low-density Lowland Dipterocarp Forest (not representative)
[7] Plots where at plot location no classification was available

3. LiDAR data and aerial photos

3.1. LiDAR and aerial photo survey

In October 2014 15 transects of LiDAR data and aerial photos were captured for an area of approximately 43,300 ha. LiDAR data was acquired in two modes (a) LiDAR full waveform mode + aerial photos with an overlap of 60% and (b) LiDAR discrete return mode + aerial photo overlap 80%. Table 8 displays the technical specification of this LiDAR and aerial photo survey. A more detailed description of the survey can be found in the report of the surveying company PT Asi Pudjiastuti Geosurvey (PT Asi Pudjiastuti Geosurvey 2014).

Table 8: Technical specifications of the LiDAR and aerial photo survey (PT Asi Pudjiastuti Geosurvey 2014).

Parameter	Flight plan	Remark
LiDAR acquisition mode	Full Waveform (FWF)	Unlimited returns of laser reflectance
	Discrete Return	4 returns of laser reflectance
Flying height	800 m	The survey was conducted at 800 m above ground level to get the accurate laser reflectance and minimize cloud cover.
Laser pulse frequency	500 KHz	Product specification in ALS70 Leica used for the project.
LiDAR point density	Full Waveform (FWF)	8-15 points/m^2
	Discrete Return	6-8 points/m^2
Aircraft speed	110 knots	
Half scan angle	28 degrees	Field of view (FOV) 56 degrees. With this FOV LiDAR coverage will be embedded with aerial photo coverage.
Swath width	851 m	A scan angle (FOV) of 56 degrees and a flying height of 800 m will provide 851 m area coverage
Ground Sample Distance (GSD)	10-12.5 m	
Forward overlap	Full Waveform (FWF)	60% overlap
	Discrete Return	80% overlap
Aerial photo coverage	86 m x 644 m	Acquisition of aerial photos using a digital camera: Leica RCD 30 with 6 µm pixel resolution, with a GSD of 10 cm per pixel will results in a coverage of 860 m x 644 m.

Figure 7 shows the location of the LiDAR transects within the BIOCLIME study area.

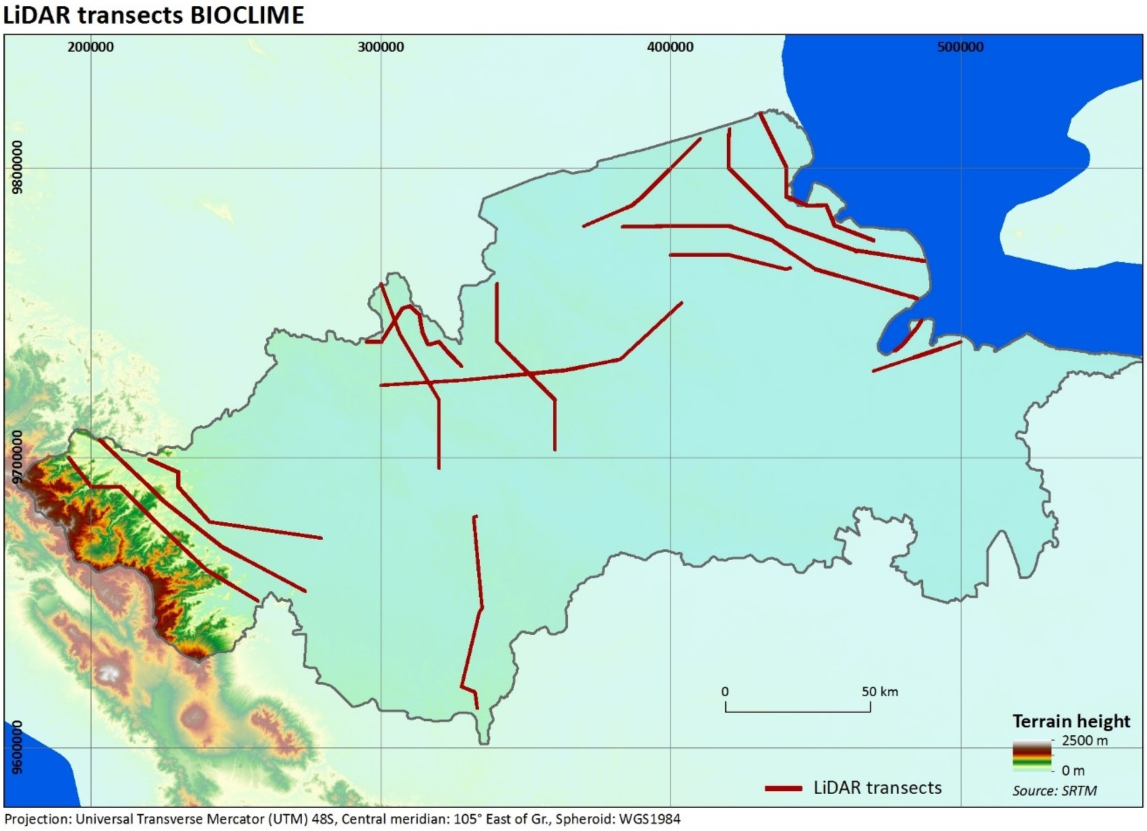

Figure 7: Location of the approximately 43,300 ha of LiDAR transects captured within the BIOCLIME study area.

3.2. LiDAR processing, filtering and interpolation

Different types of elevation models were generated from the airborne LiDAR 3D point clouds. Figure 8 shows some LiDAR 3D point could example sections representing different forest types (Lowland Dipterocarp Forest, Peat Swamp Forest and Mangrove). Figure 9 displays the location of these LiDAR 3D points clouds within the BIOCLIME study area and the corresponding LiDAR derived Canopy Height Models (CHM) (see next paragraph).

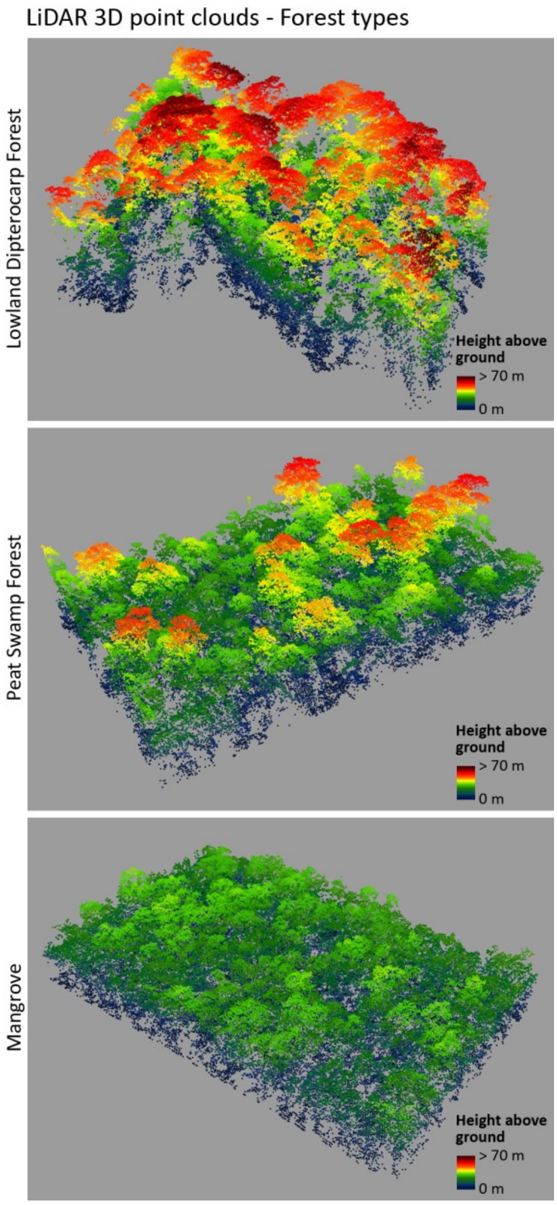

Figure 8: Example of LiDAR 3D point clouds for Lowland Dipterocarp Forest, Peat Swamp Forest and Mangrove.

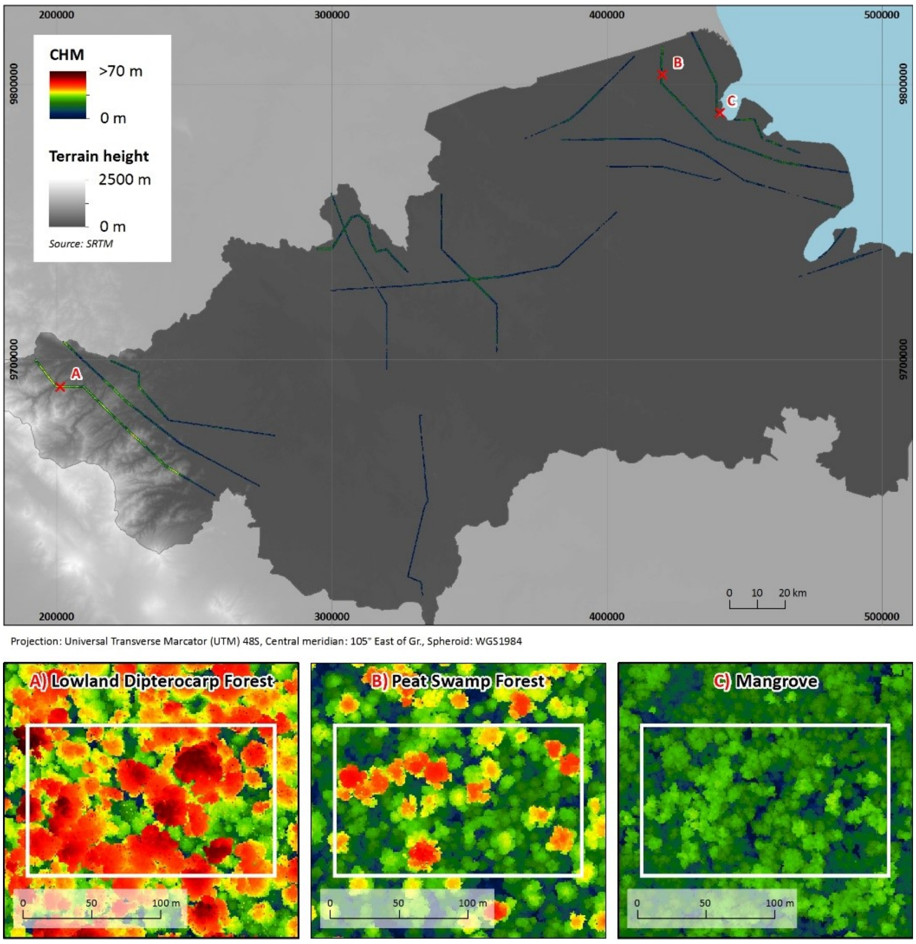

Figure 9: Location of the LiDAR 3D points clouds shown in Figure 8 within the BIOCLIME study area and the corresponding LiDAR derived Canopy Height Models (CHM).

Products derived from these LiDAR 3D point clouds include a Digital Surface Model (DSM) which represents the elevation of the vegetation canopy, a Digital Terrain Model (DTM) which represents the ground elevation, and a Canopy Height Model (CHM) which is generated by subtraction of the DTM from the DSM and represents the vegetation height. The LiDAR data was processed using the Trimble Inpho software package.

A crucial step within the DTM generation is the LiDAR filtering. A hierarchic robust filter was applied to the LiDAR 3D point clouds, separating the ground and non-ground (vegetation) points (Pfeifer *et al.* 2001). The linear adaptable prediction interpolation (kriging) was utilized to generate the DTM (1 m spatial resolution). The DSM (1 m spatial resolution) was created by extracting the highest point of the 3D point cloud (the first returns of each laser beam) within a grid of 1 m which were then interpolated into a continuous raster. Pixels containing no data were filled using the highest point of the neighborhood and the morphological operator “closing” (Dougherty and Lotufo 2003). The CHM (1 m spatial resolution) was produced by calculating the difference between the elevation of the DSM and the underlying terrain of the DTM. Figure 10 exemplarily shows the resulting models for the BIOCLIME study area. Also shown are the positions of the field plots (n = 66) which are located within the LiDAR transects.

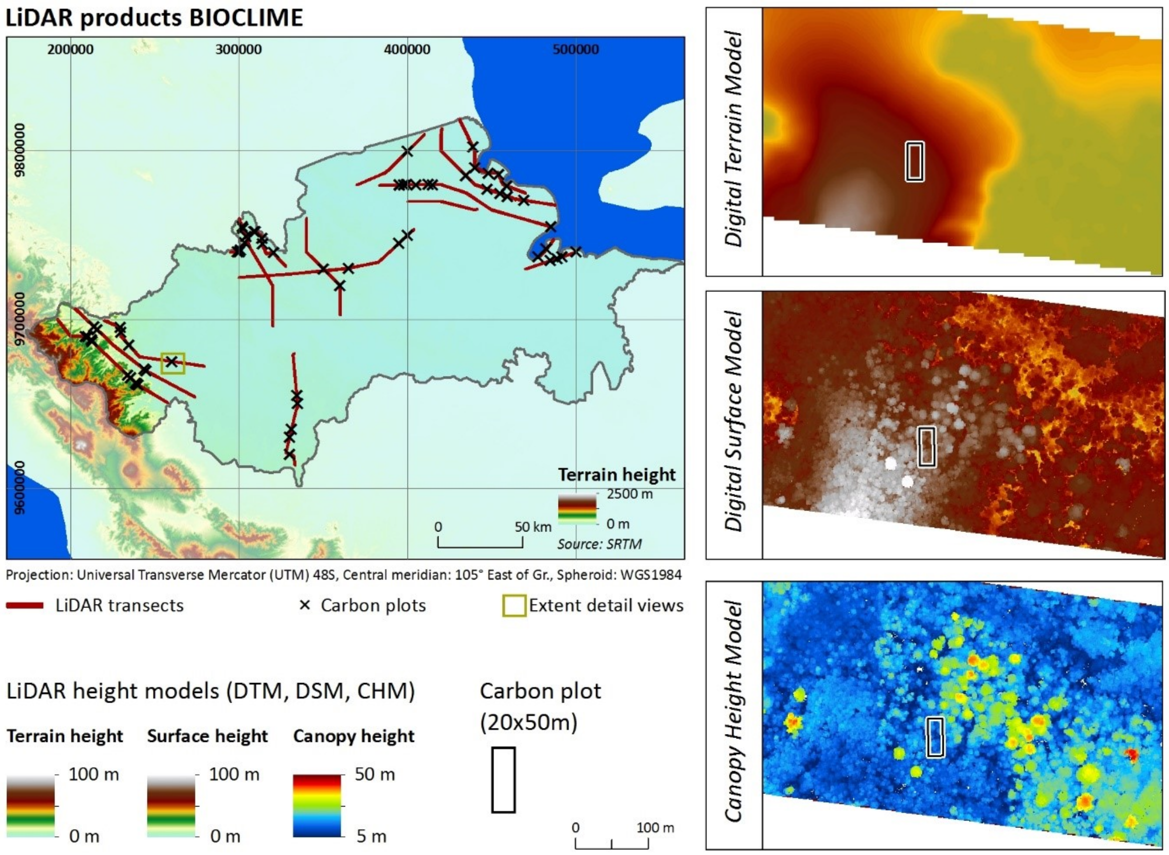

Figure 10: Example from the LiDAR products generated for the BIOCLIME study area. Shown are examples for the Digital Terrain Model (DTM; 1 m spatial resolution) the Digital Surface Model (DSM; 1 m spatial resolution) and the Canopy Height Model (CHM; 1 m spatial resolution). Also shown are the position of the 66 carbon plots that are located within the LiDAR transects.

4. LiDAR based aboveground biomass model

4.1. Regression analysis and aboveground biomass model development

Previous studies revealed that height metrics like the Quadratic Mean Canopy Height (QMCH) or the Centroid Height (CH) are appropriate parameters of the LiDAR 3D point cloud to estimate aboveground biomass in tropical forests (Jubanski *et al.* 2013, Englhart *et al.* 2013, Ballhorn *et al.* 2011).

LiDAR height histograms were calculated by normalizing all points within the carbon plot extent (usually 20x30 m except in plantations where, dependent on age, two different circular plot sizes were used; see Chapter 2.1 Inventory design) to the ground using the DTM as reference. A height interval of 0.5 m was defined and the number of points within this interval was stored in form of a histogram. The first (lowest) interval was considered as ground return and therefore excluded from further processing. The QMCH and the CH of the height histogram were calculated by weighing each 0.5 m height interval with the relative number of LiDAR points stored within this interval. QMCH and CH were related to field inventory estimated of aboveground biomass and regression models were developed. Jubanski *et al.* (2013) showed that the accuracy of the aboveground biomass estimations derived from LiDAR height histograms increased with higher point densities. For this reason, point density was also implemented in the regression as a weighting factor.

The commonly used power function resulted in significant overestimations in the higher biomass range within our study areas. For this reason, a more appropriate aboveground regression model was implemented, which is a combination of a power function (in the lower biomass range up to a certain threshold $QMCH_0$; the example here uses QMCH but the same would be done with CH) and a linear function (in the higher biomass range) (Englhart *et al.* 2013). The threshold of $QMCH_0$ was determined by increasing the value of $QMCH_0$ in steps of 0.001 m through identifying the lowest Root Mean Square Error (*RMSE)*. The linear function is the tangent through $QMCH_0$ and was calculated on the basis of the first derivative of the power function:

$$AGB = \begin{cases} a * QMCH^b & if\ QMCH \leq QMCH_0 \\ \left(a * b * QMCH_0^{(b-1)}\right)(QMCH - QMCH_0) + a * QMCH_0^b & if\ QMCH\ > QMCH_0 \end{cases}$$

Where QMCH is the quadratic Mean Canopy Height (the example here uses QMCH but the same would be done with CH), $QMCH_0$ is the threshold of function change and a, b are coefficients. Next the aboveground regression with the highest coefficient of determination (r^2) based on the QMCH or the CH was chosen.

Of the 66 carbon plots that were located within the LiDAR transects 54 plots (after removal of obvious outliers) were used for calibration. The model based on QMCH achieved better results as the one based on CH. Figure 11 displays the results of the QMCH based LiDAR regression model.

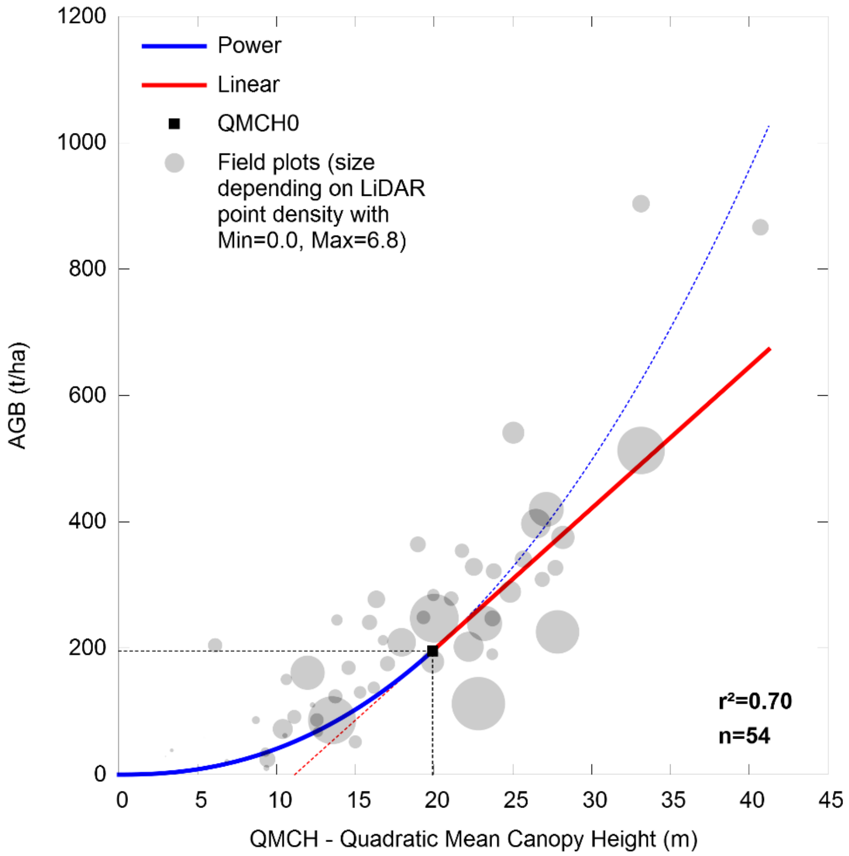

Figure 11: Predictive aboveground biomass (AGB) model used for the BIOCLIME study area based on carbon plot data and airborne LiDAR data. The Quadratic Mean Canopy Height (QMCH) was chosen as it had a higher coefficient of determination (r^2) as the Centroid Height (CH) based model. Of the 66 carbon plots that were located within the LiDAR transects 54 plots (after removal of obvious outliers) were used for calibration.

Next a spatially explicit aboveground biomass model was created by applying the above described regression model. The LiDAR based aboveground biomass model was created at 5 m spatial resolution i.e. each pixel represents an area of 0.1 ha. For ease of interpretation the cell values were scaled to represent aboveground biomass in tons per hectare. Figure 12 displays the final LiDAR based aboveground biomass model and gives examples of Lowland Dipterocarp Forest, Peat Swamp Forest and Mangrove.

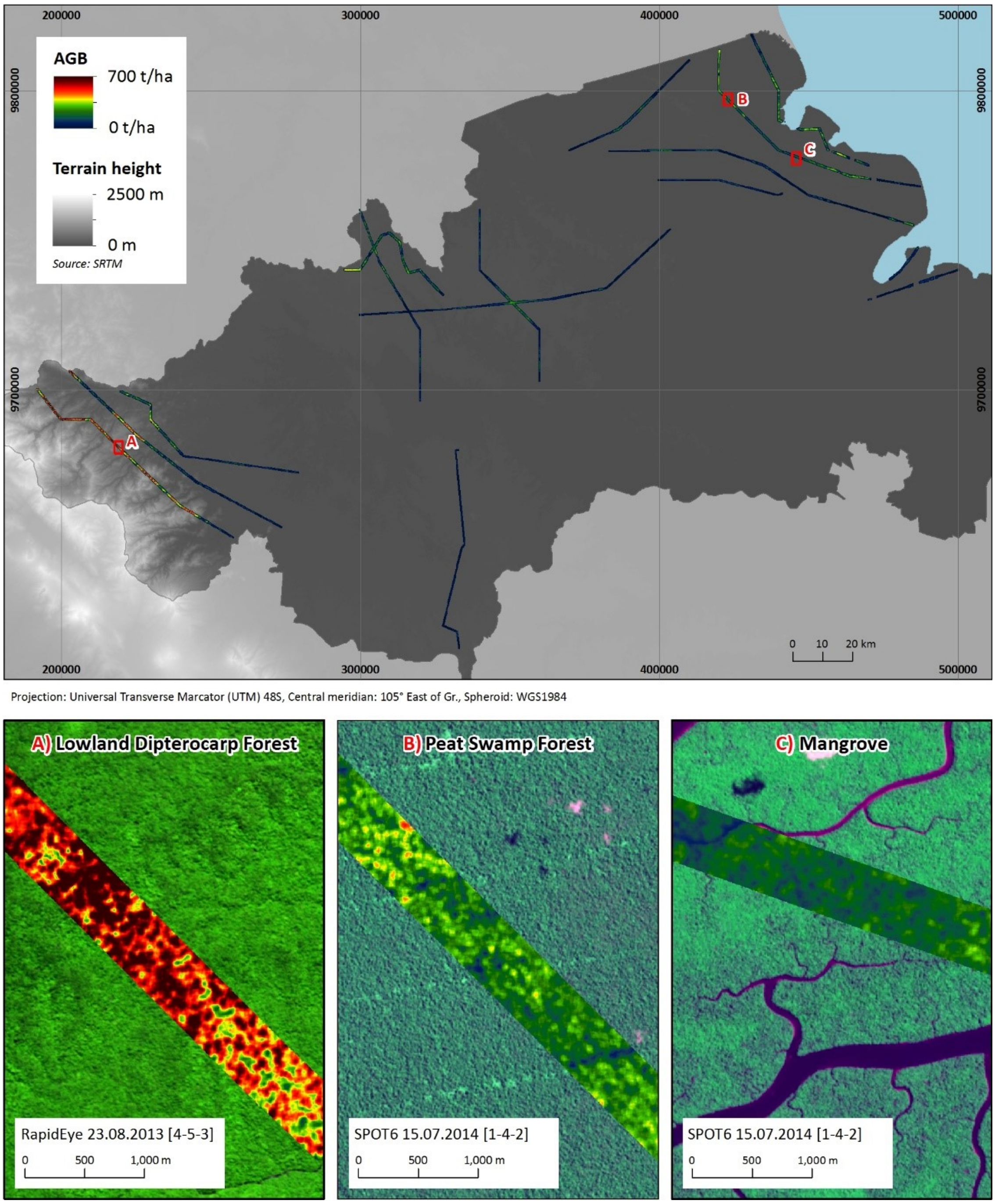

Figure 12: Final LiDAR based aboveground biomass model and examples of Lowland Dipterocarp Forest, Peat Swamp Forest and Mangrove (lower three figures). The location of the lover three figures is shown as red rectangles in the upper figure.

4.2. Determination of local aboveground biomass values

In order to derive local aboveground biomass values for the different land cover classes, the spatial aboveground biomass model was overlaid with the land cover classification from Work Package 2 (WP 2) and zonal statistics (minimum, maximum, mean and standard deviation) on aboveground biomass were extracted for the respective land cover class (see Figure 13). To avoid possible misclassifications at land cover class borders a buffer of 60 m was excluded from the zonal statistics.

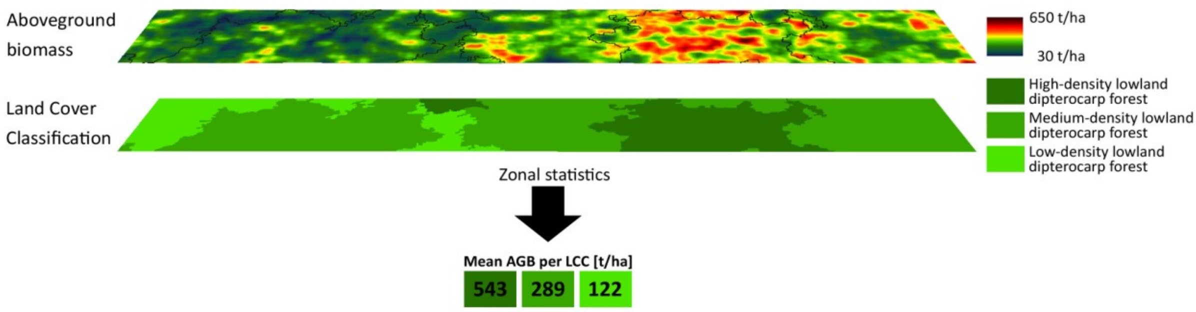

Figure 13: Schematic representation of the extraction of zonal statistics. The aboveground biomass (AGB) model is overlaid with the land cover classification (from Work Package 2) and zonal statistics on aboveground biomass are extracted for the respective land cover class. In this example the mean AGB in tons per hectare (t/ha) for the respective land cover class (LCC) is shown.

Zonal statistics were extracted for the BAPLAN and BAPLAN enhanced land cover classes. Table 9 and Table 10 display these derived local aboveground biomass values. For the land cover classes not present in the aboveground biomass model missing values were estimated based on existing values or missing values were based on values from scientific literature.

These local aboveground biomass values were used for the emission calculations in the other work packages.

Table 9: Local aboveground biomass values derived from zonal statistics of the LiDAR aboveground biomass model for the different forest type / land cover classes based on BAPLAN.

Forest type / land cover BAPLAN[1]	Mean AGB (t/ha)[2]	SD (t/ha)[3]	Min AGB (t/ha)[4]	Max AGB (t/ha)[5]	Area (ha)[6]
Primary Dryland Forest	545	±165.5	20.8	1,405.0	2,285.2
Secondary / Logged over Dryland Forest	256	±160.3	0.0	1.196.8	5,685.3
Primary Swamp Forest	226	±97.2	1.8	674.3	1,806.5
Secondary / Logged over Swamp Forest	74	±64.4	0.0	460.5	1,363.3
Primary Mangrove Forest	198	±102.7	0.0	632.2	4,031.9
Secondary / Logged over Mangrove Forest	44	±25.1	6.4	228.5	71.7
Mixed Dryland Agriculture / Mixed Garden	105	±84.1	0.0	677.8	1,883.0
Tree Crop Plantation	32	±47.2	0.0	380.2	442.2
Plantation Forest	40	±32.2	0.0	356.7	517.5
Scrub	25	±42.6	0.0	730.4	964.6
Swamp Scrub	8	±11.8	0.0	81.6	3.3
Rice Field[7]	10	-	-	-	-
Dryland Agriculture	31	±47.9	0.0	441.2	126.3
Grass[8]	6	-	-	-	-
Open Land[9]	(0) 20	±65.9	0.0	716.4	13.4
Settlement / Developed Land[9]	(0) 12	±8.6	0.1	50.6	1.3
Water Body[9]	(0) 118	±58.5	0.3	422.2	83.2
Swamp	12	±12.3	0.1	49.9	1.3
Embankment[9]	(0) 1	±1.9	0.0	12.8	9.5

[1] Forest type/land cover class BAPLAN classification system
[2] Mean aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[3] Standard deviation (SD) in tons per hectare for the forest type/land cover class
[4] Minimum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[5] Maximum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[6] Area in hectare from which zonal statistics are based on
[7] Value for Rice Field from scientific literature (Confalonieri *et al.* 2009)
[8] Value for Grass from scientific literature (IPCC 2006)
[9] Value in brackets was finally used as local aboveground biomass value as the value from zonal statistics is obviously too high due to misclassification

Table 10: Local aboveground biomass values derived from zonal statistics of the LiDAR aboveground biomass model for the different forest type / land cover classes based on BAPLAN enhanced.

Forest type / land cover BAPLAN enhanced[1]	Mean AGB (t/ha)[2]	SD (t/ha)[3]	Min AGB (t/ha)[4]	Max AGB (t/ha)[5]	Area (ha)[6]
High-density Upper Montane Forest[7]	304	-	-	-	-
Medium-density Upper Montane Forest[8]	228	-	-	-	-
Low-density Upper Montane Forest[7]	192	-	-	-	-
High-density Lower Montane Forest	615	±135.5	171.8	1,092.0	52.0
Medium-density Lower Montane Forest	486	±81.2	306.0	758.3	5.5
Low-density Lower Montane Forest[7]	268	-	-	-	-
High-density Lowland Dipterocarp Forest	543	±165.8	20.8	1,405.0	2,233.2
Medium-density Lowland Dipterocarp Forest	289	±157.1	0.0	1,196.8	4,536.6
Low-density Lowland Dipterocarp Forest	122	±84.7	0.1	966.1	1,143.2
High-density Peat Swamp Forest	235	±99.7	2.1	674.3	1,430.7
Medium-density Peat Swamp Forest[8]	176	-	-	-	-
Low-density (Regrowing) Peat Swamp Forest	77	±73.7	0.3	460.5	590.7
Permanently Inundated Peat Swamp Forest	192	±83.9	1.8	526.4	301.1
High-density Swamp Forest (incl. Back- and Freshwater Swamp)	200	±49.4	6.2	348.8	74.8
Medium-density Swamp Forest (incl. Back- and Freshwater Swamp)[8]	150	-	-	-	-
Low-density (Regrowing) Swamp Forest (incl. Back- and Freshwater Swamp)	73	±56.1	0.0	396.5	772.6
Heath Forest[7]	224	-	-	-	-
Mangrove 1	216	±97.7	0.0	632.2	3,473.1
Mangrove 2	153	±86.7	13.4	471.0	86.0
Nipah Palm	77	±29.6	0.3	409.3	472.8
Degraded Mangrove	46	±25.5	6.4	161.5	57.8
Young Mangrove	39	±22.8	8.4	228.5	13.9
Dryland Agriculture mixed with Scrub	23	±33.2	0.0	464.0	414.2
Rubber Agroforestry	129	±79.4	0.0	677.8	1,468.8
Oil palm plantation	16	±29.6	0.0	282.6	304.2
Coconut plantation	35	±18.2	0.9	88.7	94.1
Rubber	135	±57.4	0.2	380.2	43.9
Acacia plantation	41	±33.7	0.0	178.7	360.2
Industrial forest	39	±28.6	0.1	356.7	157.3
Scrubland	25	±42.6	0.0	730.4	964.6
Swamp Scrub	8	±11.8	0.0	81.6	3.3
Rice Field[9]	10	-	-	-	-
Dryland Agriculture	31	±47.9	0.0	441.2	126.3
Grassland[10]	6	-	-	-	-
Bare Area[11]	(0) 20	±65.9	0.0	716.4	13.4
Settlement[11]	(0) 5	±8.7	0.1	50.6	0.4
Road[11]	(0) 15	±6.2	0.1	28.2	0.9
Water[11]	(0) 118	±58.5	0.3	422.6	83.2
Wetland	12	±12.3	0.1	49.9	1.3
Aquaculture[11]	(0) 1	±1.9	0.0	12.8	9.5

[1] Forest type/land cover class BAPLAN enhanced classification system
[2] Mean aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[3] Standard deviation (SD) in tons per hectare for the forest type/land cover class
[4] Minimum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[5] Maximum aboveground biomass (AGB) in tons per hectare for the forest type/land cover class
[6] Area in hectare from which zonal statistics are based on
[7] Values from FORCLIME (Navratil 2012)
[8] Calculated as 75% of respective high density class
[9] Value for Rice Field from scientific literature (Confalonieri *et al.* 2009)
[10] Value for Grass from scientific literature (IPCC 2006)
[11] Value in brackets was finally used as local aboveground biomass value as the value from zonal statistics is obviously too high due to misclassification

5. Analyses of tree community composition of lowland dipterocarp forests

5.1. *Calculation of different LiDAR metrics for the biodiversity plots*

From the airborne LiDAR data following 19 LiDAR metrics per biomass plot located within a LiDAR transect (n = 28) were derived (Table 11).

Table 11: LiDAR metrics derived for each biomass plot located within the LiDAR transects (n = 28). Also shown in the respective abbreviation and which software method was used to derive them.

LiDAR metric	Abbreviation	Software / method used
Quadratic Mean Canopy Height (QMCH)	QMCH	in house script
Centroid Height (CH)	CH	in house script
Maximum height	Max	LASTools[1]
Mean height	Mean	LASTools[1]
Standard deviation height	SD	LASTools[1]
Forest cover at 1 m height	cov 1m	LASTools[1]
Forest cover at 2 m height	cov 2m	LASTools[1]
Forest cover at 5 m height	cov 5m	LASTools[1]
Forest cover at 7 m height	cov 7m	LASTools[1]
Forest cover at 10 m height	cov 10m	LASTools[1]
Forest cover at 12 m height	cov 12m	LASTools[1]
5th height percentile	p 5th	LASTools[1]
10th height percentile	p 10th	LASTools[1]
25th height percentile	p 25th	LASTools[1]
50th height percentile	p 50th	LASTools[1]
75th height percentile	p 75th	LASTools[1]
90th height percentile	p 90th	LASTools[1]
95th height percentile	p 95th	LASTools[1]
99th height percentile	p 99th	LASTools[1]

[1] https://rapidlasso.com/lastools/

Appendix C displays these LiDAR metrics for all the biodiversity plots located in lowland dipterocarp forest (all further tree community composition analyses are for lowland dipterocarp forest only). These LiDAR metrics were then correlated to the nMDS scores and biodiversity indices derived in Chapter 5.2 (Derivation of nMDS scores and biodiversity indices) in order to derive a predictive LiDAR based tree community composition model (see Chapter 5.3 LiDAR based tree community composition model).

5.2. *Derivation of nMDS scores and biodiversity indices*

Within all the biodiversity plots 378 types of species where identified belonging to 192 genera. Table 12 displays the absolute numbers and percentage of trees within the biodiversity plots where the species could be identified, where only genus, family, common name was known and unidentified trees.

Table 12: Absolute and percentage of tree identification (species, only genus, only family, only common name and unidentified) within the biodiversity plots.

	All trees recorded	Species identified	Only genus identified	Only family identified	Only common name	Unidentified
Absolute number	2733	2408	284	15	4	22
Percent (%)	100%	88%	10%	1%	0%	1%

All further analyses on tree community composition were conducted for lowland dipterocarp forest only. Mangrove was excluded as the variety of different tree species in the observed mangroves was very low (only up to six different tree species). Peat swamp forest was excluded because only three biodiversity plots were available and all were recorded after the fires of 2015.

Because some trees could not be identified to the species level all analyses on tree community composition are based on the genus level. Imai *at al.* (2014) showed that results on the genus level are highly correlated with those at the species level.

The similarity in tree community composition for the different lowland dipterocarp forest density classes (low, medium and high) was not only assessed for the stratification of the biodiversity plots based on the satellite classification derived from Work Package 2 (WP 2) but also for two further stratifications based on (a) aboveground biomass estimated for the plot and (b) the forest cover at 10 meter height above the ground (LiDAR metric was derived in the previous chapter). The thresholds for the two additional stratifications are shown in Table 13.

Table 13: Additional stratification of the biodiversity plots based on the estimated aboveground biomass and the forest cover at 10 meter height above the ground (LiDAR metric was derived in Chapter 5.1).

Lowland dipterocarp forest density class	Stratification thresholds	
	Aboveground biomass (t/ha)	Forest cover at 10 m height above ground (%)
Low-density Lowland Dipterocarp Forest	0-<150	0-<40
Medium-density Lowland Dipterocarp Forest	150≤-<250	40≤-<80
High-density Lowland Dipterocarp Forest	250≤	80≤

To asses tree community composition nonmetric multidimensional (nMDS) scaling was applied and four biodiversity indicators per biodiversity plot were calculated (see below). All the statistics were calculated in PAST Version 3.13 (http://folk.uio.no/ohammer/past/) and were only based on the genera identified in the large plot of the biodiversity plots (see Chapter 2.1 Inventory design).

Nonmetric multidimensional scaling (nMDS)

To assess the effects of different degradation levels on forest biodiversity the degree of similarity in tree community composition has gained increasing attention (Ioki *et al.* 2016, Barlow *et al.* 2007, Imai *et al.* 2012, Imai *et al.* 2014, Magurran and McGill 2011, Su *et al.* 2004, Ding *et al.* 2012). Nonmetric multidimensional scaling (nMDS) was applied to assess the differences in tree community composition among the biodiversity plots. The number of trees of each genus within the 38 biodiversity plots located in lowland dipterocarp forest was used as input to the Bray-Curtis similarity index to calculate the nMDS scores of axis 1 and axis 2. Figure 14, Figure 15 and Figure 16 display the resulting scatter plots from the nMDS calculation for the three density stratifications (base on the satellite classification of Work Package 2, the aboveground biomass and the forest cover at 10 m height). In all three scatterplots the nMDS axis 1 scores of High-density Lowland Dipterocarp Forest and Low-density Lowland Dipterocarp Forest are mostly located at the opposite ends of nMDS axis 1 indicating a difference in tree community composition of these two classes. The nMDS axis 1 scores of Medium-density Lowland Dipterocarp Forest is mostly located between the scores of the two other density classes.

Also indicated is the stress value. The stress value is used as an indicator of the performance of the nMDS (the lower the stress value the better). In our analyses the nMDS based on the forest cover at 10 m stratification had, with 0.235, the lowest stress value, so that for all further analyses the nMDS scores from this stratification were used.

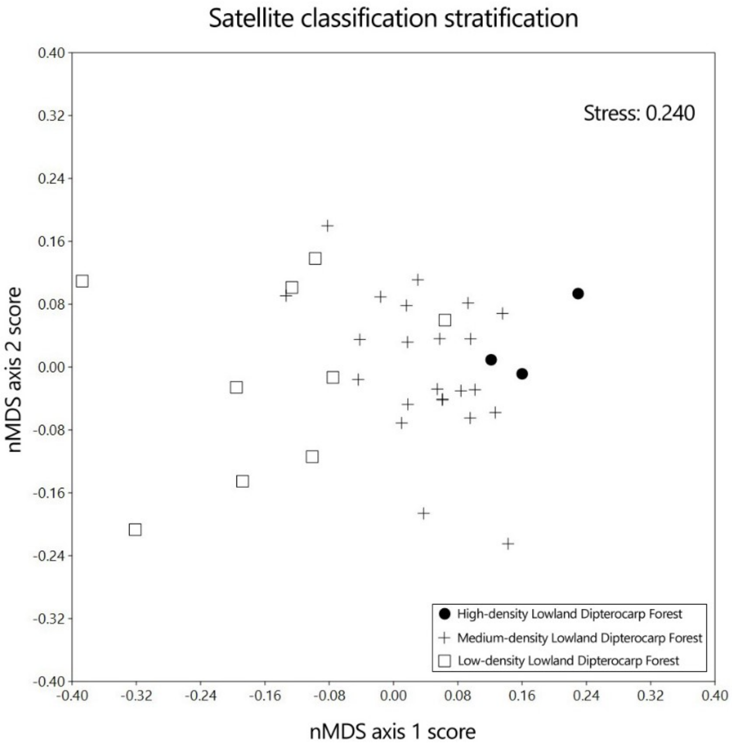

Figure 14: Nonmetric multidimensional scaling (nMDS) ordination diagram for the biodiversity plots located in the Lowland Dipterocarp Forest class. The stratification into different density classes was based on the satellite classification conducted in Work Package 2 (WP 2). The number of plots going into the ordination was 35. Shown are the scores of axis 1 and axis 2, with axis 1 indicating the similarity in tree community composition among the 35 plots. The nMDS axis 1 scores of High-density Lowland Dipterocarp Forest and Low-density Lowland Dipterocarp Forest are located at the opposite ends of nMDS axis 1 indicating a difference in tree community composition of these two classes. The nMDS axis 1 scores of Medium-density Lowland Dipterocarp Forest is mostly located between the scores of the two other density classes. Also indicated is the stress value (0.240).

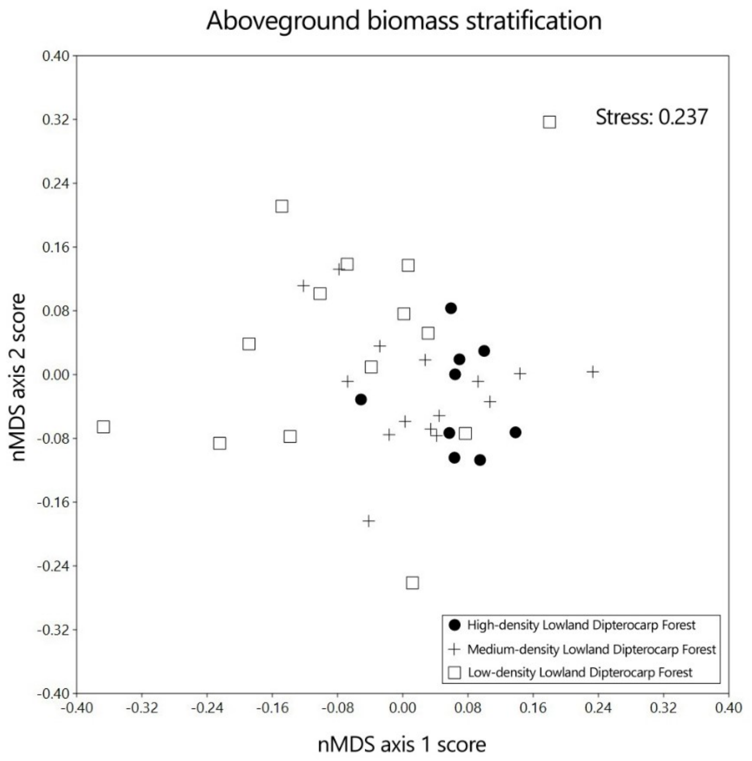

Figure 15: Nonmetric multidimensional scaling (nMDS) ordination diagram for the biodiversity plots located in the Lowland Dipterocarp Forest class. The stratification into different density classes was based on the aboveground biomass of the biodiversity plots. The number of plots going into the ordination was 38. Shown are the scores of axis 1 and axis 2, with axis 1 indicating the similarity in tree community composition among the 38 plots. The nMDS axis 1 scores of High-density Lowland Dipterocarp Forest and Low-density Lowland Dipterocarp Forest are located at the opposite ends of nMDS axis 1 indicating a difference in tree community composition of these two classes. The nMDS axis 1 scores of Medium-density Lowland Dipterocarp Forest is mostly located between the scores of the two other density classes. Also indicated is the stress value (0.237).

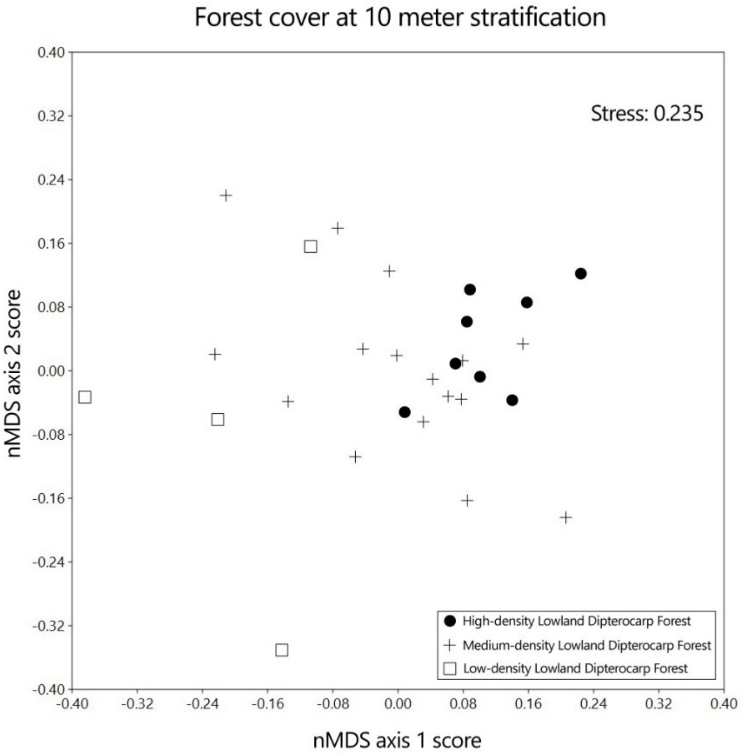

Figure 16: Nonmetric multidimensional scaling (nMDS) ordination diagram for the biodiversity plots located in the Lowland Dipterocarp Forest class. The stratification into different density classes was based the forest cover at 10 m height (derived from LiDAR). The number of plots going into the ordination was 28. Shown are the scores of axis 1 and axis 2, with axis 1 indicating the similarity in tree community composition among the 28 plots. The nMDS axis 1 scores of High-density Lowland Dipterocarp Forest and Low-density Lowland Dipterocarp Forest are located at the opposite ends of nMDS axis 1 indicating a difference in tree community composition of these two classes. The nMDS axis 1 scores of Medium-density Lowland Dipterocarp Forest is mostly located between the scores of the two other density classes. Also indicated is the stress value (0.235).

Simpson index 1-D

The Simpson index 1-D was calculated for each biodiversity plot. This index measures 'evenness' of the community from 0 (one taxon dominates the community completely) to 1 (all taxa are equally present).

$$D = -\sum_i \left(\frac{n_i}{n}\right)^2$$

where n_i is the number of individuals of taxon i.

Shannon index (entropy)

The Shannon index (entropy) was calculated for each biodiversity plot. The Shannon index (entropy) is a diversity index, taking into account the number of individuals as well as the number of taxa. The index increases as both the 'richness' and the 'evenness' of the community increases. It varies from 0 for communities with only a single taxon to high values for communities with many taxa, each with few individuals.

$$H = -\sum_i \frac{n_i}{n} ln \frac{n_i}{n}$$

where n_i is the number of individuals of taxon i.

In most ecological studies the values are generally between 1.5 and 3.5 and the index is rarely greater than 4.

Margalef's richness index

The Margalef's 'richness' index was calculated for each biodiversity plot. This index is a 'richness' index that attempts to compensate for sampling effects such as sample size. The higher the index the higher the 'richness'.

Equitability

Equitability was calculated for each biodiversity plot. Equitability is the Shannon diversity divided by the logarithm of number of taxa. This measures the 'evenness' with which individuals are divided among the taxa present. The higher the index the higher the 'evenness'.

Appendix D gives an overview of the different forest stratification (satellite classification, aboveground biomass and forest cover at 10 m height), the nMDS scores of axes 1 and 2 for the respective forest stratifications and the four biodiversity indices.

As there was no statistical significant correlation between the forest density classes and the nMDS scores of axis 2, only scores from axis 1 very implemented in subsequent analyses.

Table 14 displays the descriptive statistics on the nMDS axis 1 scores and the four biodiversity indicators for the different Lowland Dipterocarp Forest density classes (Low, Medium and High). The stratification of the density classes is based on the forest cover at 10 m height. These results show that there is a gradient in the mean nMDS axis 1 scores where Low-density Lowland Dipterocarp Forest with -0.214 had the lowest mean and High-density Lowland Dipterocarp Forest the highest with 0.109. Looking at the biodiversity indicators the two indices for ‘richness/diversity’ (Shannon index and Margelef’s index) also had a similar gradient where the Low-density Lowland Dipterocarp Forest had the lowest and the High-density Lowland Dipterocarp Forest had the highest mean values indicating that High-density Lowland Dipterocarp Forest has the highest biodiversity. Also the other two biodiversity indicators for ‘evenness’ (Simpson index 1-D and Equitability) have a similar gradient which indicates that the High-density Lowland Dipterocarp Forest has the highest ‘evenness’ (all taxa are more equally present). All these findings indicate that high nMDS axis 1 scores go hand in hand with higher ‘richness/diversity’ and ‘evenness’.

Table 14: Descriptive statistics on the nMDS axis 1 scores and the four biodiversity indicators for the different Lowland Dipterocarp Forest density classes: Low, Medium and High. The density classes are based on the forest cover at 10 m height stratification.

		Lowland Dipterocarp Forest		
		Low-density	Medium-density	High-density
nMDS axis 1 score	n	4	16	8
	Min[1]	-0.384	-0.225	0.008
	Max[2]	-0.107	0.206	0.224
	Mean	-0.214	-0.001	0.109
	SD[3]	±0.123	±0.120	±0.065
Simpson index 1-D	n	4	16	8
	Min[1]	0.392	0.720	0.870
	Max[2]	0.810	0.955	0.964
	Mean	0.677	0.898	0.935
	SD[3]	±0.193	±0.069	±0.029
Shannon index	n	4	16	8
	Min[1]	0.807	1.632	2.383
	Max[2]	2.069	3.310	3.453
	Mean	1.623	2.703	3.008
	SD[3]	±0.560	±0.490	±0.318
Margelef's index	n	4	16	8
	Min[1]	1.039	2.424	3.938
	Max[2]	3.376	8.266	8.384
	Mean	2.463	5.384	6.300
	SD[3]	±1.046	±1.574	±1.312
Equitability	n	4	16	8
	Min[1]	0.501	0.667	0.880
	Max[2]	0.840	0.987	0.964
	Mean	0.725	0.892	0.932
	SD[3]	±0.154	±0.089	±0.027

[1] Minimum (Min)
[2] Maximum (Max)
[3] Standard deviation (SD)

Next, to test whether there is a statistical significant difference between the different density classes (density stratification based on forest cover at 10 m height) with regard to nMDS and the biodiversity indicators a One-way ANOVA was performed. When the ANOVA results were significant, a Tukey's pairwise post-hoc test was used to identify the different pairs of groups. Before the ANOVA, normality of data was tested by means of the Shapiro-Wilk test (Shapiro and Wilk 1965). Table 15 shows the results of these statistical analyses. As can be seen the One-way ANOVA showed that there was a statistical significant ($p < 0.05$) difference between the means of the different density classes (Low, Medium and High) for the nMDS axis 1 scores, Shannon index and Margelef's index. Further, for all these three indicators the Tukey's pairwise post-hoc test showed there was a statistical significant ($p < 0.05$) difference between the density pairs Low vs Medium and Low vs High but not for Medium vs High. For the Simpson index 1-D and the Equitability no statement on the difference between the density classes could be made as one or more of the density groups was not normally distributed, which is a requirement for a One-Way ANOVA.

Table 15: Results of the statistical analyses comparing the different Lowland Dipterocarp Forest density classes: Low, Medium and High. The density classes are based on the forest cover at 10 m height stratification. Numbers in the cells represent the p values. Cells in green show that the respective test results are positive and cells in red that the respective test results are negative. Shaded cells indicate that here a One-Way ANOVA could not be conducted as one or more of the density groups was not normally distributed. ($p < 0.05$; $n = 28$)

		nMDS axis 1			Simpson index 1-D			Shannon index		
Test normal distribution[1]		Low	Medium	High	Low	Medium	High	Low	Medium	High
		0.477	0.752	0.896	0.079	0.000	0.033	0.187	0.097	0.574
One-way ANOVA[2]		0.000			0.000			0.000		
Tukey's pairwise[3]		Medium	High		Medium	High		Medium	High	
	Low	0.003	0.000		0.000	0.000		0.001	0.000	
	Medium	X	0.161		X	0.716		X	0.445	

		Margelef's index			Equitability		
Test normal distribution[1]		Low	Medium	High	Low	Medium	High
		0.509	0.976	0.914	0.164	0.003	0.500
One-way ANOVA[2]		0.001			0.002		
Tukey's pairwise[3]		Medium	High		Medium	High	
	Low	0.003	0.000		0.005	0.001	
	Medium	X	0.481		X	0.694	

[1] Shapiro-Wilk test on normal distribution: if $p > 0.05$ normal distribution (green); if $p < 0.005$ no normal distribution (red)
[2] if $p < 0.005$ difference between means (green); if $p > 0.005$ no difference between groups (red); shaded: no One-Way ANOVA possible because one or more of the density groups is not normally distributed
[3] if $p < 0.005$ difference between density pair (green); if $p > 0.005$ no difference between density pair (red)

These statistical results indicate that there is a significant different with regard to tree community composition between these different density classes and that the density classes Low vs Medium and Low vs High could be best differentiated.

5.3. LiDAR based tree community composition model

First a correlation analysis was conducted to assess whether nMDS axis 1 scores or one of the four biodiversity indices correlated best with the derived LiDAR metrics. Table 16 displays the Spearman's correlation coefficients (r_s) and Table 17 the corresponding *p* values. Overall the nMDS axis 1 scores correlated best with the LiDAR metrics with regard to the r_s and the corresponding *p* values. Except for the LiDAR metric p 99th ($r_s = 0.69$) all r_s were equal to or higher than 0.70. For the LiDAR metrics QMCH ($r_s = 0.83$), CH ($r_s = 0.82$), Mean ($r_s = 0.82$), p 75th ($r_s = 0.82$), cov 12m ($r_s = 0.80$), p 50th ($r_s = 0.80$) the r_s was even equal to or higher than 0.80.

Table 16: Results of the correlation analyses displaying the Spearman's correlation coefficient (r_s). Shown are the correlation results between the nMDS axis 1 scores and the 19 LiDAR metrics. Cells in: green $r_s \geq 0.70$; orange $r_s < 0.70 - \geq 0.50$; red $r_s < 0.50$ (n = 28).

	nMDS axis 1	Simpson index 1-D	Shannon index	Margelef's index	Equitability
QMCH	0.83	0.60	0.55	0.55	0.62
CH	0.82	0.59	0.53	0.54	0.62
Max	0.70	0.57	0.51	0.51	0.67
Mean	0.82	0.59	0.53	0.53	0.61
SD	0.72	0.57	0.51	0.50	0.64
cov 1m	0.71	0.49	0.47	0.48	0.47
cov 2m	0.74	0.51	0.48	0.50	0.49
cov 5m	0.74	0.54	0.50	0.51	0.51
cov 7m	0.74	0.56	0.52	0.53	0.53
cov 10m	0.79	0.56	0.52	0.52	0.55
cov 12m	0.80	0.55	0.51	0.51	0.55
p 5th	0.73	0.51	0.50	0.51	0.48
p 10th	0.77	0.57	0.55	0.56	0.53
p 25th	0.77	0.57	0.53	0.53	0.54
p 50th	0.80	0.57	0.52	0.52	0.58
p 75th	0.82	0.59	0.54	0.53	0.61
p 90th	0.79	0.58	0.53	0.52	0.64
p 95th	0.71	0.56	0.51	0.50	0.64
p 99th	0.69	0.57	0.51	0.50	0.68

Table 17: Results of the correlation analyses displaying the *p* values. Shown are the correlation results between the nMDS axis 1 scores and the 19 LiDAR metrics. Cells in: green $p \leq 0.001$; orange $p > 0.001$ -≤ 0.05 ($n = 28$).

	nMDS axis 1	Simpson index 1-D	Shannon index	Margelef's index	Equitability
QMCH	0.0000	0.0009	0.0032	0.0029	0.0006
CH	0.0000	0.0013	0.0042	0.0039	0.0006
Max	0.0000	0.0018	0.0068	0.0069	0.0001
Mean	0.0000	0.0013	0.0041	0.0042	0.0007
SD	0.0000	0.0018	0.0068	0.0084	0.0003
cov 1m	0.0000	0.0092	0.0144	0.0106	0.0140
cov 2m	0.0000	0.0063	0.0110	0.0080	0.0094
cov 5m	0.0000	0.0034	0.0082	0.0067	0.0069
cov 7m	0.0000	0.0026	0.0060	0.0047	0.0043
cov 10m	0.0000	0.0025	0.0060	0.0050	0.0027
cov 12m	0.0000	0.0030	0.0072	0.0068	0.0030
p 5th	0.0000	0.0066	0.0084	0.0065	0.0121
p 10th	0.0000	0.0018	0.0028	0.0022	0.0041
p 25th	0.0000	0.0018	0.0046	0.0047	0.0039
p 50th	0.0000	0.0017	0.0050	0.0050	0.0014
p 75th	0.0000	0.0012	0.0037	0.0041	0.0007
p 90th	0.0000	0.0016	0.0047	0.0055	0.0003
p 95th	0.0000	0.0026	0.0072	0.0085	0.0003
p 99th	0.0000	0.0017	0.0069	0.0076	0.0001

Due to this high overall correlation of the LiDAR metrics to nMDS axis 1 scores it was decided that these scores are used to derive the predictive LiDAR based tree community composition model.

Next a stepwise forward and backward multiple regression was performed (R software was used for this). The final model included three significant variables (Mean, cov 12m and p 50th) and four biodiversity plots were excluded (outliers) from the model development. An r^2 of 0.72 was obtained (see Figure 17)

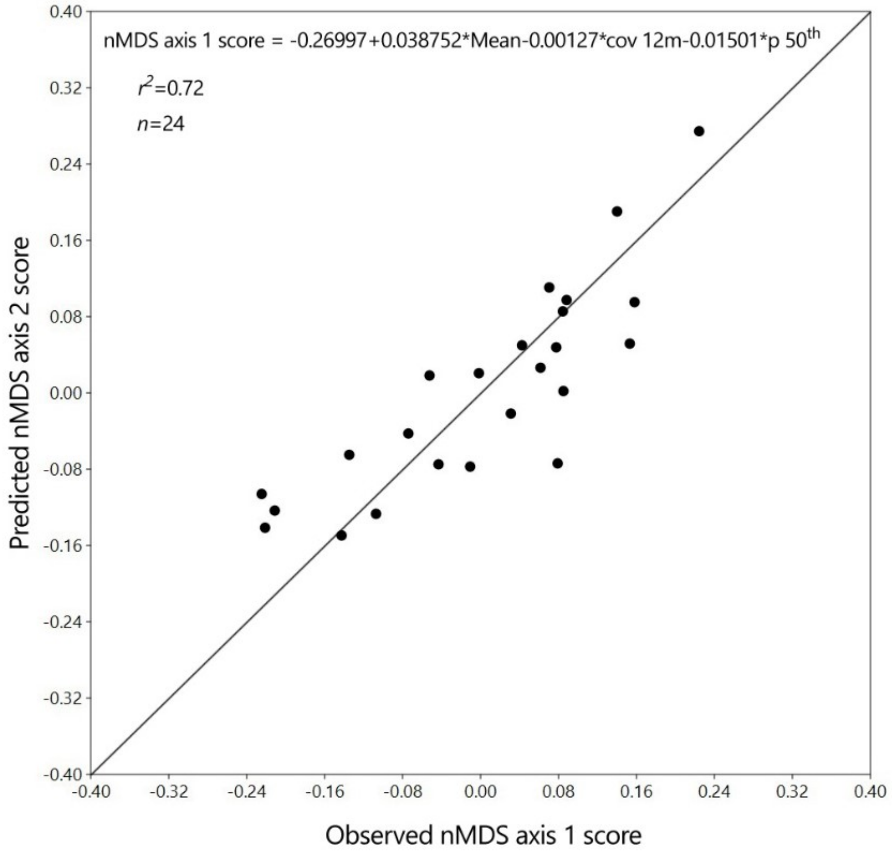

Figure 17: Predictive tree community composition model.

This final model was then applied (spatial resolution 31.25 m) to the areas of the LiDAR transects that cover Lowland Dipterocarp Forest (based on the land cover classification from Work Package 2) (Figure 18). To exclude non-forested areas all areas where the LiDAR metric Max was smaller than 6 m were excluded. The predicted nMDS axis 1 scores of this map ranged from -0.264 to 0.741. The highest nMDS axis 1 scores were found in Kerinci Sebelat National Park and the lowest in eastern lowlands of the Musi Banyuasin district. These results indicate that the areas within the Kerinci Sebelat National Park have tree community compositions that indicate high biodiversity compared to the ones in the eastern lowlands of the Musi Banyuasin District.

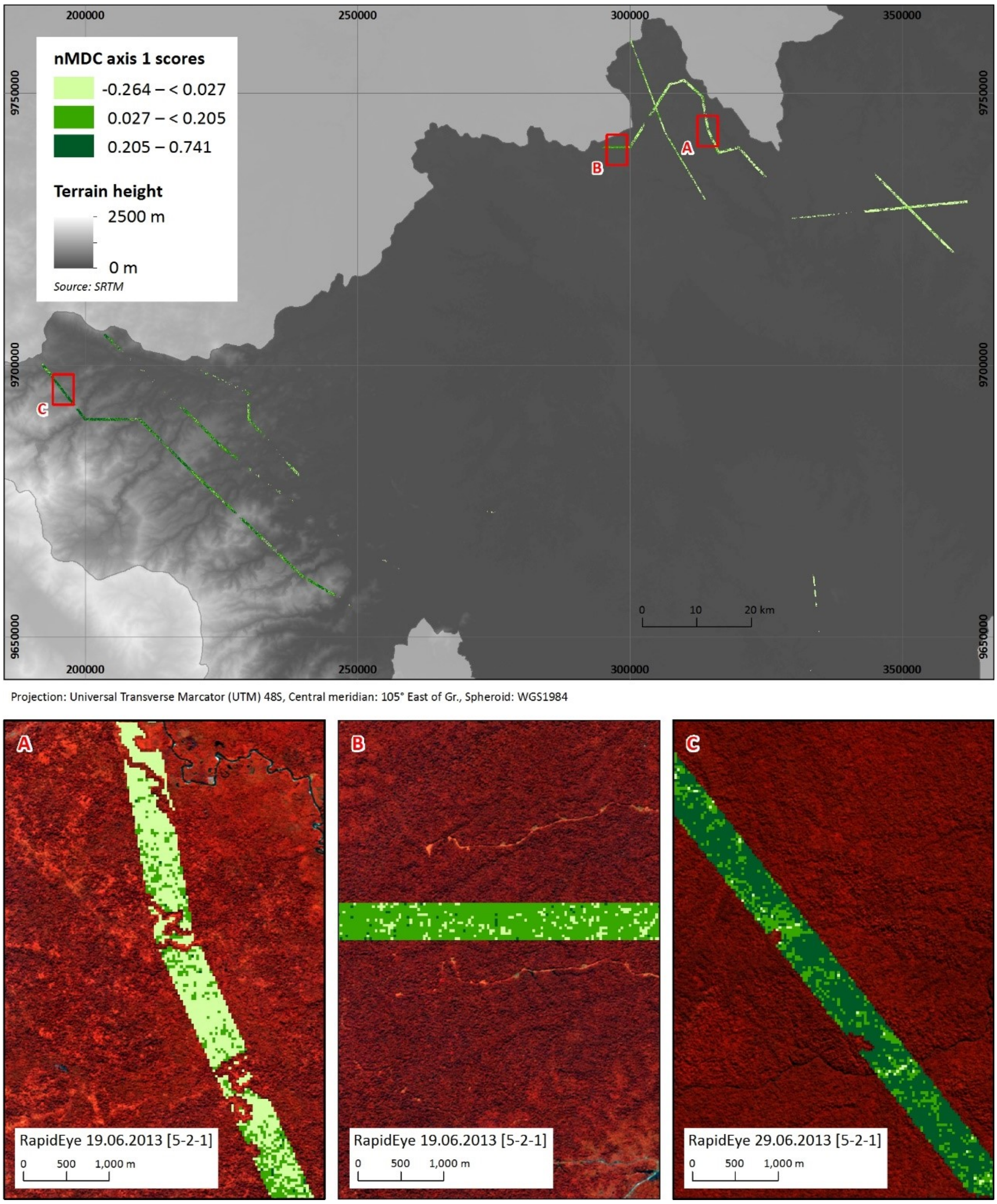

Figure 18: Final predictive LiDAR based tree community composition model. The predictive map shown here was reclassified into three classes using the Natural Breaks (Jenks) provided in ArcGIS (www.esri.com). The predicted nMDS axis 1 scores of this map ranged from -0.264 to 0.741. The lower three figures exemplarily show areas with low, medium and high nMDS axis 1 scores. The location of the lover three figures is shown as red rectangles in the upper figure. The highest nMDS axis 1 scores were found in Kerinci Sebelat National Park which indicates that this area has tree community compositions that indicate high biodiversity compared to the eastern lowland (e.g. District of Musi Banyuasin).

6. Conclusions

Following conclusions could be drawn (separated into the aboveground biomass and the tree community composition modelling).

Aboveground biomass modelling

- Local aboveground biomass (AGB) values could be derived from the LiDAR based aboveground biomass model for almost all identified vegetation cover classes.
- High aboveground biomass variability within vegetation classes could be identified (e.g. Primary Dryland Forest has a standard deviation for aboveground biomass of ±165.5 t/ha).
- Areas with the highest aboveground biomass (AGB) values were located within and around the Kerinci Seblat National Park.

Tree community composition modelling

- The findings of this study indicate that the similarity in tree community composition can be predicted and monitored by means of airborne LiDAR.
- In addition to using airborne LiDAR data as mapping tool for aboveground biomass this data could be further developed to provide a biodiversity mapping tool, so that biodiversity assessments could be carried out simultaneously with aboveground biomass analyses (same dataset).
- A further advantage of the approach is that the tree community composition can be carried out without identifying individual tree crowns in remotely sensed imagery.

7. Outlook

A next step would be to harmonize the results from the carbon plots. As the aboveground biomass calculations derived by the experts from the Bogor Agricultural University (IPB) are based on more differentiated allometric equations (e.g. species specific) it is recommended to use these aboveground biomass estimates to calibrate the LiDAR based aboveground biomass model, which would lead to revised local aboveground biomass values for the different vegetation classes. This consequently would lead to a recalculation of the emissions derived in Work Packages 1, 2 and 4.

Further interesting research topics would be:

- It would be of interest to analyse the abundance of pioneer and climax species within the different biodiversity plots.
- Also of interest would be a spatial comparison of the LiDAR based aboveground biomass model with the LiDAR based tree community composition model.
- Finally it would also be interesting to analyse what influence do different historical land use patterns (e.g. logging) have on the aboveground biomass and tree community composition for similar forest classes (e.g. Secondary Dryland Forest), that were classified on the basis of multispectral satellite imagery.

Outputs / deliverables

- Processed and filtered LiDAR data (.las format)
- Digital Surface Model (DSM) in 1 m spatial resolution (.img format)
- Digital Terrain Model (DTM) in 1 m spatial resolution (.img format)
- Canopy Height Model (CHM) in 1 m spatial resolution (.img format)
- LiDAR based aboveground biomass model in 5 m spatial resolution (.img format)
- Local aboveground biomass values (tables in final report)
- LiDAR based tree community composition model for Lowland Dipterocarp Forest in 31.25 m spatial resolution (.img format)

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Appendix A: Overview field plots

Plot ID[1]	X[2]	Y[2]	District[3]	Forest type / land cover tally sheet[4]	Forest type / land cover classification[5]	Forest type / land cover BAPLAN[6]	Date[7]	Shape / size[8]	LiDAR[9]	Biodiversity plot[10]	After 2015 fires[11]	AGB (t/ha)[12]	Max tree height (m)[13]	Mean tree height (m)[14]	Max DBH (cm)[15]	Mean DBH (cm)[16]
1	320363	9739599	Musi Banyuasin	Low Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest / Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	22.03.2016	rectangle (0.1ha)	yes	yes	no	112.3	28.5	21.9 ±4.5	56.5	36.1 ±12.7
2	298915	9740016	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	30.03.2016	rectangle (0.1ha)	yes	yes	no	375.4	39.4	23.1 ±8.3	56.2	29.7 ±14.9
3	300728	9741161	Musi Banyuasin	Low Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest / Road	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	30.03.2016	circle (0.02ha)	yes	yes	no	29.0	13.8	9.8 ±2.0	12.0	7.7 ±2.2
4	313455	9748123	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	23.03.2016	rectangle (0.1ha)	yes	yes	no	244.7	35.6	18.8 ±8.7	90.0	29.6 ±22.7
4a	239605	9661350	Musi Rawas	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.05.2016	rectangle (0.1ha)	yes	yes	no	513.1	58.2	27.9 ±11.7	98.3	43.3 ±20.9
4b (4)	240095	9661054	Musi Rawas	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.05.2016	rectangle (0.1ha)	yes	yes	no	247.5	35.2	18.3 ±8.8	62.5	24.4 ±15.1
5	304031	9749251	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	31.03.2016	rectangle (0.1ha)	yes	yes	no	239.4	47.6	19.3 ±9.7	74.0	27.5 ±16.9
5a (5)	239255	9661714	Musi Rawas	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest / Water	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	18.05.2016	rectangle (0.1ha)	yes	yes	no	278.6	51.4	17.7 ±9.7	59.7	27.1 ±15.5
6	308927	9752068	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	27.03.2016	rectangle (0.1ha)	yes	yes	no	72.2	16.6	11.9 ±3.3	23.9	16.1 ±5.7
7	330045	9620107	Musi Rawas	Timber Plantation (Hutan Tanaman)	NoData	NoData	14.08.2015	rectangle (0.0025ha)	yes	no	no	58.7	7.2	5.4 ±1.1	6.5	3.0 ±1.2
7a (7)	309422	9752206	Musi Banyuasin	Low Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	27.03.2016	rectangle (0.1ha)	yes	yes	no	86.1	22.2	12.3±4.7	51.8	18.9 ±12.2
8	324953	9620007	Musi Rawas	Timber Plantation (Hutan Mangium)	NoData	NoData	14.08.2015	circle (0.04ha)	no	no	no	121.0	22.8	15.8 ±5.4	26.9	17.8 ±3.5
8a (8)	233787	9666883	Musi Rawas Utara	Secondary Forest (Hutan Sekunder)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	17.05.2016	rectangle (0.1ha)	yes	yes	no	178.7	27.4	17.4 ±8.3	86.5	29.1 ±20.4
9	302182	9754118	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	25.03.2016	rectangle (0.1ha)	yes	yes	no	322.0	44.2	24.7 ±9.0	50.2	30.7 ±13.1
9a (9)	244691	9669626	Musi Rawas Utara	Mixed Farms (Kebun Campuran)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.05.2016	rectangle (0.1ha)	yes	yes	no	86.2	23.6	12.0 ±6.5	58.2	25.3 ±16.0
10	301850	9754991	Musi Banyuasin	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	25.03.2016	rectangle (0.1ha)	yes	yes	no	247.3	37.8	19.5 ±8.3	68.3	24.9 ±15.9
10a (10)	243650	9670440	Musi Rawas Utara	Mixed Rubber Plantation (Kebun Karet Campuran)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.05.2016	rectangle (0.1ha)	yes	yes	no	24.2	13.3	10.1 ±2.1	22.1	16.7 ±4.7
11	238688	9662073	Musi Rawas	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	18.05.2016	rectangle (0.1ha)	yes	yes	no	206.9	48.4	19.6 ±13.6	83.2	34.5 ±22.1

[1] In brackets the plot ID from the tally sheets
[2] X and Y coordinates of the plots in WGS84 UTM Zone 48S
[3] District in South Sumatra (Indonesia) where the plot is located
[4] Forest type/land cover at plot location as indicated in the tally sheets (in brackets Bahasa Indonesia)
[5] Forest type/land cover at plot location based on the land cover classification derived in WP 2 (year 2013-2015; Spot-6 and RapidEye)
[6] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[7] Date the plots was recorded (N/A = not available)
[8] Shape and size of the plot
[9] Is the plot located in one of the LiDAR transects?
[10] Was there also a biodiversity plot recorded?
[11] Was the plot recorded after the 2015 fires?
[12] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations
[13] Maximum tree height (meters) measured in the plot
[14] Mean tree height (meters) in the plot (± standard deviation)
[15] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot
[16] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation)

Plot ID[1]	X[2]	Y[2]	District[3]	Forest type / land cover tally sheet[4]	Forest type / land cover classification[5]	Forest type / land cover BAPLAN[6]	Date[7]	Shape / size[8]	LiDAR[9]	Biodiversity plot[10]	After 2015 fires[11]	AGB (t/ha)[12]	Max tree height (m)[13]	Mean tree height (m)[14]	Max DBH (cm)[15]	Mean DBH (cm)[16]
12 (12a)	212854	9687056	Musi Rawas Utara	Primary Dryland Forest (Hutan Lahan Kering Primer)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	25.04.2016	rectangle (0.1ha)	yes	yes	no	289.3	37.0	23.1 ±9.3	95.2	39.0 ±23.7
13	212197	9687986	Musi Rawas Utara	Primary Dryland Forest (Hutan Lahan Kering Primer)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	24.04.2016	rectangle (0.1ha)	yes	yes	no	302.8	34.3	20.1 ±8.1	62.4	30.7 ±16.1
14	334935	9625012	Musi Rawas	Timber Plantation (Hutan Tanaman)	NoData	NoData	13.08.2015	circle (0.02 ha)	no	no	no	16.9	10.5	7.4 ±2.6	12.4	7.7 ±3.4
15	208782	9690034	Musi Rawas Utara	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest / High-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	24.04.2016	rectangle (0.1ha)	yes	yes	no	179.6	42.7	14.3 ±8.0	63.3	24.3 ±13.6
17 (HS17)	349871	9640154	Musi Banyuasin	Rubber Plantation (Kebun Karet)	NoData	NoData	15.08.2015	circle (0.04 ha)	no	no	no	42.9	21.1	11.6 ±3.4	40.1	17.9 ±7.2
18	215756	9693948	Musi Rawas Utara	Secondary Garden (Kebun Sekunder)	Low-density Lowland Dipterocarp Forest / Dryland Agriculture	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	26.04.2016	rectangle (0.1ha)	yes	yes	no	209.4	18.5	13.8 ±3.2	34.9	19.2 ±8.4
19	213953	9695747	Musi Rawas Utara	Mixed Garden (Kebun Campur)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	26.04.2016	rectangle (0.1ha)	yes	yes	no	204.7	35.8	18.6 ±8.3	79.6	33.7 ±21.3
20	339994	9630002	Musi Rawas	Timber Plantation (Hutan Tanaman)	NoData	NoData	13.08.2015	circle (0.02 ha)	no	no	no	4.4	8.1	5.2 ±1.2	8.0	3.8 ±1.3
22	329996	9629987	Musi Rawas	Rubber Plantation (Kebun Karet)	NoData	NoData	14.08.2015	circle (0.04 ha)	yes	no	no	20.9	12.5	10.6 ±1.2	18.7	12.7 ±2.1
27	330998	9634964	Musi Rawas	Timber Plantation (Hutan Mangium)	NoData	NoData	14.08.2015	circle (0.04 ha)	yes	no	no	110.2	24.0	16.2 ±5.1	25.5	17.0 ±4.1
28	488609	9736294	Banyuasin	Mangrove - Nipa Palm (Mangrove - Nipah)	Young mangrove	Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	05.04.2016	rectangle (0.1ha)	yes	yes	no	150.6	15.0	11.1 ±2.5	55.1	18.9 ±9.9
30	491819	9737166	Banyuasin	Mangrove (Hutan Mangrove)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	04.04.2016	rectangle (0.1ha)	yes	yes	no	38.4	21.2	14.3 ±4.7	40.7	34.5 ±7.1
32	482366	9741853	Banyuasin	Mangrove (Mangrove)	Mangrove 1 / Young mangrove	Primary Mangrove Forest (Hutan Mangrove Primer)	02.04.2016	rectangle (0.1ha)	yes	yes	no	241.0	27.0	15.9 ±5.3	75.0	29.0 ±21.4
34	477323	9737066	Banyuasin	Mangrove (Hutan Mangrove)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	04.02.2016	rectangle (0.1ha)	yes	yes	no	248.8	23.3	17.4 ±5.7	53.2	32.4 ±15.4
39	334954	9639933	Musi Rawas	Timber Plantation Mixed (Hutan Mangium Sekunder)	Acacia Plantation	Plantation Forest (Hutan Tanaman)	15.08.2015	rectangle (0.1ha)	no	no	no	141.1	17.0	13.2 ±4.1	22.3	12.5 ±4.1
54	395338	9779852	Musi Banyuasin	Peat (Gambut)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	12.04.2016	rectangle (0.1ha)	yes	no	yes	0.0	19.0	15.0 ±5.1	40.7	29.5 ±10.0
55	397562	9780001	Musi Banyuasin	Peat (Gambut)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	13.04.2016	rectangle (0.1ha)	yes	no	yes	0.0	23.5	19.9 ±3.7	40.1	32.0 ±4.6
68	334647	9650014	Musi Rawas	Timber Plantation (Hutan Tanaman)	Acacia Plantation	Plantation Forest (Hutan Tanaman)	15.08.2015	circle (0.04 ha)	yes	no	no	91.3	20.1	10.5 ±6.5	28.8	15.3 ±4.9
76	334283	9654848	Musi Rawas	Secondary Forest (Hutan Sekunder)	Industrial Forest	Plantation Forest (Hutan Tanaman)	15.08.2015	circle (0.04 ha)	yes	no	no	10.5	17.5	11.2 ±3.5	33.8	18.0 ±8.5
110 (110a)	235493	9665340	Musi Rawas Utara	Secondary Forest Burned (Hutan sekunder Bekas Terbakar)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	18.05.2016	rectangle (0.1ha)	yes	yes	yes	6.0	21.8	16.8 ±5.1	32.1	22.6 ±7.1

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111	394951	9774996	Musi Banyuasin	Secondary Peat Swamp Forest (Hutan Gambut Sekunder)	High-density Peat Swamp Forest / Low-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	27.05.2015	rectangle (0.1ha)	no	no	no	82.6	18.5	10.9 ±3.6	47.6	14.0 ±11.4
113	414985	9779992	Musi Banyuasin	Secondary Peat Swamp Forest (Gambut Sekunder)	High-density Peat Swamp Forest / Low-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	28.05.2015	rectangle (0.1ha)	yes	no	no	212.6	28.8	12.1 ±8.0	43.2	12.3 ±11.6
114	399580	9780084	Musi Banyuasin	Primary Peat Swamp Forest (Hutan Gambut Primer)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	28.05.2015	rectangle (0.1ha)	yes	no	no	328.8	30.0	19.8 ±7.7	75.0	26.7 ±17.6
115	395000	9780008	Musi Banyuasin	Secondary Peat Swamp Forest (Hutan Gambut Sekunder)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	27.05.2015	rectangle (0.1ha)	yes	no	no	169.1	26.0	12.5 ±8.7	41.4	15.5 ±12.8
115a (115)	395020	9780012	Musi Banyuasin	Peat (Gambut)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	14.04.2016	rectangle (0.1ha)	yes	yes	yes	0.0	0.0	0.0 ±0.0	0.0	0.0 ±0.0
128 (HP128)	400005	9794999	Musi Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	15.06.2015	rectangle (0.1ha)	no	no	no	342.2	37.8	16.7 ±11.8	52.4	19.5 ±17.1
140	280276	9674721	Musi Rawas	Secondary Peat Swamp Forest (Hutan Rawa Gambut Sekunder)	Dryland Agriculture mixed with Scrub	Mixed Dryland Agriculture / Mixed Garden (Pertanian Lehan Kering Campur Semak / Kebun Campur)	18.08.2015	rectangle (0.1ha)	no	no	no	59.8	15.0	10.6 ±3.1	15.6	12.4 ±3.0
142	260007	9674994	Musi Rawas Utara	Dryland Mixed Scrub (Lahan Kering Campur Semak)	NoData	NoData	13.08.2015	rectangle (0.1ha)	yes	no	no	51.9	21.6	9.7 ±7.3	48.4	15.9 ±15.9
143	254996	9675002	Musi Rawas Utara	Dryland Mixed Scrub (Lahan Kering Campur Semak)	NoData	NoData	14.08.2015	rectangle (0.1ha)	no	no	no	98.9	18.9	12.2 ±5.5	40.7	26.1 ±11.6
158	238904	9679564	Musi Rawas Utara	Mixed Dryland Agriculture Scrub (Pertanian Lahan Kering Campur Semak)	Low-density Lowland Dipterocarp Forest / Scrubland	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	18.09.2015	rectangle (0.1ha)	no	no	no	419.0	34.1	19.6 ±8.3	111.6	41.7 ±27.6
160	230992	9680925	Musi Rawas Utara	Mixed Dryland Agriculture Scrub (Pertanian Lahan Kering Campur Semak)	Low-density Lowland Dipterocarp Forest / Scrubland	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	17.09.2015	rectangle (0.1ha)	no	no	no	426.5	31.0	23.1 ±8.6	99.5	59.0 ±29.5
173	285023	9685049	Musi Rawas	Scrub (Semak Belukar)	Dryland Agriculture mixed with Scrub / Low-density Lowland Dipterocarp Forest / Rubber	Mixed Dryland Agriculture / Mixed Garden (Pertanian Lehan Kering Campur Semak / Kebun Campur)	15.08.2015	rectangle (0.1ha)	no	no	no	16.0	10.2	7.8 ±2.4	30.2	17.3 ±10.4
174	280339	9685201	Musi Rawas Utara	Secondary Peat Swamp Forest (Hutan Rawa Gambut Sekunder)	Industrial Forest	Plantation Forest (Hutan Tanaman)	16.08.2015	rectangle (0.1ha)	no	no	no	65.8	22.6	8.1 ±4.4	37.9	14.3 ±9.0
181	234702	9684692	Musi Rawas Utara	Mixed Dryland Agriculture Scrub (Pertanian Lahan Kering Campur Semak)	Low-density Lowland Dipterocarp Forest / Dryland Agriculture	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	15.09.2015	rectangle (0.1ha)	yes	no	no	137.6	30.4	16.0 ±6.9	43.0	25.3 ±12.2
203	229934	9692416	Musi Rawas Utara	Secondary Dryland Forest (Hutan Lahan Kering Sekunder)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	20.09.2015	rectangle (0.1ha)	yes	no	no	903.6	46.5	27.2 ±10.4	136.2	42.4 ±38.3
207	209994	9689931	Musi Rawas Utara	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	25.04.2016	rectangle (0.1ha)	yes	yes	no	419.8	35.0	19.1 ±7.9	66.1	25.7 ±17.7
226	229618	9695378	Musi Rawas Utara	Secondary Dryland Forest (Hutan Lahan Kering Sekunder)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.09.2015	rectangle (0.1ha)	yes	no	no	866.3	43.6	26.9 ±12.1	155.7	58.4 ±45.6

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273	359928	9720136	Musi Banyuasin	Natural Forest (Hutan Alam)	NoData	NoData	29.11.2015	rectangle (0.1ha)	yes	yes	no	161.3	31.5	11.7 ±4.4	34.5	15.7 ±7.2
285	409988	9724964	Musi Banyuasin	Palm Oil Plantation (Perkebunan Sawit)	NoData	NoData	18.09.2015	circle (0.04 ha)	no	no	no	8.2	1.3	0.9 ±0.3	0.0	0.0 ±0.0
290	353069	9725250	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	28.11.2015	rectangle (0.1ha)	no	yes	no	258.1	35.2	19.1 ±6.7	68.5	30.9 ±12.3
291	349991	9725004	Musi Banyuasin	Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	27.11.2015	rectangle (0.1ha)	no	yes	no	173.8	33.6	18.7 ±6.9	52.8	29.0 ±10.6
308	471001	9730111	Banyuasin	Mangrove (Mangrove)	Mangrove 1 / Young Mangrove	Primary Mangrove Forest (Hutan Mangrove Primer)	20.05.2015	rectangle (0.1ha)	no	no	no	146.8	22.7	12.6 ±7.3	37.6	17.5 ±12.5
313	404994	9730002	Banyuasin	Palm Oil Plantation (Perkebunan Sawit)	NoData	NoData	18.09.2015	circle (0.04 ha)	no	no	no	31.1	4.8	3.6 ±0.8	0.0	0.0 ±0.0
316	364889	9730465	Musi Banyuasin	Natural Forest (Hutan Alam)	NoData	NoData	01.12.2015	rectangle (0.1ha)	yes	yes	no	123.9	26.0	14.0 ±5.5	59.0	20.7 ±12.0
319	350016	9729985	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	26.11.2015	rectangle (0.1ha)	yes	yes	no	277.4	61.4	18.8 ±10.0	72.0	27.1 ±15.6
321	340000	9730000	Musi Banyuasin	Secondary Forest (Hutan Sekunder)	Road / Low-density Lowland Dipterocarp Forest	Settlement / Developed Land (Pemukiman / Lahan Terbangun)	15.09.2015	rectangle (0.1ha)	no	no	no	138.8	51.2	15.9 ±14.2	30.6	9.9 ±9.1
322	334983	9730149	Musi Banyuasin	Secondary Forest (Hutan Sekunder)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	14.09.2015	rectangle (0.1ha)	no	no	no	36.4	15.0	8.8 ±5.0	66.0	22.9 ±17.5
340	484937	9735105	Banyuasin	Mangrove - Nipa Palm (Nipah)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	04.04.2016	rectangle (0.1ha)	yes	yes	no	67.6	23.5	14.9 ±5.3	39.9	25.0 ±7.4
344	420001	9734997	Musi Banyuasin	Palm Oil Plantation (Perkebunan Sawit)	NoData	NoData	19.09.2015	circle (0.02 ha)	no	no	no	0.2	0.2	0.1 ±0.0	0.0	0.0 ±0.0
349	395003	9735003	Musi Banyuasin	Palm Oil Plantation (Perkebunan Sawit)	NoData	NoData	19.09.2015	circle (0.04 ha)	no	no	no	43.3	4.8	4.1 ±0.8	0.0	0.0 ±0.0
351	365033	9734871	Musi Banyuasin	Natural Forest (Hutan Alam)	NoData	NoData	30.11.2015	rectangle (0.1ha)	no	yes	no	183.3	26.2	12.8 ±4.6	51.5	19.6 ±11.6
354	350206	9734931	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	30.11.2015	rectangle (0.1ha)	no	yes	no	312.4	38.6	17.3 ±6.5	67.0	24.7 ±14.0
356	339981	9734973	Musi Banyuasin	Secondary Forest and Scrubs (Hutan Sekunder & Semak)	Acacia Plantation / Low-density Lowland Dipterocarp Forest	Plantation Forest (Hutan Tanaman)	16.09.2015	rectangle (0.1ha)	no	no	no	203.8	30.0	18.1 ±6.9	76.0	29.2 ±19.2
357	335006	9735015	Musi Banyuasin	Rubber Plantation (Hutan Tanaman Karet)	Rubber	Tree Crop Plantation (Perkebunan / Kebun)	16.09.2015	circle (0.02 ha)	no	no	no	99.3	17.9	14.2 ±2.5	20.0	16.9 ±2.7
358	329797	9734961	Musi Banyuasin	Secondary Forest (Hutan Sekunder)	NoData	NoData	17.09.2015	rectangle (0.1ha)	no	no	no	125.1	30.5	18.0 ±6.8	48.0	25.6 ±12.7
373	512041	9736364	Banyuasin	Mangrove (Mangrove)	Young Mangrove	Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	21.05.2015	rectangle (0.1ha)	no	no	no	125.7	26.2	11.5 ±7.3	42.6	17.4 ±13.7
374	499997	9739997	Banyuasian	Mangrove (Hutan Mangrove)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	04.05.2016	rectangle (0.1ha)	yes	yes	no	35.7	24.3	21.1 ±5.3	44.9	36.7 ±9.8

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378	420277	9737864	Musi Banyuasin	Secondary Swamp Forest (Hutan Rawa Sekunder)	NoData	NoData	20.09.2015	rectangle (0.1ha)	no	no	no	54.3	14.0	12.1 ±2.0	14.3	11.7 ±2.7
379	414724	9739968	Musi Banyuasin	Secondary Swamp Forest (Hutan Rawa Sekunder)	Low-density Freshwater Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	20.09.2015	rectangle (0.1ha)	no	no	no	155.5	18.6	10.6 ±4.3	34.2	13.9 ±8.5
380	409997	9739997	Musi Banyuasin	Swamp Scrub (Belukar Rawa)	Dryland Agriculture mixed with Scrub / Swamp Scrub	Mixed Dryland Agriculture / Mixed Garden (Pertanian Lehan Kering Campur Semak / Kebun Campur)	19.09.2015	rectangle (0.1ha)	no	no	no	20.3	7.2	4.5 ±1.1	9.5	3.8 ±2.4
391	310102	9741180	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	13.10.2015	rectangle (0.1ha)	no	yes	no	345.1	48.0	21.2 ±11.5	104.0	28.9 ±21.9
393	300177	9740152	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	11.10.2015	rectangle (0.1ha)	yes	yes	no	225.9	36.0	19.8 ±8.4	80.0	25.9 ±17.7
401	483093	9746100	Banyuasin	Mangrove (Mangrove)	Young Mangrove / Mangrove 1	Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	N/A	rectangle (0.1ha)	no	no	no	234.7	28.7	15.2 ±9.9	68.1	23.5 ±19.2
403	410001	9744999	Musi Banyuasin	Rubber Plantation (Kebun Karet)	Road	Settlement / Developed Land (Pemukiman / Lahan Terbangun)	19.09.2015	circle (0.02 ha)	no	no	no	0.3	4.7	3.3 ±0.7	3.4	2.6 ±0.6
405 (405a)	415884	9777060	Musi Banyuasin	Secondary Peat Swamp Forest (Gambut Sekunder)	Low-density Peat Swamp Forest / High-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	27.05.2015	rectangle (0.1ha)	no	no	no	107.3	27.9	8.2 ±7.0	41.2	10.4 ±11.9
406	394675	9745246	Musi Banyuasin	Rubber Plantation (Kebun Karet)	Dryland Agriculture mixed with Scrub / Low-density Lowland Dipterocarp Forest	Mixed Dryland Agriculture / Mixed Garden (Pertanian Lehan Kering Campur Semak / Kebun Campur)	18.09.2015	circle (0.04 ha)	yes	no	no	61.9	14.9	11.6 ±1.9	28.6	17.1 ±5.2
406a	410011	9770783	Musi Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	29.05.2015	rectangle (0.1ha)	no	no	no	151.7	17.7	10.8 ±5.1	37.2	14.6 ±10.7
414	319992	9744984	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	16.10.2015	rectangle (0.1ha)	no	yes	no	153.7	34.8	19.3 ±9.2	76.5	30.2 ±19.4
415	314132	9744875	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest / Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	15.10.2015	rectangle (0.1ha)	yes	yes	no	130.3	30.8	16.0 ±6.2	51.0	20.7 ±12.1
416	310050	9745019	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	14.10.2015	rectangle (0.1ha)	no	yes	no	241.6	37.6	23.0 ±7.4	102.0	34.8 ±19.3
417	303423	9745787	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	12.10.2015	rectangle (0.1ha)	yes	yes	no	397.1	36.3	18.7 ±6.7	94.0	29.5 ±19.1
421	399946	9750077	Musi Banyuasin	Rubber Plantation (Kebun Karet)	Dryland Agriculture / Dryland Agriculture mixed with Scrub	Dryland Agriculture (Pertanian Lahan Kering)	18.09.2015	circle (0.02 ha)	yes	no	no	2.3	5.9	5.1 ±0.6	8.9	6.5 ±2.1
431	310000	9750001	Musi Banyuasin	Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest / Water	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	17.10.2015	rectangle (0.1ha)	no	yes	no	369.8	36.6	17.2 ±9.0	100.5	34.5 ±24.5
434	485046	9754993	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	03.02.2016	rectangle (0.1ha)	yes	yes	no	305.3	27.3	20.0 ±5.5	56.2	34.2 ±14.7
446	309929	9755015	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	18.10.2015	rectangle (0.1ha)	no	yes	no	284.6	39.8	20.4 ±6.9	76.0	35.1 ±16.8

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[5] Forest type/land cover at plot location based on the land cover classification derived in WP 2 (year 2013-2015; Spot-6 and RapidEye)
[6] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[7] Date the plots was recorded (N/A = not available)
[8] Shape and size of the plot
[9] Is the plot located in one of the LiDAR transects?
[10] Was there also a biodiversity plot recorded?
[11] Was the plot recorded after the 2015 fires?
[12] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations
[13] Maximum tree height (meters) measured in the plot
[14] Mean tree height (meters) in the plot (± standard deviation)
[15] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot
[16] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation)

Plot ID[1]	X[2]	Y[2]	District[3]	Forest type / land cover tally sheet[4]	Forest type / land cover classification[5]	Forest type / land cover BAPLAN[6]	Date[7]	Shape / size[8]	LiDAR[9]	Biodiversity plot[10]	After 2015 fires[11]	AGB (t/ha)[12]	Max tree height (m)[13]	Mean tree height (m)[14]	Max DBH (cm)[15]	Mean DBH (cm)[16]
461	304847	9761193	Musi Banyuasin	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	19.10.2015	rectangle (0.1ha)	no	yes	no	436.9	31.7	18.5 ±7.3	70.0	29.3 ±19.1
481 (481a)	469027	9770717	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	02.02.2016	rectangle (0.1ha)	yes	yes	no	541.1	32.2	21.3 ±7.1	63.4	36.8 ±15.6
501 (501a)	459274	9773104	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	02.02.2016	rectangle (0.1ha)	yes	yes	no	190.6	24.5	16.5 ±5.1	56.3	29.5 ±13.7
502	454886	9774608	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	30.01.2016	rectangle (0.1ha)	yes	yes	no	354.3	25.8	18.6 ±3.7	62.0	35.2 ±12.5
504 (504a)	447400	9777388	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	30.01.2016	rectangle (0.1ha)	yes	yes	no	341.1	28.7	18.1 ±6.9	57.5	31.4 ±15.0
518	459098	9779263	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 2 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	29.01.2016	rectangle (0.1ha)	yes	yes	no	364.4	25.9	21.0 ±3.4	60.0	33.1 ±11.3
527	412319	9780062	Musi Banyuasin	Peat Swamp Forest (Hutan Rawa Gambut)	Low-density Peat Swamp Forest / High-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	14.04.2016	rectangle (0.1ha)	yes	yes	yes	22.8	11.9	10.0 ±1.5	22.5	14.4 ±4.0
528	404999	9780011	Musi Banyuasin	Peat Swamp Forest (Hutan Rawa Gambut)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	13.04.2016	rectangle (0.1ha)	yes	yes	yes	42.1	28.6	11.4 ±6.4	65.6	18.5 ±18.4
538 (538a)	454196	9785872	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	29.01.2016	rectangle (0.1ha)	yes	yes	no	309.0	26.3	17.2 ±5.5	54.4	27.6 ±12.1
539 (539a)	447919	9786916	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	01.02.2016	rectangle (0.1ha)	yes	yes	no	327.2	22.9	16.2 ±4.8	77.3	27.6 ±15.6
542 (542a)	434668	9785304	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	31.01.2016	rectangle (0.1ha)	yes	yes	no	175.6	23.9	13.7 ±6.1	50.0	24.8 ±14.4
561	440103	9790074	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	01.02.2016	rectangle (0.1ha)	yes	yes	no	202.4	27.2	16.3 ±7.0	54.0	34.5 ±15.4
566	414954	9789958	Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	NoData	NoData	23.08.2015	rectangle (0.1ha)	no	no	no	406.5	42.3	22.0 ±11.1	126.0	37.0 ±29.4
583	415819	9795171	Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	High-density Peat Swamp Forest / Heath Forest	Primary Swamp Forest (Hutan Rawa Primer)	25.08.2015	rectangle (0.1ha)	no	no	no	503.1	39.2	23.8 ±10.7	85.3	37.3 ±21.8
596 (596a)	438823	9802425	Banyuasin	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	31.01.2016	rectangle (0.1ha)	yes	yes	no	284.2	25.6	18.9 ±5.4	70.0	35.0 ±17.3
601	414123	9800087	Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	27.08.2015	rectangle (0.1ha)	no	no	no	452.1	35.2	21.1 ±9.6	73.5	32.0 ±19.5
602	400035	9799983	Musi Banyuasin	Rubber Scrub (Karet Belukar)	NoData	NoData	14.06.2015	rectangle (0.1ha)	yes	no	no	86.5	23.3	10.7 ±6.7	48.4	12.9 ±13.7
603	394994	9800414	Musi Banyuasin	Secondary Peat Swamp Forest (Hutan Gambut Sekunder)	Bare Area / High-density Peat Swamp Forest	Open Land (Tanah Terbuka)	14.06.2015	rectangle (0.1ha)	no	no	no	123.5	19.5	11.7 ±6.7	33.7	15.2 ±10.8
604	388935	9798461	Musi Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	13.06.2015	rectangle (0.1ha)	no	no	no	147.2	33.9	10.7 ±8.4	54.0	11.4 ±14.1
614	395036	9804983	Musi Banyuasin	Rubber Plantation (Kebun Karet)	NoData	NoData	14.06.2015	circle (0.04 ha)	no	no	no	42.2	16.1	13.3 ±3.2	24.9	16.3 ±5.4
615	390018	9804990	Musi Banyuasin	Secondary Mixed Agriculture (Pertanian campuran sekunder)	NoData	NoData	15.06.2015	rectangle (0.1ha)	no	no	no	103.1	18.9	5.6 ±8.9	27.1	27.1 ±13.5
622	413271	9810044	Banyuasin	Secondary Peat Swamp Forest (Rawa Gambut Sekunder)	High-density Peat Swamp Forest	Primary Swamp Forest (Hutan Rawa Primer)	21.08.2015	rectangle (0.1ha)	no	no	no	413.8	32.3	21.2 ±8.3	91.6	34.7 ±19.3

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[7] Date the plots was recorded (N/A = not available)
[8] Shape and size of the plot
[9] Is the plot located in one of the LiDAR transects?
[10] Was there also a biodiversity plot recorded?
[11] Was the plot recorded after the 2015 fires?
[12] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations
[13] Maximum tree height (meters) measured in the plot
[14] Mean tree height (meters) in the plot (± standard deviation)
[15] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot
[16] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation)

Appendix B: Overview biodiversity plots

Plot ID[1]	Forest type / land cover tally sheet[2]	Forest type / land cover Classification[3]	Forest type / land cover BAPLAN[4]	LiDAR[5]	After 2015 fires[6]	AGB (t/ha)[7]	Max tree height (m)[8]	Mean tree Height (m)[9]	Max DBH (cm)[10]	Mean DBH (cm)[11]
1	Low Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest / Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	151.0	28.5	18.7 ±4.0	56.7	27.4 ±10.4
						151.0	28.5	18.7 ±4.0	56.7	27.4 ±10.4
2	Medium Natural Forest (Hutan Alam)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	yes	no	238.4	28.4	15.8 ±5.6	56.2	21.7 ±13.4
						236.8	28.4	15.9 ±5.5	56.2	22.0 ±13.4
3	Low Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest / Road	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	26.3	11.5	8.5 ±1.7	12.0	7.8 ±2.3
						9.8	11.5	10.9 ±0.5	12.0	11.1 ±0.8
4	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	284.5	30.8	15.1 ±4.9	66.0	19.9 ±12.0
						280.3	30.8	15.3 ±4.8	66.0	20.4 ±12.0
4a	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	534.8	58.2	21.2 ±11.4	98.3	28.7 ±20.2
						533.1	58.2	21.6 ±11.3	98.3	29.2 ±20.2
4b (4)	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	183.2	35.2	16.0 ±7.1	62.5	19.6 ±11.7
						174.3	35.2	17.3 ±6.7	62.5	21.5 ±11.3
5	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	181.1	32.5	15.8 ±5.2	74.0	21.6 ±13.5
						175.3	32.5	16.1 ±5.1	74.0	22.3 ±13.5
5a (5)	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest / Water	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	250.5	51.9	14.4 ±7.3	59.7	19.4 ±11.9
						238.8	51.9	15.7 ±7.0	59.7	21.6 ±11.3
6	Medium Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	51.0	19.6	12.5 ±2.8	28.7	14.1 ±5.1
						46.7	19.6	12.9 ±2.5	28.7	14.7 ±4.8
7	Timber Plantation (Hutan Tanaman)	NoData	NoData	yes	no	89.6	27.2	14.6 ±4.7	51.8	18.7 ±10.1
						84.2	27.2	15.5 ±4.2	51.8	20.4 ±9.6
8a (8)	Secondary Forest (Hutan Sekunder)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	183.3	27.4	15.3 ±5.8	86.5	21.7 ±13.7
						181.7	27.4	15.7 ±5.5	86.5	22.4 ±13.6
9	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	220.1	26.8	17.4 ±5.2	50.2	25.0 ±12.4
						218.3	26.8	17.6 ±5.1	50.2	25.4 ±12.3
9a (9)	Mixed Farms (Kebun Campuran)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	72.6	23.6	13.8 ±4.0	58.2	23.0 ±11.0
						72.6	23.6	13.8 ±4.0	58.2	23.0 ±11.0
10	Medium Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	218.5	31.3	15.1 ±5.3	68.3	20.1 ±13.0
						217.3	31.3	15.4 ±5.2	68.3	20.7 ±12.9
10a (10)	Mixed Rubber Plantation (Kebun Karet Campuran)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	28.9	13.8	10.6 ±1.7	23.0	15.5 ±3.9
						28.9	13.8	10.6 ±1.7	23.0	15.5 ±3.9
11	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	116.6	35.0	14.4 ±7.0	56.7	19.1 ±10.7
						116.1	35.0	14.9 ±6.7	56.7	19.8 ±10.5
12 (12a)	Primary Dryland Forest (Hutan Lahan Kering Primer)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	yes	no	282.9	36.5	16.3 ±5.6	95.2	23.0 ±16.0
						278.1	36.5	16.8 ±5.4	95.2	24.0 ±16.1
13	Primary Dryland Forest (Hutan Lahan Kering Primer)	High-density Lowland Dipterocarp Forest	Primary Dryland Forest (Hutan Lahan Kering Primer)	yes	no	174.3	29.9	16.7 ±5.4	62.4	23.7 ±13.5
						173.2	29.9	17.0 ±5.3	62.4	24.2 ±13.4
15	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest / High-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	157.1	42.7	14.2 ±6.0	63.3	17.9 ±10.1
						150.9	42.7	14.8 ±6.0	63.3	19.0 ±9.9
18	Secondary Garden (Kebun Sekunder)	Low-density Lowland Dipterocarp Forest / Dryland Agriculture	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	119.3	21.9	14.0 ±3.2	34.9	16.9 ±6.3
						113.8	21.9	14.3 ±2.9	34.9	17.5 ±6.0
19	Mixed Garden (Kebun Campur)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	140.1	35.8	15.5 ±7.5	79.6	22.6 ±18.7
						137.5	35.8	16.2 ±7.5	79.6	24.1 ±18.9

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[3] Forest type/land cover at plot location based on the land cover classification derived in WP 2
[4] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[5] Is the plot located in one of the LiDAR transects?
[6] Was the plot recorded after the 2015 fires?
[7] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations (lower value only for large plot)
[8] Maximum tree height (meters) calculated for the plot (lower value only for large plot)
[9] Mean tree height (meters) calculated for the plot (± standard deviation; lower value only for large plot)
[10] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot (lower value only for large plot)
[11] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation; lower value only for large plot)

Plot ID[1]	Forest type / land cover tally sheet[2]	Forest type / land cover Classification[3]	Forest type / land cover BAPLAN[4]	LiDAR[5]	After 2015 fires[6]	AGB (t/ha)[7]	Max tree height (m)[8]	Mean tree Height (m)[9]	Max DBH (cm)[10]	Mean DBH (cm)[11]
28	Mangrove - Nipa Palm (Mangrove - Nipah)	Young mangrove	Secondary / Logged over Mangrove Forest (Hutan Mangrove Sekunder / Bekas Tebangan)	yes	no	105.1	28.1	14.2 ±3.1	55.1	17.4 ±6.6
						101.4	28.1	14.5±2.9	55.1	17.8 ±6.5
30	Mangrove (Hutan Mangrove)	Mangrove 1	Primary Mangrove Forest Hutan Mangrove Primer)	yes	no	53.6	21.2	14.0 ±4.3	46.2	28.6 ±10.0
						53.6	21.2	14.0 ±4.3	46.2	28.6 ±10.0
32	Mangrove (Mangrove)	Mangrove 1 / Young mangrove	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	301.9	32.7	14.9 ±6.5	75.0	20.7 ±16.9
						290.7	32.7	15.8 ±6.4	75.0	22.5 ±17.3
34	Mangrove (Hutan Mangrove)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	238.7	23.3	15.0 ±4.6	53.2	23.6 ±12.0
						238.7	23.3	15.0 ±4.6	53.2	23.6 ±12.0
110 (110a)	Secondary Forest Burned (Hutan sekunder Bekas Terbakar)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	yes	8.9	14.8	10.6 ±3.4	23.4	14.4 ±3.9
						8.9	14.8	10.6 ±3.4	23.4	14.4 ±3.9
115a (115)	Peat (Gambut)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	yes	yes	0.0	0.0	0.0 ±0.0	0.0	0.0 ±0.0
						0.0	0.0	0.0 ±0.0	0.0	0.0 ±0.0
207	Primary Highland Forest (Hutan Primer Dataran Tinggi)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	272.0	32.2	16.5 ±6.0	54.5	18.7 ±12.4
						255.5	32.2	17.8 ±5.6	54.5	20.8 ±12.3
273	Natural Forest (Hutan Alam)	NoData	NoData	yes	no	76.4	21.6	13.3 ±2.6	34.0	15.5 ±5.1
						76.4	21.6	13.3 ±2.6	34.0	15.5 ±5.1
290	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	208.3	31.2	15.8 ±5.6	68.0	21.7 ±13.3
						208.3	31.2	15.8 ±5.6	68.0	21.7 ±13.3
291	Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	131.9	27.5	16.6 ±5.0	53.0	23.1 ±11.5
						131.9	27.5	16.6 ±5.0	53.0	23.1 ±11.5
316	Natural Forest (Hutan Alam)	NoData	NoData	yes	no	81.2	24.0	15.0 ±4.3	41.0	19.5 ±9.7
						81.2	24.0	15.0 ±4.3	41.0	19.5 ±9.7
319	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	161.7	32.1	17.2 ±5.9	72.0	25.0 ±15.3
						161.7	32.1	17.2 ±5.9	72.0	25.0 ±15.3
340	Mangrove - Nipa Palm (Nipah)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	35.9	23.6	17.2 ±3.2	39.9	23.5 ±7.5
						35.9	23.6	17.2 ±3.2	39.9	23.5 ±7.5
351	Natural Forest (Hutan Alam)	NoData	NoData	no	no	117.5	27.0	15.0 ±4.5	51.0	19.6 ±10.5
						117.5	27.0	15.0 ±4.5	51.0	19.6 ±10.5
354	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	169.1	31.0	15.6 ±4.9	67.0	20.9 ±12.3
						169.1	31.0	15.6 ±4.9	67.0	20.9 ±12.3
374	Mangrove (Hutan Mangrove)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	53.6	24.3	16.1 ±7.0	40.7	26.3 ±11.3
						53.6	24.3	16.1 ±7.0	40.7	26.3 ±11.3
391	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	323.7	37.9	15.6 ±5.0	104.0	21.2 ±14.3
						323.7	37.9	15.6 ±5.0	104.0	21.2 ±14.3
393	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	218.0	33.7	14.5 ±4.3	80.0	18.5 ±10.6
						216.5	33.7	14.7 ±4.2	80.0	18.8 ±10.5
414	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	129.9	26.7	14.4 ±4.8	50.0	18.6 ±10.8
						127.5	26.7	14.7 ±4.8	50.0	19.1 ±10.8
415	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest / Low-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	146.6	27.0	13.7 ±4.2	51.0	16.8 ±8.7
						133.7	27.0	14.6 ±3.8	51.0	18.3 ±8.4
416	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	188.5	27.7	17.3 ±5.1	53.5	24.8 ±11.9
						188.5	27.7	17.3 ±5.1	53.5	24.8 ±11.9
417	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	yes	no	373.6	36.3	16.1 ±5.8	94.0	22.7 ±15.4
						371.2	36.3	16.2 ±5.8	94.0	22.9 ±15.4
431	Natural Forest (Hutan Alam)	Low-density Lowland Dipterocarp Forest / Water	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	450.4	37.4	14.8 ±6.5	100.5	20.5 ±17.3
						441.8	37.4	15.5 ±6.3	100.5	22.0 ±17.6
434	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	271.2	28.4	17.3 ±5.3	56.2	24.8 ±13.5
						271.2	28.4	17.3 ±5.3	56.2	24.8 ±13.5

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[3] Forest type/land cover at plot location based on the land cover classification derived in WP 2
[4] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[5] Is the plot located in one of the LiDAR transects?
[6] Was the plot recorded after the 2015 fires?
[7] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations (lower value only for large plot)
[8] Maximum tree height (meters) calculated for the plot (lower value only for large plot)
[9] Mean tree height (meters) calculated for the plot (± standard deviation; lower value only for large plot)
[10] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot (lower value only for large plot)
[11] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation; lower value only for large plot)

Plot ID[1]	Forest type / land cover tally sheet[2]	Forest type / land cover Classification[3]	Forest type / land cover BAPLAN[4]	LiDAR[5]	After 2015 fires[6]	AGB (t/ha)[7]	Max tree height (m)[8]	Mean tree Height (m)[9]	Max DBH (cm)[10]	Mean DBH (cm)[11]
446	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	282.9	32.9	17.6 ±5.9	76.0	26.0 ±15.2
						278.4	32.9	18.0 ±5.8	76.0	26.8 ±15.0
461	Natural Forest (Hutan Alam)	Medium-density Lowland Dipterocarp Forest	Secondary / Logged over Dryland Forest (Hutan Lahan Kering Sekunder / Bakas Tebangan)	no	no	348.9	31.7	15.7 ±6.3	70.0	22.1 ±15.8
						341.3	31.7	16.3 ±6.1	70.0	23.3 ±15.9
481 (48a)	Primary Mangrove (Mangrove Primer)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	640.2	30.2	18.1 ±4.6	63.4	26.3 ±11.8
						635.7	30.2	18.3 ±4.4	63.4	26.7 ±11.6
501 (501a)	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	237.0	28.4	16.7 ±4.7	56.3	23.1 ±11.3
						237.0	28.4	16.7 ±4.7	56.3	23.1 ±11.3
502	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	340.5	29.8	18.7 ±5.6	62.0	28.4 ±13.8
						340.3	29.8	19.1 ±5.2	62.0	29.0 ±13.4
504 (504a)	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	336.5	28.7	17.1 ±5.5	57.5	24.4 ±12.8
						330.3	28.7	17.8 ±5.1	57.5	25.9 ±12.2
518	Primary Mangrove (Mangrove Primer)	Mangrove 2 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	186.7	24.6	19.5 ±3.1	43.0	29.1 ±7.5
						186.7	24.6	19.5 ±3.1	43.0	29.1 ±7.5
527	Peat Swamp Forest (Hutan Rawa Gambut)	Low-density Peat Swamp Forest / High-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	yes	yes	61.1	15.6	11.9 ±1.9	24.4	16.8 ±3.4
						61.1	15.6	11.9 ±1.9	24.4	16.8 ±3.4
528	Peat Swamp Forest (Hutan Rawa Gambut)	Low-density Peat Swamp Forest	Secondary / Logged over Swamp Forest (Hutan Rawa Sekunder / Bakas Tebangan)	yes	yes	6.5	12.7	10.7 ±1.1	13.2	10.7 ±1.5
						6.5	12.7	10.7 ±1.1	13.2	10.7 ±1.5
538 (538a)	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	236.1	27.9	16.7 ±3.9	54.4	22.8 ±9.3
						233.9	27.9	16.9 ±3.8	54.4	23.1 ±9.2
539 (539a)	Primary Mangrove (Mangrove Primer)	Mangrove 1 / Water	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	277.0	33.2	16.9 ±4.7	77.3	23.7 ±12.3
						277.0	33.2	16.9 ±4.7	77.3	23.7 ±12.3
542 (542a)	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	223.0	26.7	15.0 ±4.5	50.0	19.5 ±10.0
						209.8	26.7	15.8 ±4.1	50.0	21.0 ±9.7
561	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	221.0	26.1	15.1 ±5.3	48.0	20.1 ±12.0
						214.5	26.1	15.7 ±5.1	48.0	21.3 ±11.9
596 (596a)	Primary Mangrove (Mangrove Primer)	Mangrove 1	Primary Mangrove Forest (Hutan Mangrove Primer)	yes	no	319.2	31.7	17.9 ±6.1	70.0	26.8 ±15.4
						318.0	31.7	18.2 ±5.9	70.0	27.4 ±15.3

[1] In brackets the plot ID from the tally sheets
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[3] Forest type/land cover at plot location based on the land cover classification derived in WP 2
[4] Forest type/land cover translated to the BAPLAN classification system (in brackets Bahasa Indonesia)
[5] Is the plot located in one of the LiDAR transects?
[6] Was the plot recorded after the 2015 fires?
[7] Aboveground biomass (AGB) in tons per hectare for the plot derived from allometric equations (lower value only for large plot)
[8] Maximum tree height (meters) calculated for the plot (lower value only for large plot)
[9] Mean tree height (meters) calculated for the plot (± standard deviation; lower value only for large plot)
[10] Maximum Diameter at Breast Height (DBH) (centimeters) measured in the plot (lower value only for large plot)
[11] Mean Diameter at Breast Height (DBH) (centimeters) in the plot (± standard deviation; lower value only for large plot)

Appendix C: Overview LiDAR metrics lowland dipterocarp forest

Plot ID[1]	Forest type Classification[2]	QMCH[3]	CH[4]	Max[5]	Mean	SD[6]	Forest cover at[7]						Height percentile							
							1m	2m	5m	7m	10m	12m	5th	10th	25th	50th	75th	90th	95th	99th
1	Low-density Lowland Dipterocarp Forest	22.81	16.18	41.91	14.97	9.81	95.40	92.90	82.20	75.30	65.30	59.60	1.37	2.96	7.14	14.41	20.30	27.83	36.07	40.77
2	High-density Lowland Dipterocarp Forest	28.18	21.02	36.91	19.96	9.37	93.20	92.30	89.00	86.10	82.40	79.30	0.57	5.08	14.35	21.15	26.93	31.26	33.86	36.00
4	Medium-density Lowland Dipterocarp Forest	13.84	10.32	23.15	9.91	5.33	93.60	91.80	77.50	66.70	46.20	34.80	1.27	3.20	5.74	9.58	13.64	17.29	19.44	21.84
4a	Medium-density Lowland Dipterocarp Forest	33.14	23.58	48.88	23.07	11.74	97.40	96.90	94.00	91.20	86.60	81.70	4.31	7.87	14.37	22.00	32.07	39.51	42.64	47.50
4b (4)	Medium-density Lowland Dipterocarp Forest	20.01	16.56	44.60	16.37	10.79	86.20	83.60	77.00	71.60	62.70	57.20	0.47	2.02	7.87	16.12	23.88	29.79	38.23	42.90
5	Medium-density Lowland Dipterocarp Forest	23.20	17.29	37.71	16.39	9.22	87.90	85.00	79.00	75.40	70.40	66.90	0.44	1.42	8.96	18.55	23.32	26.18	29.54	34.95
5a (5)	Medium-density Lowland Dipterocarp Forest	21.09	16.89	39.25	14.04	12.69	78.40	67.40	56.20	52.90	48.20	45.40	0.17	0.43	1.77	11.24	24.54	33.70	35.96	38.30
6	Low-density Lowland Dipterocarp Forest	10.40	8.64	17.16	7.24	4.67	82.80	79.40	67.00	54.30	33.80	18.10	0.13	0.23	3.07	7.62	11.15	13.30	14.33	15.77
7a (7)	Low-density Lowland Dipterocarp Forest	13.53	11.49	21.46	9.53	6.69	76.40	73.80	64.60	58.80	48.30	42.60	0.13	0.25	2.49	10.08	15.73	17.81	18.70	19.84
8a (8)	Medium-density Lowland Dipterocarp Forest	19.91	14.34	29.27	13.45	7.31	94.70	93.20	85.40	76.40	64.60	56.10	1.06	3.78	7.34	13.44	18.97	23.77	25.44	27.91
9	Medium-density Lowland Dipterocarp Forest	23.79	17.57	34.47	16.81	9.15	93.60	92.00	84.00	79.10	72.60	67.40	1.03	3.21	9.34	18.34	23.56	28.93	30.78	33.14
9a (9)	Low-density Lowland Dipterocarp Forest	8.69	8.79	18.31	6.17	5.17	62.80	61.00	50.90	42.90	26.70	15.20	0.09	0.17	0.49	6.07	10.49	13.28	14.64	17.28
10	Medium-density Lowland Dipterocarp Forest	23.70	16.98	42.87	15.88	9.25	93.00	90.90	85.40	82.40	72.60	65.40	0.49	2.49	9.25	15.73	22.68	26.60	31.50	39.61
10a (10)	Low-density Lowland Dipterocarp Forest	9.42	7.42	15.50	6.53	4.13	82.30	75.90	61.70	49.10	25.30	7.70	0.23	0.52	2.50	7.04	10.07	11.75	12.34	13.51
11	Medium-density Lowland Dipterocarp Forest	41.82	29.37	52.29	28.08	12.98	96.60	95.30	92.20	89.60	86.70	84.10	3.23	7.41	18.88	30.84	38.19	43.71	45.93	49.24
12 (12a)	High-density Lowland Dipterocarp Forest	24.83	18.23	37.41	18.08	9.25	96.10	94.80	86.90	82.00	74.30	69.60	2.51	4.46	10.07	19.37	25.20	29.23	32.74	35.99
13	High-density Lowland Dipterocarp Forest	42.71	29.80	48.75	29.02	11.60	98.40	97.50	94.60	93.00	90.10	88.50	5.16	10.72	22.57	31.18	38.27	42.65	44.34	46.07
15	Medium-density Lowland Dipterocarp Forest	33.96	24.85	49.64	24.09	13.51	97.50	96.30	92.70	88.10	80.30	75.00	4.12	6.59	12.26	23.36	36.59	41.86	45.14	48.22
18	Low-density Lowland Dipterocarp Forest	17.94	13.32	23.86	12.71	6.14	89.20	86.80	83.50	79.60	69.10	59.80	0.48	1.35	9.06	14.10	17.59	19.49	20.43	22.21

[1] In brackets the plot ID from the tally sheets
[2] Forest type/land cover at plot location based on the land cover classification derived in WP 2
[3] Quadratic Mean Canopy Height (QMCH)
[4] Centroid Height (CH)
[5] Maximum (Max) height
[6] Standard deviation (SD) of height
[7] Forest cover at 1-12m from 0(0%)-1(100%)

Plot ID[1]	Forest type Classification[2]	QMCH[1]	CH[2]	Max[3]	Mean[4]	SD[5]	Forest cover at						Height percentile							
							1m	2m	5m	7m	10m	12m	5th	10th	25th	50th	75th	90th	95th	99th
19	Low-density Lowland Dipterocarp Forest	6.10	5.27	18.22	3.82	4.30	52.20	37.70	26.60	22.20	10.10	4.60	0.12	0.24	0.59	1.44	7.31	10.40	12.17	15.79
110 (110a)	Medium-density Lowland Dipterocarp Forest	-	-	35.54	13.90	7.57	92.70	90.90	83.00	75.80	66.30	58.80	0.80	3.14	7.96	14.71	19.57	23.06	24.81	32.23
207	Medium-density Lowland Dipterocarp Forest	27.12	19.65	47.63	20.04	9.21	97.20	96.60	93.80	91.50	86.40	82.10	4.58	8.24	14.08	19.45	26.11	33.65	35.24	42.69
273	NoData[7]	11.97	9.60	19.38	8.40	5.49	78.70	76.30	65.50	55.70	44.10	31.90	0.13	0.25	3.51	9.22	13.09	15.34	16.23	17.94
290	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
291	Low-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
316	NoData	13.73	11.41	39.47	9.27	9.04	70.00	67.60	57.30	52.30	40.90	24.30	0.09	0.17	0.73	8.88	12.10	22.19	29.63	37.80
319	Medium-density Lowland Dipterocarp Forest	16.34	12.43	37.64	10.96	9.05	84.60	78.60	62.50	57.50	47.40	40.90	0.20	0.50	2.76	9.69	16.92	22.26	30.98	34.82
351	NoData	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
354	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
391	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
393	Medium-density Lowland Dipterocarp Forest	27.83	20.53	43.58	19.90	9.89	95.00	94.20	89.70	86.30	81.20	76.00	2.22	5.49	12.72	20.63	27.87	32.74	35.41	38.02
414	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
415	Medium-density Lowland Dipterocarp Forest	15.30	11.54	24.14	10.74	6.13	90.70	87.30	75.80	67.30	53.50	45.10	0.55	1.93	5.87	11.08	15.23	19.04	20.78	22.15
416	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
417	Medium-density Lowland Dipterocarp Forest	26.46	19.93	41.43	19.85	9.97	94.70	93.60	89.30	86.40	80.40	74.50	2.24	5.76	12.29	20.48	28.06	32.68	34.73	38.42
431	Low-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
446	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
461	Medium-density Lowland Dipterocarp Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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[3] Quadratic Mean Canopy Height (QMCH)
[4] Centroid Height (CH)
[5] Maximum (Max) height
[6] Standard deviation (SD) of height
[7] Forest cover at 1-12m from 0(0%)-1(100%)

Appendix D: Overview nMDS scores and biodiversity indices lowland dipterocarp forest

Plot ID[1]	Forest type Classification[2]	Forest type AGB stratification[3]	Forest type Forest cover 10m startification[4]	nMDS scores Class. stratification[5]		nMDS scores AGB stratification[6]		nMDS scores forest cover 10m stratification[7]		Simpson index 1-D	Shannon index (entropy)	Margalef's richness index	Equitability
				Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2				
1	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-0.075	-0.013	-0.068	-0.008	-0.052	-0.108	0.875	2.412	4.219	0.870
2	High-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.121	0.009	0.107	-0.034	0.084	0.062	0.941	3.062	6.518	0.929
4	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.084	-0.030	0.057	-0.073	0.079	0.013	0.949	3.310	8.266	0.924
4a	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.127	-0.058	0.095	-0.107	0.140	-0.037	0.936	2.946	6.005	0.940
4b (4)	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.061	-0.041	0.034	-0.068	0.042	-0.010	0.952	3.138	6.493	0.963
5	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.037	-0.186	-0.042	-0.184	0.085	-0.163	0.896	2.631	5.223	0.878
5a (5)	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.061	-0.042	0.041	-0.077	0.078	-0.036	0.932	2.926	5.728	0.909
6	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	-0.097	0.138	-0.068	0.139	-0.107	0.156	0.810	2.069	3.100	0.807
7a (7)	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-0.196	-0.026	-0.189	0.039	-0.225	0.021	0.720	1.632	2.424	0.709
8a (8)	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.018	-0.047	0.003	-0.059	0.031	-0.064	0.934	2.980	6.342	0.926
9	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.017	0.032	0.027	0.018	-0.002	0.019	0.942	3.014	6.154	0.948
9a (9)	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	-0.188	-0.145	-0.225	-0.086	-0.221	-0.061	0.725	1.869	3.376	0.752
10	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.054	-0.028	0.045	-0.052	0.061	-0.032	0.955	3.276	7.669	0.954
10a (10)	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	-0.321	-0.207	-0.367	-0.066	-0.384	-0.033	0.392	0.807	1.039	0.501
11	Medium-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.101	-0.029	0.077	-0.074	0.100	-0.007	0.949	3.121	6.777	0.958
12 (12a)	High-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.160	-0.009	0.138	-0.072	0.153	0.034	0.936	2.886	5.285	0.948
13	High-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.230	0.094	0.233	0.004	0.224	0.122	0.870	2.383	3.938	0.880
15	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.010	-0.071	-0.017	-0.075	0.008	-0.052	0.934	2.921	5.746	0.932
18	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-0.101	-0.114	-0.138	-0.078	-0.135	-0.038	0.889	2.605	4.864	0.843

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[3] Forest type at plot location based on the aboveground biomass (AGB) stratification
[4] Forest type at plot location based on the forest cover at 10m height (from LiDAR) stratification
[5] nMDS scores based on the land cover classification derived in WP 2
[6] nMDS scores based on the aboveground biomass (AGB) stratification
[7] nMDS scores based on the forest cover at 10m height (from LiDAR) stratification

Plot ID[1]	Forest type Classification[2]	Forest type AGB stratification[3]	Forest type Forest cover 10m startification[4]	nMDS scores Class. stratification[5]		nMDS scores AGB stratification[5]		nMDS scores forest cover 10m stratification[6]		Simpson index 1-D	Shannon index (entropy)	Margalef's richness index	Equitability
				Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2				
19	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	-0.387	0.110	0.180	0.317	-0.143	-0.351	0.780	1.748	2.337	0.840
110 (110a)	Medium-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	0.143	-0.225	0.012	-0.261	0.206	-0.184	0.893	2.272	3.753	0.987
207	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.095	-0.065	0.063	-0.104	0.070	0.009	0.930	2.894	5.689	0.911
273	NoData[7]	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-	-	-0.148	0.211	-0.211	0.220	0.750	1.759	2.950	0.667
290	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	NoData	-0.134	0.091	-0.078	0.132	-	-	0.859	2.436	4.492	0.843
291	Low-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	NoData	-0.126	0.101	-0.102	0.102	-	-	0.900	2.568	4.465	0.906
316	NoData	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-	-	-0.039	0.010	-0.043	0.027	0.932	2.819	5.242	0.957
319	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-0.082	0.180	-0.122	0.111	-0.074	0.179	0.885	2.571	4.905	0.890
351	NoData	Low-density Lowland Dipterocarp Forest	NoData	-	-	0.007	0.137	-	-	0.891	2.535	4.578	0.877
354	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	NoData	-0.042	0.035	-0.028	0.036	-	-	0.902	2.710	5.624	0.864
391	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	NoData	0.057	0.036	0.064	0.000	-	-	0.958	3.371	8.206	0.948
393	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.135	0.068	0.144	0.001	0.158	0.086	0.955	3.286	7.345	0.940
414	Medium-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	NoData	0.016	0.078	0.031	0.052	-	-	0.914	2.717	5.021	0.907
415	Medium-density Lowland Dipterocarp Forest	Low-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	-0.016	0.089	0.001	0.076	-0.011	0.125	0.928	3.020	6.622	0.906
416	Medium-density Lowland Dipterocarp Forest	Medium-density Lowland Dipterocarp Forest	NoData	0.096	0.036	0.092	-0.009	-	-	0.949	3.138	6.871	0.952
417	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	0.093	0.082	0.100	0.030	0.088	0.102	0.964	3.453	8.384	0.964
431	Low-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	NoData	0.064	0.060	0.070	0.019	-	-	0.916	2.916	6.547	0.866
446	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	NoData	-0.044	-0.016	-0.051	-0.031	-	-	0.935	2.935	5.814	0.936
461	Medium-density Lowland Dipterocarp Forest	High-density Lowland Dipterocarp Forest	NoData	0.030	0.111	0.059	0.083	-	-	0.938	3.094	6.839	0.919

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