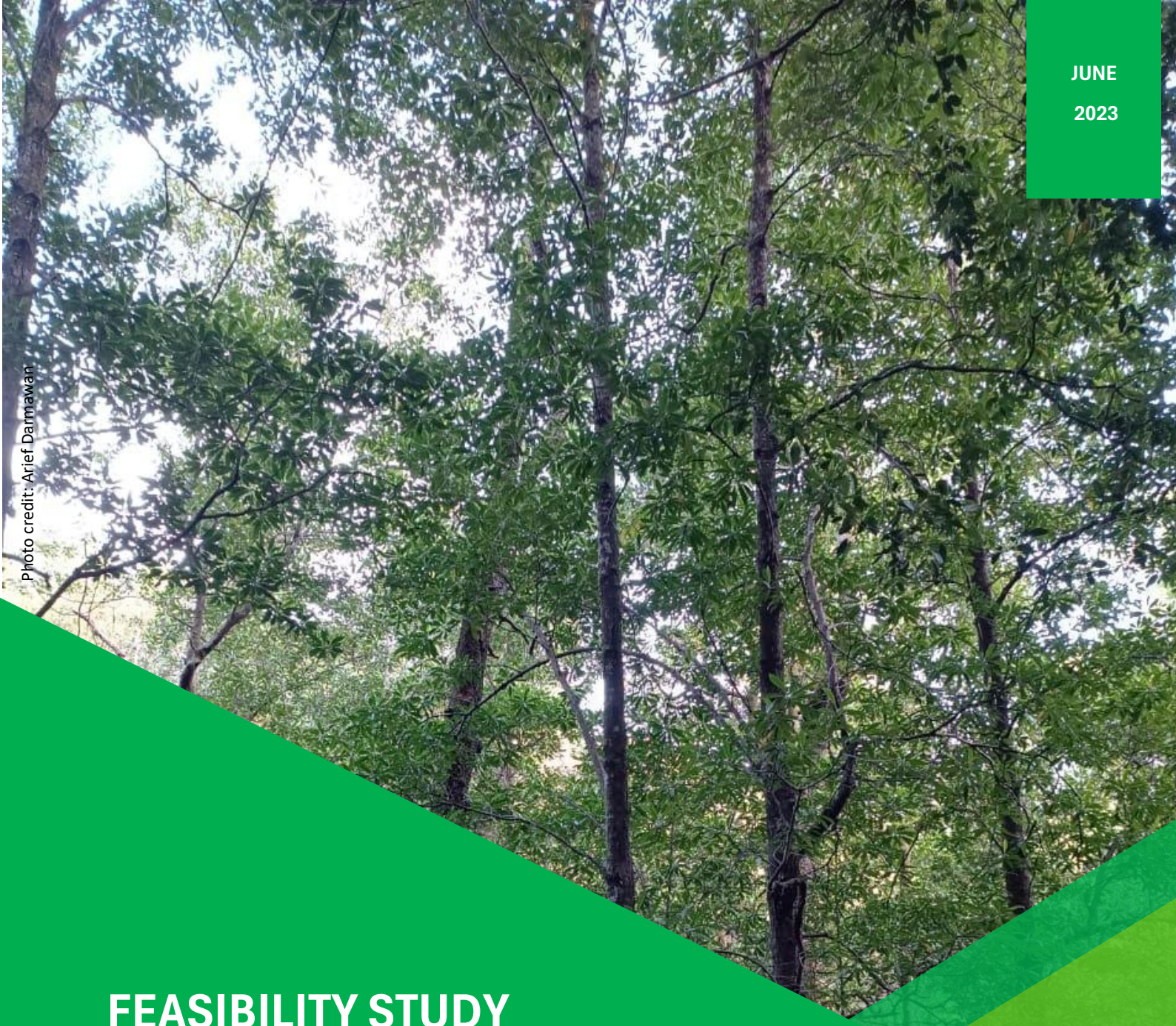

Photo credit: Arief Darmawan

JUNE
2023

FEASIBILITY STUDY FOR BP FOREST CARBON OFFSET PROJECT

CARBON STOCK ASSESSMENT IN WATERSHED REHABILITATION AREA , BINTUNI BAY - WEST PAPUA PROVINCE

IPB University
Bogor Indonesia

bp

KATA PENGANTAR

Laporan penelitian Survei Karbon Hutan di Areal Rehabilitasi Hutan di DAS Teluk Bintuni ini merupakan bagian dari kegiatan kerjasama antara BP Berau Ltd dan Fakultas Kehutanan dan Lingkungan IPB yang berjudul : Studi Kelayakan Proyek Offset Karbon Hutan di Provinsi Papua Barat.

BP Berau Ltd. adalah perusahaan minyak dan gas yang beroperasi di Kabupaten Teluk Bintuni, berkomitmen untuk mengurangi emisi gas rumah kaca dari kegiatan Perusahaan hingga mencapai 1 juta ton CO2 per tahun. Target pengurangan emisi sebagian akan diperoleh melalui offset emisi yang berbasis dari pengelolaan hutan di wilayah Papua Barat. Melalui penelitian studi kelayakan akan dilakukan identifikasi areal yang potensial untuk offset karbon, analisis regulasi dan persyaratan implementasi, bentuk kegiatan mitigasi emisi dan penilaian kelayakan implementasi proyek karbon. Areal rehabilitasi hutan dengan luas keseluruhan 1320 ha, di Kabupaten Teluk Bintuni seluruhnya berada di ekosistem mangrove. Areal ini ditetapkan sebagai bagian dari kewajiban BP Berau Ltd untuk melakukan rehabilitasi hutan sebagaimana diatur dalam mekanisme pinjam pakai kawasan hutan. Laporan penelitian ini memuat historis lahan sebelum dan sesudah dilakukan penanaman rehabilitasi, kondisi tutupan lahan dan stok biomas karbon, termasuk capaian stok karbon hasil penanaman rehabilitasi. Kegiatan penelitian ini juga untuk mengindentifikasi sejauhmana areal rehabilitasi hutan dapat dikembangkan lebih jauh sebagai lokasi proyek offset karbon.

TIM PENELITI

TIM PENELITI

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1 BACKGROUND

BP Indonesia, an oil and gas company operating in Teluk Bintuni District, has a commitment to reduce emissions by around 1 million tons of CO_2 per year. One of the efforts that has been made to achieve this target is carrying out rehabilitation activities on 1,320 hectares of rehabilitation land. However, this action is still far from reaching the emission reduction target. Therefore, additional efforts are needed through other mechanisms, such as forest carbon offset or other mechanisms that are recognized by the central government and the international community. For this reason, BP Indonesia require a feasibility study prior make further decisions regarding emission reduction strategies that comply with national regulations or international carbon trading requirements.

Faculty of Forestry and Environment, IPB University is mandated to conduct the feasibility study for BP carbon offset project. The project deliverables consist of four reports: (i) preliminary report; (ii) mid-term report 1; (iii) mid-term report 2; and (iv) final report. This report is a mid-term report 2, which presents the result of carbon stock inventory survey in BP rehabilitation area located in KPHL Teluk Bintuni, West Papua.

BP forest rehabilitation area covers a total of 1,320 ha. Administratively, the area located in Weriagar and Kamundar District, Teluk Bintuni Regency (Figure 1). The planting area is divided into 3 blocks, namely Block I (320 ha), Block II (500 ha) and Block III (500 ha). Planting was carried out in stages according to the location of the block, from 2019 to 2021. Selection of tree species planted in rehabilitation are made based on the habitat type. There are two large habitat type in BP forest rehabilitation area: mangrove and swamp. Mangrove species was planted only on mangrove areas, while sago and fruit trees were planted in swamp areas. Planting distance are made regularly at 3 x 4 m, or 833 trees/ha.

Forest rehabilitation is part of BP Berau obligation to provide replacement land as regulated in the forest area lending and use mechanism (*Izin Pinjam Pakai Kawasan Hutan*/IPPKH) at the Ministry of Environment and Forestry (MOEF) through forest rehabilitation activities in critical watersheds, which locations are determined by MOEF/BPDASHL. Tree planting and maintenance activities carried out by a contractor, while monitoring activity is carried out by BPDASHL and the Provincial Forestry Service.

This report contains a result of potential carbon stock inventory survey, which was conducted by the team from 19 to 27 May 2023 in BP rehabilitation area. The results are expected to provide an overview of the potential carbon stock and sequestration from natural vegetation in the rehabilitation area and the possibility of carbon stock and sequestration in a wider area.

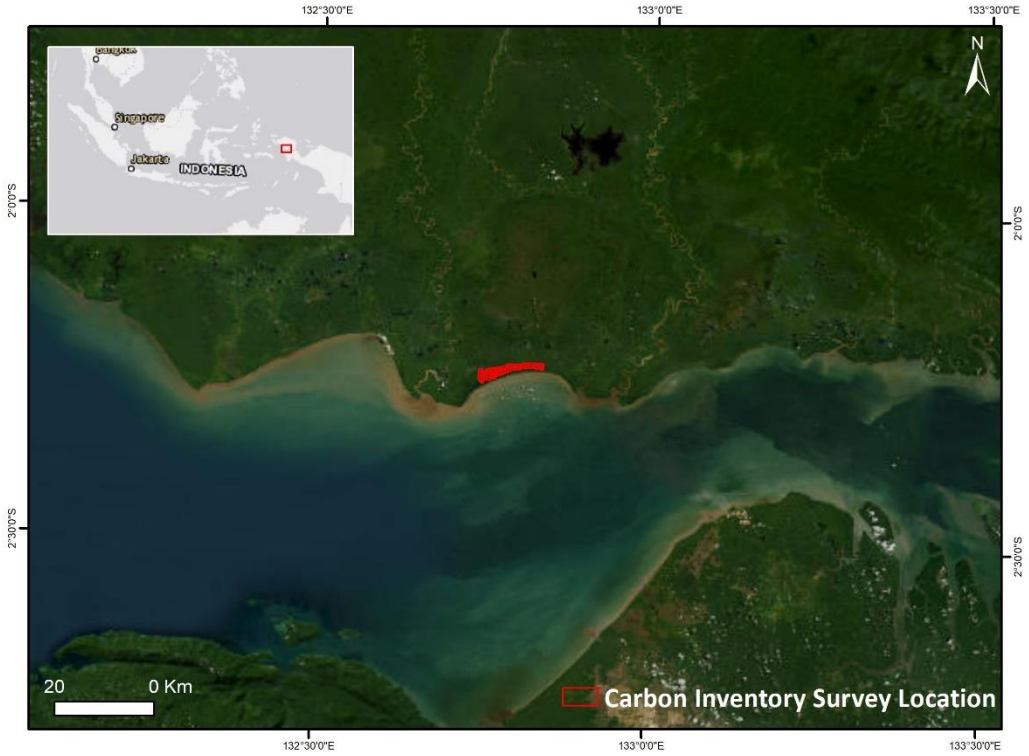


Figure 1 Carbon inventory survey location.

2 OBJECTIVES

Objectives of the carbon inventory survey in BP rehabilitation area are:

1. To obtain information on the most recent land cover on forest rehabilitation area and forest rehabilitation progress;
2. To collect primary data through carbon biomass measurement and calculation, which represents the forest rehabilitation areal condition; and
3. To obtain information on carbon stock potential from natural vegetation and forest rehabilitation vegetation, as well as estimation of carbon stock potential on wider area.

3 METHODOLOGY

3.1 CARBON INVENTORY

Carbon inventory survey was carried out in three stages: (i) preparation & mobilization; (ii) implementation; and (iv) data analysis and reporting.

3.1.1 Preparation and Mobilization

The preparation stages include (i) secondary data collection, (ii) sampling design, and (iii) preparing the field team and work description for each team, along with the preparation of sampling tools and materials. Details of each step are presented in following sub sections.

3.1.1.1 Secondary data collection

Secondary data collected prior the survey including the most recent satellite imagery (planet, 5m spatial resolution and sentinel, 10m spatial resolution) and information on site description and accessibility from the planting contractor (PT Sarbi Moerhani Lestari). Planet satellite imagery used to determine the current landcover type in the rehabilitation area, as a basis to determined sampling plot distribution over the area, while area description also use as identification on potential risk in the area that needs to be aware and anticipated by the team.

3.1.1.2 Sampling design

Field measurement sampling design

Sampling plots were designed by taking into account the existing permanent sample plot (PSP) made by the rehabilitation contractor. The current PSP size is 40 x 25 m^2 (0.1 ha) and systematically located every 100m to the north and 200m to the south. There are 660 PSPs distributed over BP rehabilitation area. The PSP location is marked with a plank and plot coordinate information is included in the working map.

Carbon inventory sampling plot was determined based on the existing PSP location and information on the current landcover. Sampling intensity were 10% from the total PSPs, with some additional plots. Hence, 72 plots were selected purposively as a sampling plot for carbon stock inventory.

Sampling plot design

The plot shape and size designed based on carbon pool measurement guide, as follow:

1. Natural tree saplings, tree diameter <5cm, understorey and litter

- Measured on 2 x 2 m sub-plots. For natural tree saplings, species and total number were recorded, and diameter and height were measured.
- Understorey and litter are collected in sub-sub plot of 0.5 x 0.5m (located inside 2 x 2 m plots) and weighed to obtain a gross weight. Furthermore, a 200 – 300gr of understorey/litter sample were placed in a plastic bag and dried using an oven in the laboratory to obtain a dry weight of the sample.

2. Sapling, poles, small and large trees (dbh > = 5 cm) and dead tree
    - Tree with dbh >= 5-10 cm, measured in sub-plot 5 x 5 m
    - Tree with dbh >= 10-20 cm, measured in sub-plot 10 x 10 m
    - Tree with dbh >= 20-30 cm, measured in sub-plot 20 x 25 m
    - Tree with dbh >= 30 cm, measured in sub-plot 40 x 25 m

    Diameter at breast height (dbh) was measured at a height of 1.3 m above ground. DBH and tree height also measured for palm species (sago and nypa) found in the measurement plot.
3. Rehabilitation plants

    Rehabilitation plants were measured in a 20 x 25 m. Tree species, number of plants, tree height, and average diameter of the plants were recorded. Diameter is measured at a height of 0.5 m from the ground surface.
4. Woody debris (Dead tree and dan dead wood)

    Dead tree and dead wood were measured only for a diameter of minimum 10 cm. the plot size for woody debris measurement were similar to sapling, poles, and tree measurement (point #2).

Measurement Data

The measurement data from each measuring plot consists of:

- Tree species
- Diameter at breast height (DBH)
- Tree height/length
- data on wet weight of litter/undergrowth; and
- For rehabilitation plants, the year/age of the tree must be recorded

All measurement data was recorded in a Tally Sheet book and stored in digital format.

3.1.1.3 Team Mobilization

Each survey team consists of 5 persons, with 1 person as a survey team leader. The survey team leader is responsible for leading the team in survey planning, data collection, analysis and

reporting of inventory results. The survey team leader coordinates the teamwork and ensuring the quality of the data collection, measurement, and analysis.

Prior team mobilization, team leader also ensure potential risks in the area are identified and anticipated. HSE protocol were briefed to the team and health and safety equipment are also prepared, including: proper work clothes, field shoes, gloves, field hats and face/head protection (from insects), and medicine/first aid kit.

In addition to the HSE equipment, survey equipment also prepared, including:

- Global Positioning System (GPS) for determining plot location;
- Tree diameter measuring tape;
- Tree height meter (clinometer);
- Distance measuring instrument (30 m meter & plastic rope);
- Digital scales;
- Bush cutting sickle;
- Compass;
- Camera/ HP and power bank;
- Tree labels/paint marking trees and plot boundaries;
- Plastic bags;
- Tally sheet (measuring book);
- Work map; and
- Writing tools.

3.1.2 Implementation/Carbon Inventory

Carbon stock inventory was carried out in 72 sampling plots distributed on the rehabilitation area. List of sampling plots and distribution of sampling plots as shown in Table 1 and Figure 2.

Table 1 Land cover strata and sampling plots distribution on watershed rehabilitation areas in Bintuni Bay

Land cover class	Area (ha)	Percent (%)	Sample plot number
Mangrove Stratum 1	77.2	5.9	6
Mangrove Stratum 2	10.8	0.8	4
Mangrove Stratum 3	357.8	27.3	12
Mangrove Stratum 4	379.4	29.0	18
Open land	329.9	25.2	17
Nypa vegetation	16.3	1.2	3
Metroxylon Sago	57.4	4.4	5
Swamp bush	81.5	6.2	7
Total	**1,310.2**	**100.0**	**72**

Plot measurement was carried out in following stages:

1. Find the sampling plot according to the sampling design, mark the center point of PSP plot and record the coordinate location using GPS;
2. Create and mark the boundaries of sampling plots and sub plots, based on the measurement targets for each tree diameter class;
3. Measure all trees in each plot/sub plot (species, DBH and height), collect data on litter, understorey, and woody debris;
4. Record and complete all entries in the tally sheet and take photo documentation (including tree cover, tree species name and surrounding land use conditions); and
5. Conduct sampling data processing and analysis.

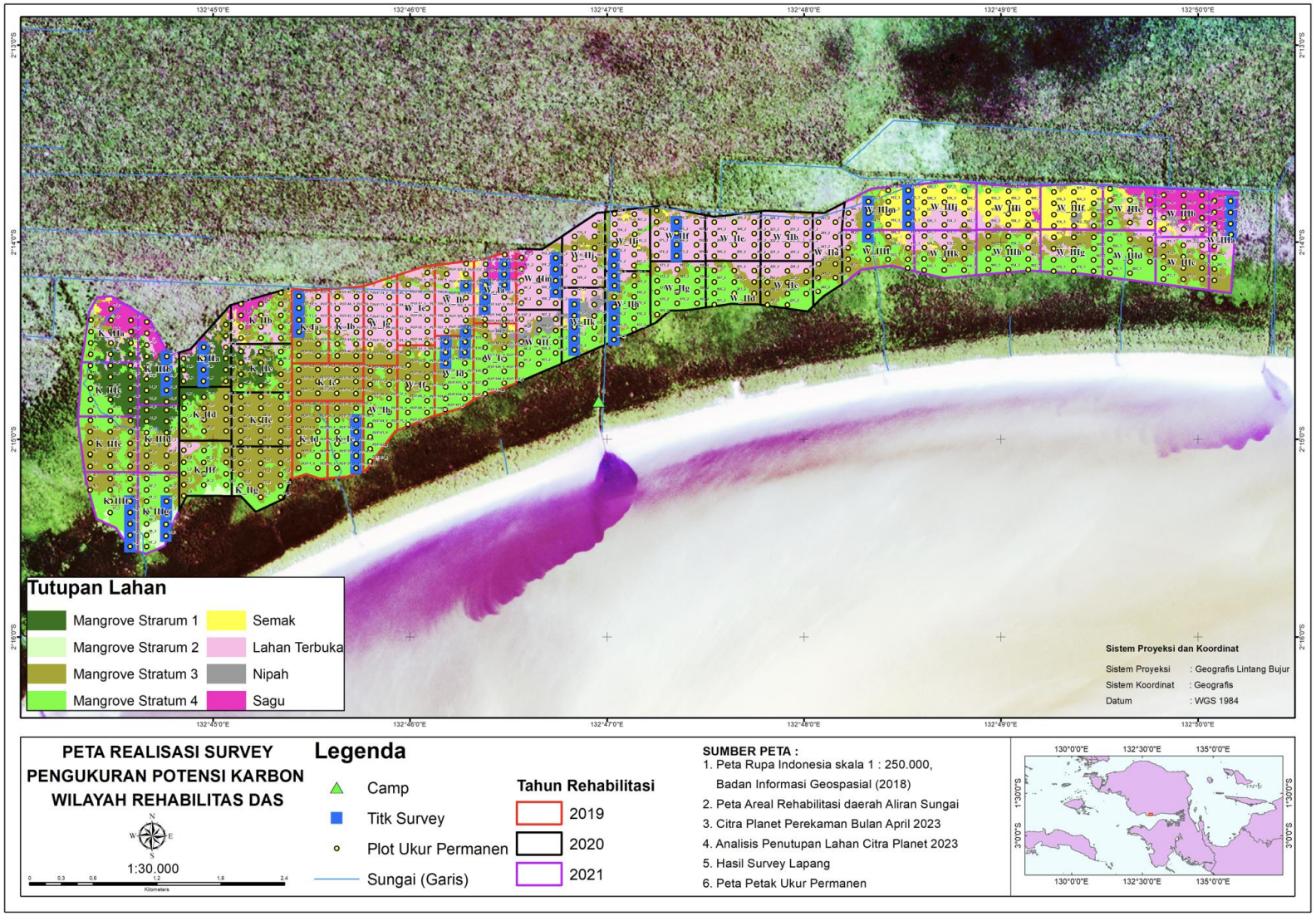


Figure 2 Map of carbon inventory sample plot on BP forest rehabilitation area in Teluk Bintuni watershed, West Papua

Table 2 Plot sampling coordinate and forest type for carbon inventory on rehabilitation area in Teluk Bintuni watershed

Plot ID	X	Y	GPS Error (m)	Altitude (masl)	Forest Type	District
103_3	255,925	9,753,017	8	24	Mangrove Forest	Weriagar
104_3	255,925	9,753,131	10	26	Mangrove Forest	Weriagar
105_3	255,925	9,753,237	9	19	Mangrove Forest	Weriagar
106_3	255,925	9,753,343	6	13	Mangrove Forest	Weriagar
118_2	252,984	9,752,495	3	13	Open Land	Weriagar
119_2	252,984	9,752,601	3	12	Open Land	Weriagar
120_2	252,984	9,752,707	3	14	Open Land	Weriagar
121_2	252,984	9,752,813	3	13	Open Land	Weriagar
122_2	253,161	9,751,953	5	12	Mangrove Forest	Weriagar
123_2	253,161	9,752,059	7	15	Mangrove Forest	Weriagar
124_2	253,161	9,752,165	3	14	Semak	Weriagar
125_2	253,161	9,752,271	6	15	Nypa	Weriagar
126_2	253,161	9,752,377	3	16	Semak	Weriagar
24_2	249,670	9,751,973	3	18	Semak	Kamundan
23_2	249,670	9,751,867	5	16	Mangrove Forest	Kamundan
149_2	253,538	9,752,553	3	10	Open Land	Weriagar
22_2	249,670	9,751,761	7	21	Mangrove Forest	Kamundan
150_2	253,535	9,752,647	3	8	Open Land	Weriagar
151_2	253,532	9,752,741	3	6	Open Land	Weriagar
152_2	253,535	9,752,844	3	4	Open Land	Weriagar
21_2	249,670	9,751,655	3	19	Mangrove Forest	Kamundan
249_3	259,337	9,753,249	5	14	Sago	Weriagar
250_3	259,337	9,753,355	5	12	Sago	Weriagar
46_1	251,107	9,750,849	8	13	Mangrove Forest	Kamundan
47_1	251,107	9,750,960	10	23	Mangrove Forest	Kamundan
48_1	251,107	9,751,071	7	21	Mangrove Forest	Kamundan
49_1	251,107	9,751,182	10	27	Mangrove Forest	Kamundan
50_1	251,107	9,751,293	4	33	Mangrove Forest	Kamundan
12_1	250,567	9,752,116	10	25	Mangrove Forest	Weriagar
13_1	250,567	9,752,227	9	23	Mangrove Forest	Weriagar
14_1	250,567	9,752,338	5	18	Mangrove Forest	Weriagar
15_1	250,567	9,752,449	7	16	Mangrove Forest	Weriagar
78_3	249,319	9,750,212	9	21	Mangrove Forest	Kamundan
79_3	249,319	9,750,318	10	24	Mangrove Forest	Kamundan
80_3	249,322	9,750,429	8	24	Mangrove Forest	Kamundan

Plot ID	X	Y	GPS Error (m)	Altitude (masl)	Forest Type	District
81_3	249,322	9,750,535	8	20	Mangrove Forest	Kamundan
130_1	252,130	9,751,927	9	16	Mangrove Forest	Weriagar
131_1	252,133	9,752,026	8	13	Mangrove Forest	Weriagar
132_1	252,138	9,752,127	11	9	Mangrove Forest	Weriagar
136_1	252,138	9,752,551	3	12	Mangrove Forest	Weriagar
144_2	253,535	9,752,047	9	14	Mangrove Forest	Weriagar
145_2	253,535	9,752,145	9	21	Mangrove Forest	Weriagar
146_2	253,535	9,752,251	5	22	Mangrove Forest	Weriagar
147_2	253,535	9,752,355	7	24	Nypa	Weriagar
149_1	252,323	9,752,560	3	12	Open Land	Weriagar
183_2	254,120	9,752,833	3	11	Open Land	Weriagar
184_2	254,120	9,752,939	3	10	Open Land	Weriagar
185_2	254,120	9,753,045	4	8	Open Land	Weriagar
186_2	254,120	9,753,151	3	10	Open Land	Weriagar
248_3	259,337	9,753,143	4	18	Sago	Weriagar
117_1	251,950	9,751,826	8	22	Mangrove Forest	Weriagar
118_1	251,950	9,751,927	9	24	Mangrove Forest	Weriagar
118_3	256,301	9,753,131	3	14	Open Land	Weriagar
119_1	251,953	9,752,026	6	14	Mangrove Forest	Weriagar
119_3	256,301	9,753,237	5	20	Semak	Weriagar
120_3	256,301	9,753,343	4	17	Semak	Weriagar
121_3	256,301	9,753,449	5	12	Semak	Weriagar
147_1	252,318	9,752,335	5	6	Semak	Weriagar
148_1	252,320	9,752,446	3	10	Semak	Weriagar
161_1	252,503	9,752,560	4	12	Bambu	Weriagar
162_1	252,500	9,752,658	5	9	Sago	Weriagar
163_1	252,503	9,752,753	4	14	Sago	Weriagar
247_3	259,341	9,753,040	2	23	Nypa	Weriagar
36_3	248,980	9,750,112	10	21	Mangrove Forest	Kamundan
37_3	248,980	9,750,218	9	14	Mangrove Forest	Kamundan
38_3	248,980	9,750,324	7	13	Mangrove Forest	Kamundan
39_3	248,980	9,750,430	8	16	Mangrove Forest	Kamundan
40_3	248,980	9,750,536	7	10	Mangrove Forest	Kamundan
91_3	249,322	9,751,567	7	18	Mangrove Forest	Kamundan
92_3	249,322	9,751,673	8	12	Mangrove Forest	Kamundan
93_3	249,322	9,751,779	11	27	Mangrove Forest	Kamundan
94_3	249,322	9,751,886	6	15	Open Land	Kamundan

3.2 DATA ANALYSIS

All measurement data recorded in tally-sheet and stored in database/spreadsheet format. Furthermore, data were processed to obtain an above ground and below ground biomass (AGB and BGB). Detail biomass calculation is presented below.

Above Ground Biomass (AGB) and Below Ground Biomass (BGB)

Data analysis includes biomass calculation of each individual tree in the sample plot for all carbon pools, which consists of above ground biomass (AGB), below ground (BGB), woody debris, and litter biomass. AGB and BGB determined using allometric calculation from Komiyama et al. (2005):

$$AGB = 0.25*2*\rho*D^{2.46}$$

$$BGB = 0.199*\rho^{0.899}*D^{2.22}$$

Note:

AGB = aboveground tree biomass (kg/tree)

BGB = tree root biomass (kg/tree)

D = tree diameter (cm), and

ρ = wood density (kg/m3)[1].

The understorey biomass in each sample plot was determined based on the results of field measurements and laboratory analysis. Understorey biomass is calculated based on the ratio between dry weight and gross weight sample, multiplied by total gross weight of all understorey in the sample plot. Total estimated AGB and BGB is the summed of AGB and BGB of trees and understorey in each plot/subplot. The estimated AGB and BGB were then converted into carbon stock using a conversion factor of 0.47 (IPCC 2006).

Woody Debris

Woody debris consists of dead tree and dead wood. Dead tree classified into 4 classes, based on the shape integrity of the tree (Rusolono et al. 2015). For Class 1, Class 2, or Class 3, the biomass is estimated using the allometric equation, multiplied by correction factor (0.9 for Class 1, 0.8 for Class 2, and 0.7 for Class 3 (BSN 2011)). Dead tree classified as class 4, the biomass is estimated using the stem volume conversion as follows:

$$\text{Dead Tree Biomass} = 0.25\pi*(D/100)^2*T*f*WD,$$

[1] Wood density data was obtained from the ICRAF online database (http://db.worldagroforestry.org)

Note:

D= stem diameter (cm),

T = height of stump or dead tree (m),

f = shape factor (0.6), and

WD = wood density.[2]

Dead wood biomass is calculated by multiplying the volume of stems or branches with wood density. The volume of fallen dead wood (stem/branch) was estimated from the base diameter, tip diameter, and stem/branch length using the Brereton formula (BSN 2011):

$$\text{Volume} = 0.25\pi*((Db + De)/200)^2 *P.$$

Note:

Db = base diameter (cm),

De = top diameter (m); and

P = stem/branch length

For each sample plot, the total woody debris biomass is the sum of dead tree and dead wood biomass (in tons/ha). A conversion factor of 0.47 (IPCC 2006) was then used to convert biomass to carbon stocks for each sample plot.

Litter Biomass

Litter biomass in each sample plot is determined based on the results of litter measurements in the field and analysis of litter samples in the laboratory. Litter biomass is calculated based on the ratio between the dry weight and the wet weight of the sample which is then multiplied by the total wet weight of the litter in a sample plot.

Litter biomass in each sample plot was converted into carbon stocks using a conversion factor of 0.47 (IPCC 2006).

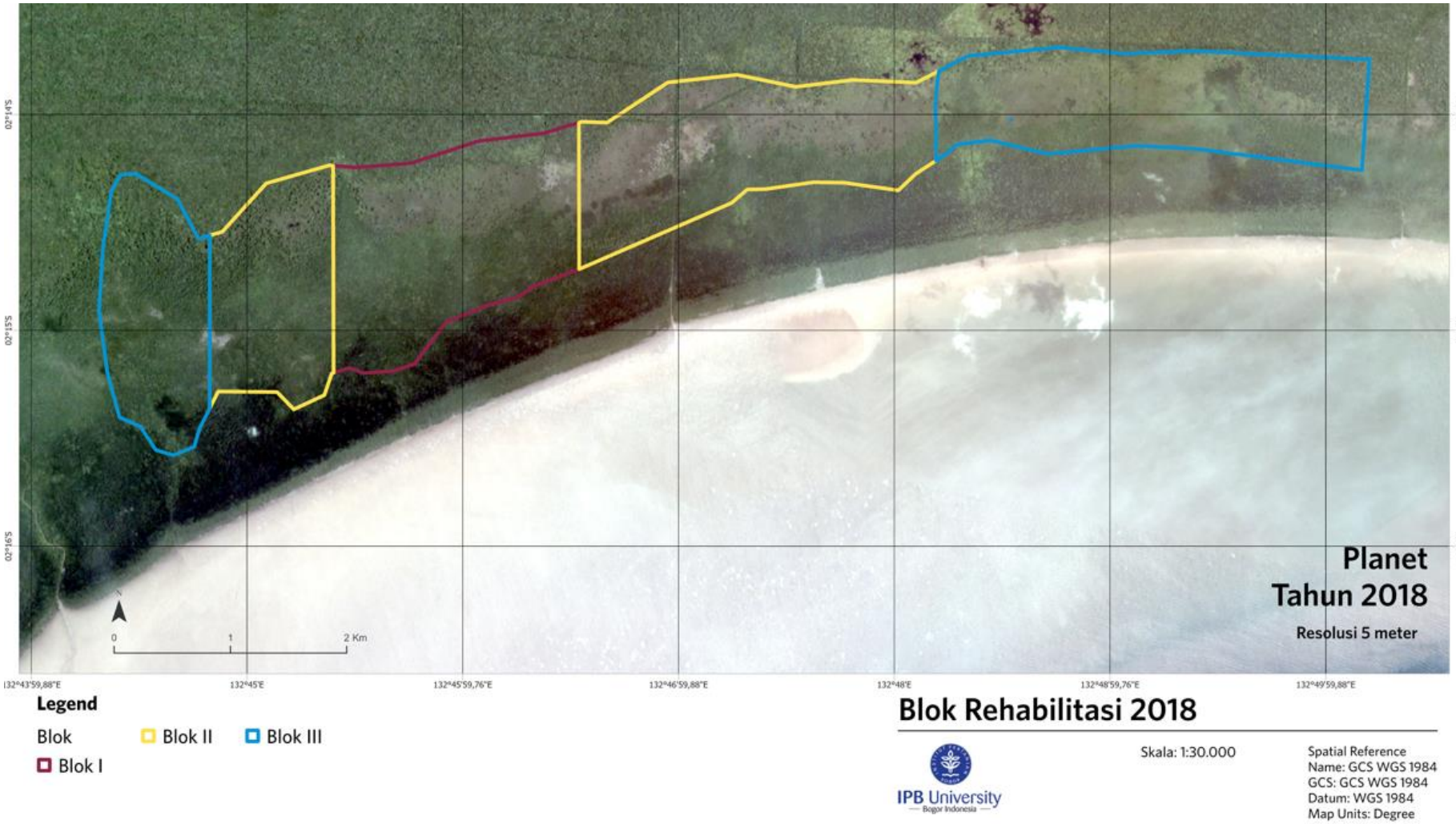
[2] Wood density data was obtained from the ICRAF online database (http://db.worldagroforestry.org)

4 RESULT

4.1 LAND COVER AND LANDCOVER CHANGE

Information on land cover and land cover change in the rehabilitation area derived from sentinel satellite imagery (year 2018) and planet satellite imagery (year 2023) using a visual interpretation method. Year 2018 and 2023 represents the condition before and after forest rehabilitation (Figure 3). Verification on landcover derived from satellite Interpretation was carried out in parallel with carbon inventory survey.

Based on land cover mapping, in year 2023, there are 825 ha or 63% of rehabilitation area covered by mangrove forests, 57 ha (4%) sago forests, 411 ha (31%) open land and swampy shrubs, and nypa trees along river channels. In general, vegetation composition in the rehabilitation area dominated by mangrove forests (Figure 4). Mangrove species found in the area consist of *Rhizophora sp., Avicennia sp., Bruguiera sp. and Sonneratia sp*. Farther from the coast, the vegetation composition transitioned from mangrove forest to swampy shrubs and sago. There are also a drainage ditches created for the purpose of sago trees harvesting. A result of rehabilitation planting (3-4 years) in this area cannot be identified yet on the satellite imagery.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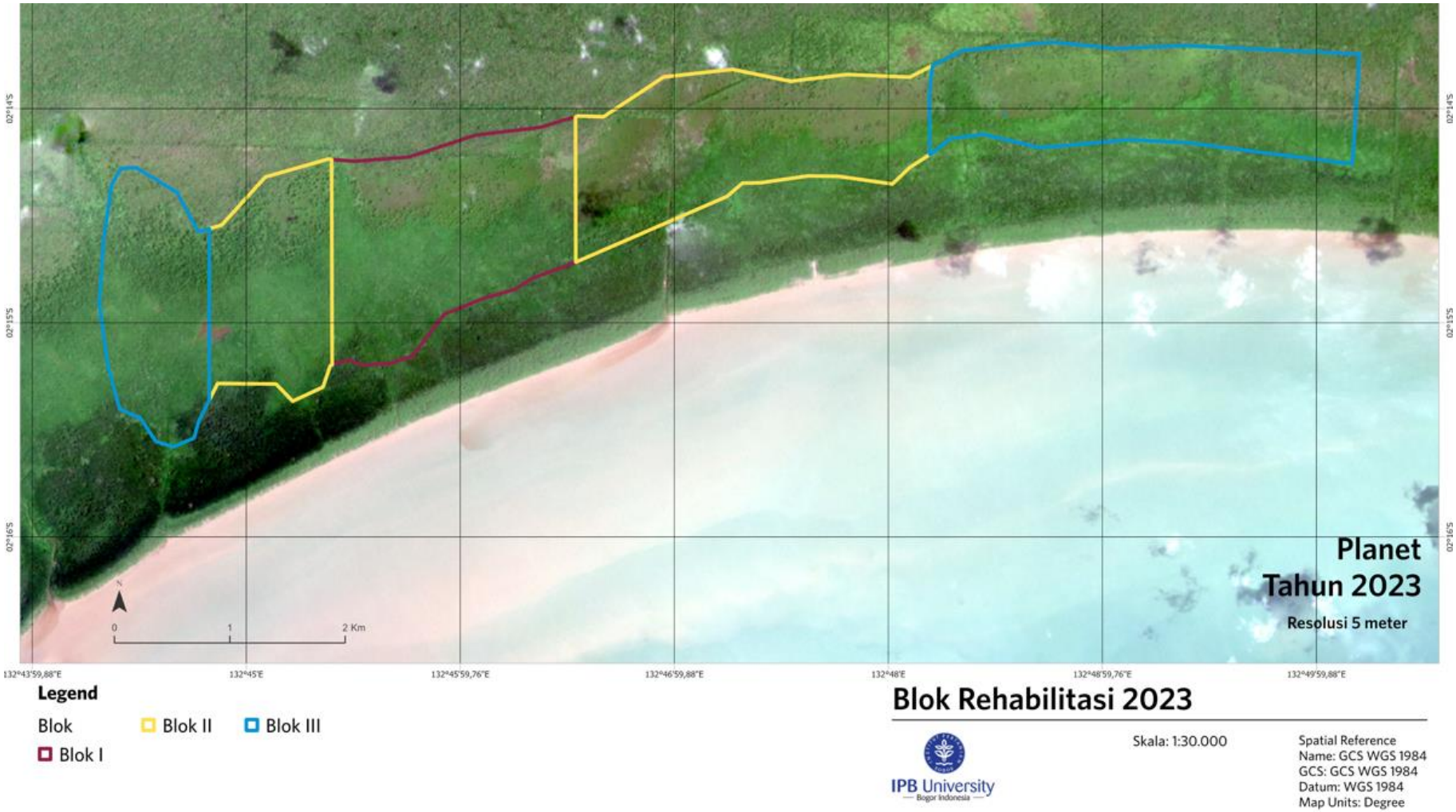

Figure 3 Land cover in BP rehabilitation area in Teluk Bintuni watershed, before rehabilitation activity (a) and after rehabilitation activity in 2019-2022 (b).

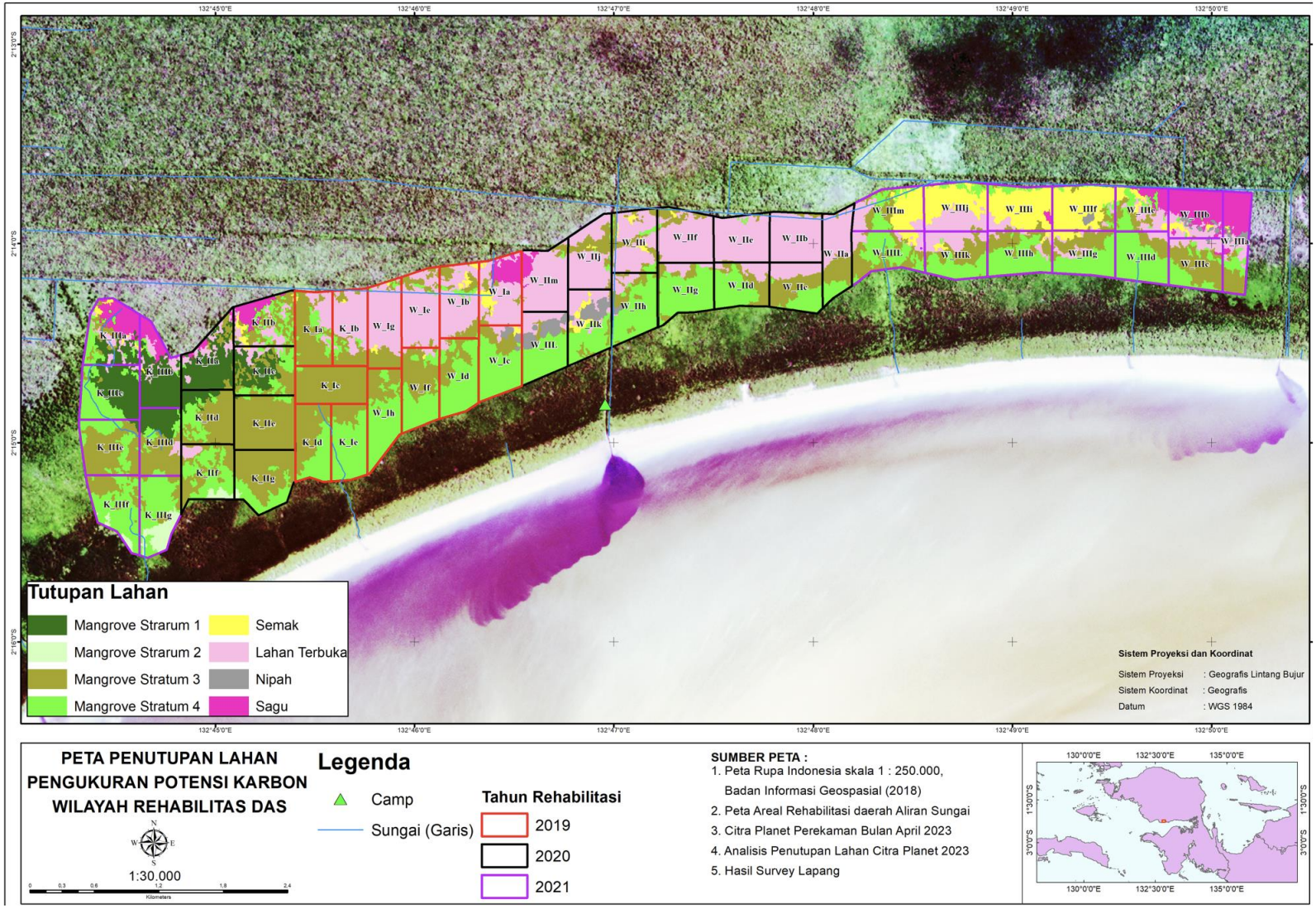

Figure 4 Current land cover condition in BP rehabilitation area, Teluk Bintuni watershed

4.2 CARBON STOCK INVENTORY

The results of carbon stock measurements include all carbon stocks from aboveground biomass (AGB), belowground biomass (BGB), deadwood and litter. Aboveground biomass derived from measurement of trees with a diameter of 5 cm and above, understorey and rehabilitation plants without minimum diameter.

The inventory survey covers an area of 7.2 ha, with a total of 72 sampling plots. 733 individual trees were recorded (diameter >5 cm) with a total number of 15 species, mainly from the Genus *Rhizophora, Bruguiera, Avicennia, Sonneratia,* and *Xylocarpus*.

The average total carbon stock for BP rehabilitation area is 120.08 tC/ha, with AGB carbon stock of 73.10 tC/ha. The highest carbon stock is in mangrove forests. Mangrove forests according to the cover strata have a total carbon stock in the range of 165.01 t C/ha – 236.19 tC/ha (with AGB 105-172 tC/ha). Meanwhile, carbon stock in open land and shrubs/bush is ranging from 4 tC/ha to 36 tC/ha) (see Table 3 and Figure 6).

Table 3 Average of carbon stock from each carbon pool and land cover strata.

Land cover class	AGB	BGB	Deadwood	Litter	Non-Tree	Herbs	Tree planting	Carbon Total	U (%)
Mangrove Stratum 1	172.39	53.07	9.82	0.37	-	0.54	0.01	236.19	48.81
Mangrove Stratum 2	124.20	47.31	28.01	0.37	-	0.54	0.02	200.43	51.50
Mangrove Stratum 3	105.47	42.21	33.38	0.37	2.58	0.54	0.20	184.74	13.11
Mangrove Stratum 4	106.81	40.76	16.50	0.37	-	0.54	0.04	165.01	15.62
Open land	1.68	0.75	-	0.30	0.66	0.25	0.37	4.00	68.36
Nypa vegetation	20.57	8.15	0.99	-	-	-	0.04	29.74	99.66
Metroxylon Sago	-	-	-	-	60.56	-	0.06	60.62	25.59
Swamp bush	24.35	10.74	-	0.30	0.51	0.25	0.16	36.31	50.62
Grand Total	**73.10**	**27.80**	**14.71**	**0.33**	**3.55**	**0.42**	**0.17**	**120.08**	**20.74**

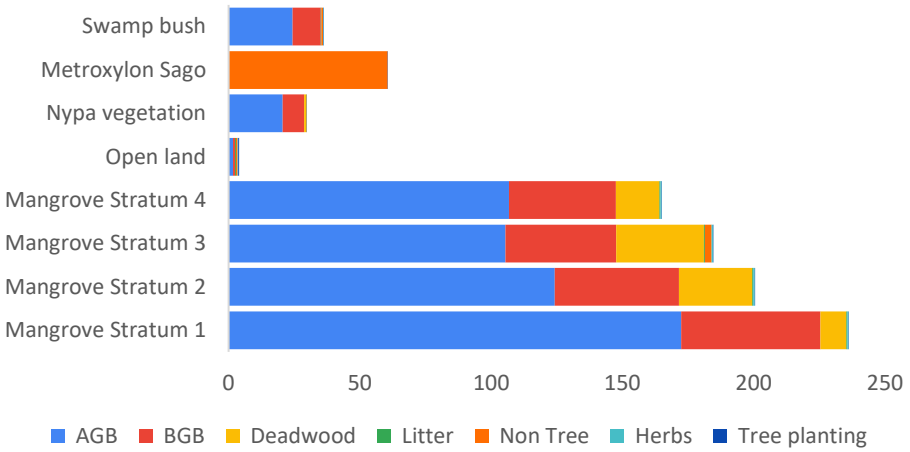

Figure 5 Distribution of carbon stock average from each carbon pool and land cover strata in rehabilitation area (in tonC/ha)

Carbon stocks derived from a measurement plot in mangrove forests have large variations compared to non-mangrove forests, due to the presence of large diameter mangrove trees (>50 cm) in several measurement plots. With a sampling intensity of 10% from the existing PSPs, the average uncertainty/sampling error is 20.74%. Carbon pool composition in mangrove forests consists of above-ground (59%), below ground (root) 26%, deadwood 11%, litter and others of less than 4% (Figure 7).

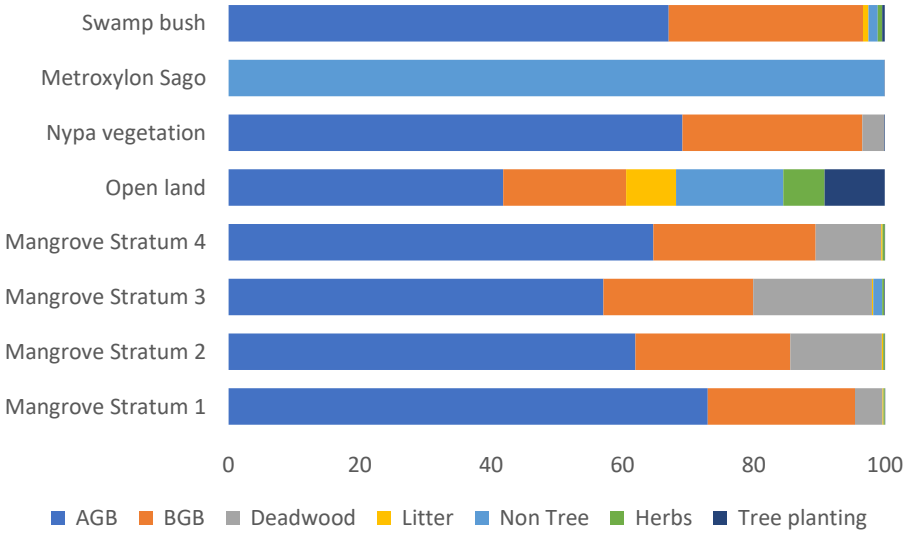

Figure 6 Percentage of average of carbon stock from each carbon pool and land cover strata

Mangrove forest stratification is mainly influenced by the sea tides. Areas with frequent expose to sea tides, the vegetation is dominated by *Rhizophora sp.* and *Avicennia sp.* Farther from sea

tides exposure, trees with larger diameter are more likely to be found. Some species found in this area including *Sonneratia sp.*, *Excoecaria sp.*, and *Bruguiera sp*. Figure 8 shows the structure of each stand according to mangrove forest strata.

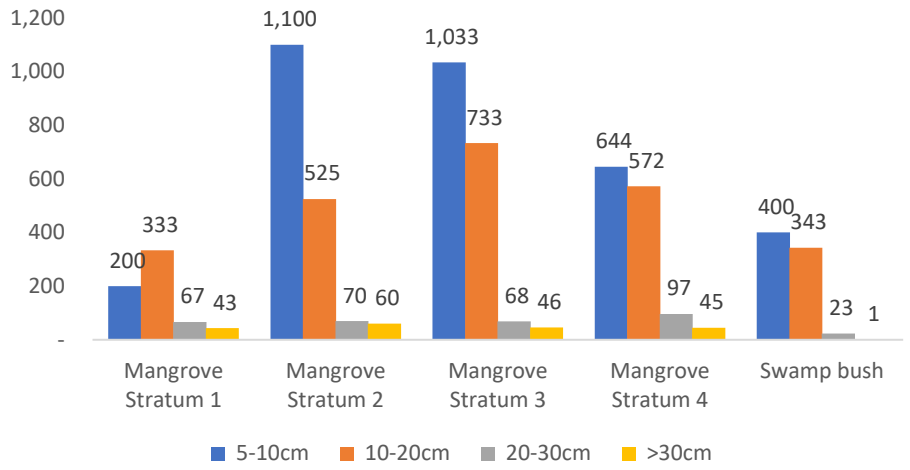

Figure 7 Tree density by mangrove strata (trees/hectare)

Based on the carbon stock inventory result, the total carbon stock potential for BP forest rehabilitation area in Bintuni Bay in 2023 reaches 157,335 tC, as shown in Table 4.

Table 4 Carbon stock potential (tC) in BP rehabilitation area.

Land cover class	Area (ha)	Percent (%)	Sample plot number	Carbon stock average (tC/ha)	Carbon stock total (tC)
Mangrove Stratum 1	77.2	5.9	6	236.19	18,229
Mangrove Stratum 2	10.8	0.8	4	200.43	2,164
Mangrove Stratum 3	357.8	27.3	12	184.74	66,098
Mangrove Stratum 4	379.4	29.0	18	165.01	62,602
Open land	329.9	25.2	17	4.00	1,321
Nypa vegetation	16.3	1.2	3	29.74	485
Metroxylon Sago	57.4	4.4	5	60.62	3,478
Swamp bush	81.5	6.2	7	36.31	2,959
Total	**1,310.2**	**100.0**	**72**	**120.08**	**157,335**

Carbon stock and carbon sequestration of rehabilitation plants

Inventory of carbon stocks in the Bintuni Bay watershed forest rehabilitation area, apart from natural vegetation, also includes tree planting as part of forest rehabilitation activities.

Forest rehabilitation through tree planting was carried out in three planting periods, namely 2019, 2020 and 2021, the locations of which were grouped into blocks I, II and III. The tree species planted are mainly species that grow in mangrove forests, namely *Rhizophora, Sonneratia, Bruguiera, Avicennia, Lopostemon*, and Sago (*Metroxylon*). The current age of the plants ranges from 1-3 years, but some are also plants resulting from replanting of dead plants. The number of trees planted was 833 trees/ha (or with an average planting distance of 3 x 4 m).

From 72 sampling plots measured at various land cover strata, an average of 669 trees/ha grew and survived rehabilitation plants or an average survival percentage of 80%. A relatively low percentage of survival (34%) occurred when trees were planted in strata 1 forest cover and mixed with nipa palm vegetation (Table 5 and Figure 9).

Table 5 Average number of rehabilitation plants and growth percentage based on land cover

Land cover class	Area (ha)	Tree planting (trees/ha)	Std Tree planting (trees/ha)	Growing percentage (%)
Mangrove Stratum 1	77.2	283	177.7	34.01
Mangrove Stratum 2	10.8	700	187.1	84.03
Mangrove Stratum 3	357.8	687	161.8	82.43
Mangrove Stratum 4	379.4	730	337.4	87.64
Open land	329.9	692	353.9	83.04
Nypa vegetation	16.3	447	299.6	53.62
Metroxylon Sago	57.4	592	255.6	71.07
Swamp bush	81.5	680	224.8	81.63
Total	**1,310.2**	**669**	**272**	**80.35**

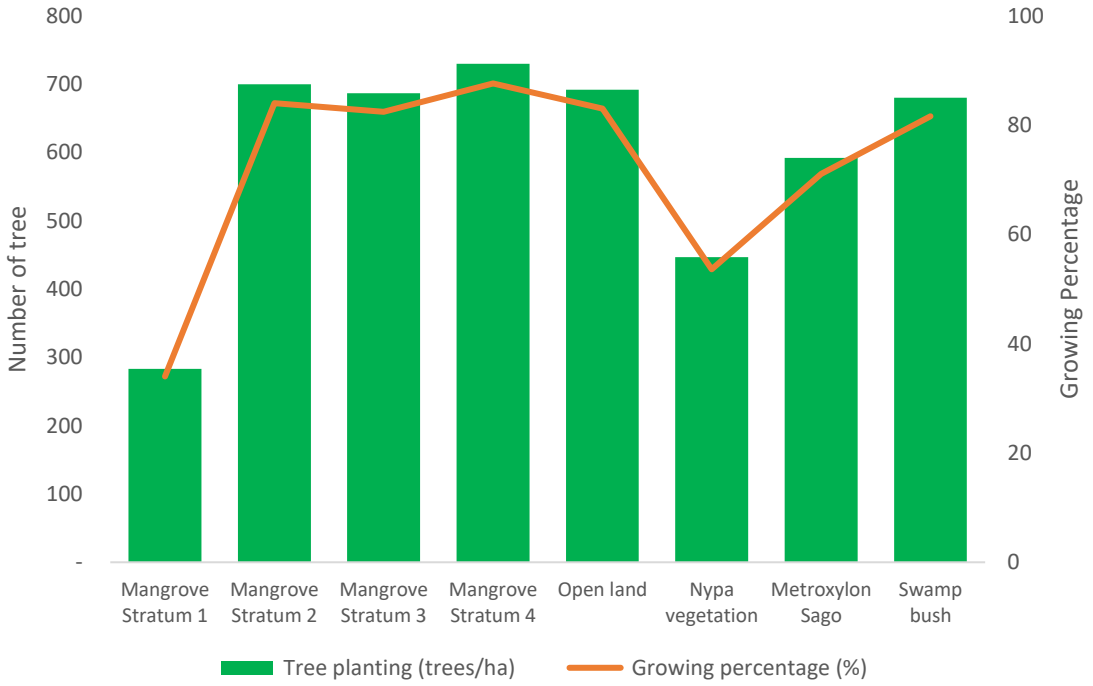

Figure 8 Average rehabilitation plants and their growth percentage according to land cover class

Altough the percentage of living trees is relatively high, the growth in diameter and height of mangrove tree plants is relatively low. Low tree growth is possibly be due to competition between planted trees and trees that are still growing naturally, the influence of shade, or also because the trees being measured are actually replanted from dead trees. The total carbon stock of all rehabilitation plants on average is 0.17 tC/ha (with a standard deviation of 0.30 tC/ha). An estimate of the average age of rehabilitation plants at around 1.5 years (age variation 1-3 years), the average carbon sequestration potential is 0.11 tC/ha/year or the equivalent of 0.42 tCO2/ha/year.

4.3 Potential Carbon Stock at Implementation Scale

The potential carbon stock in the forest rehabilitation area in the Bintuni Bay watershed, as previously described, is mostly carbon stock from natural forests, and only a small amount of carbon stock is produced from forest rehabilitation. Of the total forest rehabilitation area, around 410 ha or 37% is open and its growth can be increased through tree planting.

To meet the scale of carbon project implementation, the potential area for forest rehabilitation activities must be increased by adding the forest area in the northern part of the current forest rehabilitation area, especially to obtain a total area of up to 1,000 ha, with open land cover.

However, as the growth capacity of rehabilitated trees is relatively low, the potential for carbon sequestration that will be produced by the project is estimated to be in similar condition.

5 CONCLUSION AND NEXT STEPS

Inventory of carbon stocks in the forest rehabilitation area in the Bintuni Bay watershed with a total area of 1,320 ha has obtained the following information:

1. Based on the most recent land cover map (2023), the forest rehabilitation area is dominated by mangrove forests (63%) and the remaining part is swampy shrubs and open land. Carbon stocks in mangrove forests are relatively high, around 165-236 tC/ha. The mangrove tree stands have a high density which allows the mangrove ecosystem to maintain and increase their growth naturally.
2. Rehabilitation of mangrove forests is ongoing since 2019-2021 with a relatively high growth percentage of up to 80%, but due to the influence of shade from natural vegetation, the trees resulting from rehabilitation activity is not shown satisfactory growth in diameter and height. Carbon absorption is estimated to reach 0.42 tCO2/ha/year, in which considered low for a carbon project. Maintenance of rehabilitated trees from weeds and nuisance pests is necessary to maintain the percentage of living trees and stimulate tree growth.
3. Planting mangrove trees in areas that are still covered by natural forest canopy will not be effective and should be prioritized for areas that are already open (shrubs and open land). From the forest rehabilitation area that is currently underway, additional area to obtain relatively open land can be directed to the northern part in the transition area from mangrove to swamp forest, including additional area for carbon offset project purposes.

6 REFERENCES

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Rusolono T, Tiryana T, Purwanto J. 2015. Panduan Survei Cadangan Karbon dan Keanekaragaman Hayati di Sumatera Selatan. Palembang: Biodiversity and Climate Change Project (BIOCLIME), German International Cooperation (GIZ).

Poungparn S, Komiyama A, Intana V, Piriyaota S, Sangtiean T, Tanapermpool P, Patanaponpaiboon P, Kato S. 2002. A Quantitative Analysis on the Root System of a Mangrove, Xylocarpus granatum Koenig. Tropics 12: 35-42. 10.3759/ tropics.12.35.

APPENDICES

Appendix 1 Carbon inventory survey documentation photos

Working camp

Edge of the Bintuni Bay

River estuary

Sago near river estuary

GPS use in the survey

Mangrove Tree

Sagoo plants

Dense Mangrove forest in PSP 22 (Rehabilitation year II, Kamundan District)

Dense Mangrove forest (*Sonneratia sp.*) in PSP 22 (Rehabilitation year II, Kamundan District)

Mangrove Tree

Rehabilitation plants in PSP 152 (Rehabilitation year II, Weriagar District)

Open land

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Sagoo forest (*Metroxylon sp.*) in PSP 248

(Rehabilitation year II, Kamundan District)

Sagoo forest (*Metroxylon sp.*) in PSP 248

(Rehabilitation year II, Kamundan District)

PSP Sign

Sagoo forest (*Metroxylon sp.*) in PSP 248

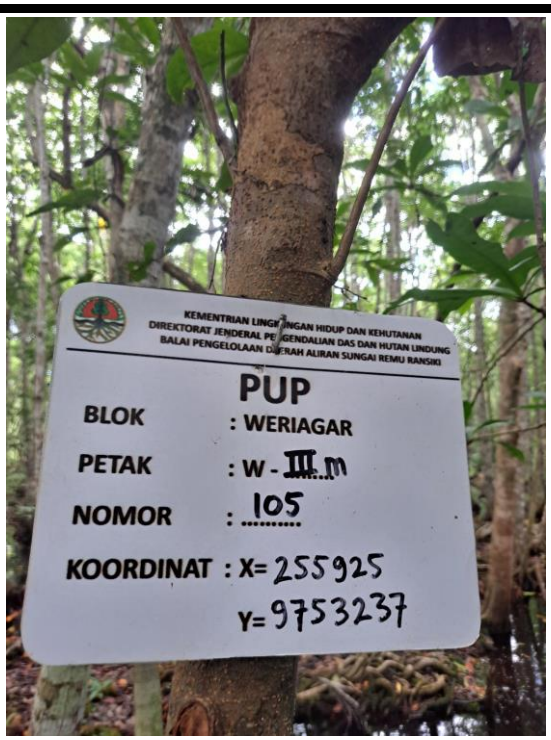
(Rehabilitation year II, Kamundan District)

PSP 119 sign (Rehabilitation year II, Weriagar District)

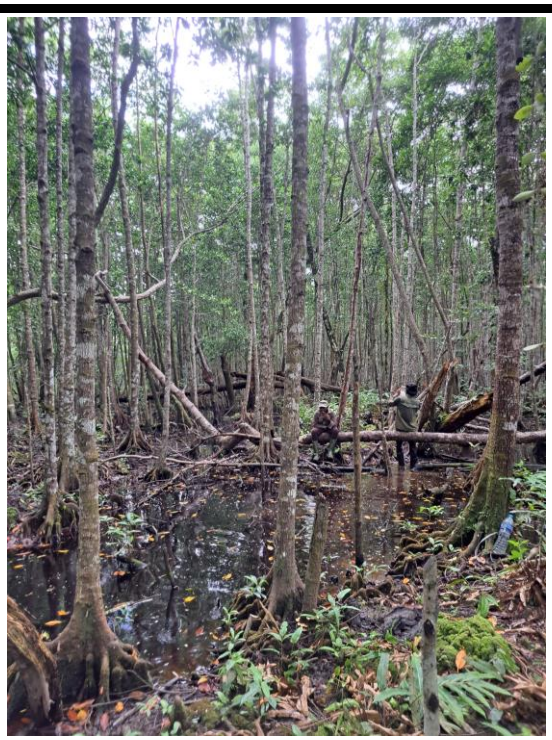
Swampy shrubs in PSP 119

Swampy shrubs in PSP 119

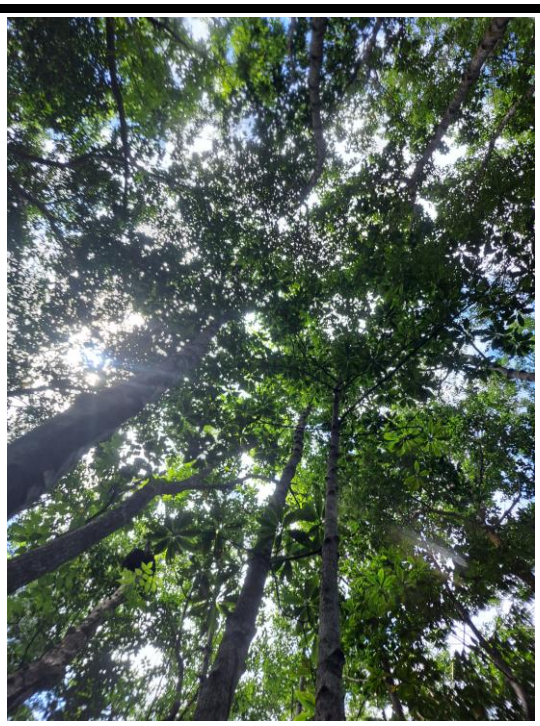
Swampy shrubs in PSP 119



PSP 105 sign (Rehabilitation year II, Weriagar District)



Mangrove stratum 3 (*Bruguiera sp., Lophostemon sp., Excoecaria agalloocha*)



Canopy cover of dense mangrove forest in PSP 105

Mangrove stratum 3 (*Bruguiera sp., Lophostemon sp., Excoecaria agalloocha*)