World Agroforestry

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CARBON STOCK ASSESSMENT IN PEATLAND

IN NORTH KALIMANTAN

CARBON STOCK ASSESSMENT IN PEATLAND

IN NORTH KALIMANTAN

World Agroforestry
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

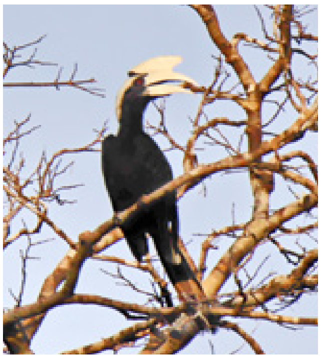
Table of Contents

List of figures

List of tables

Section 1.

Introduction




Peatland area in Indonesia was estimated at about 14.91 million hectares spread out in Sumatra 6.44 million ha (43 %), Kalimantan 4.78 million ha (32 %), and Papua 3.69 million ha (25 %) (Osaki *et al* 2016). The unique characteristics of soil, water, and Green House Gas (GHG) emission make peatland is an important ecosystem. Peatlands that are covered by forest vegetation play an important role in sustaining life through cycle and store amount of carbon (Hergoualc'h *et al* 2018). Peatland is key for several ecosystem functions. It is a habitat for biodiversity and important refugial sites for migratory birds. Peatland regulates water across the landscape, i.e., reduces the impact of floods and droughts and buffers saltwater in the coastal area. Peatland supports the economy of local communities through freshwater fish, timber and non-timber forest product.

Emission from forest and peat fires in Indonesia increase from 505.3 Mt CO_2e in 2000 to 979.4 MtCO_2e in 2014 (Republic of Indonesia, 2017). Logging activity for timber extraction remaining bare land or secondary growth then becomes the prone area to fire in the dry season. The demand for arable land for palm oil and pulp production contributes to land use and land cover conversion in peatland, then induce carbon emission.

Peatland stores a vast amount of belowground (BG) carbon stock compared to aboveground (ABG), depending on the peat thickness and maturity. In the pristine condition, peat swamp forests in Indonesia stores 220 ± 28 Mg C per ha aboveground biomass (Hergoualc'h and Verchot 2011), and 668 ± 20 Mg C per ha per meter depth of peat (Warren *et al* 2012). Belowground carbon stock in the peat soil in a 3:1 ratio compared to aboveground in the shallow peat 1-m-deep (Hergoualc'h *et al* 2019). In 160 cm depth of fibric peat in the buffer zone of Lamandau Wildlife Reserve, Central Kalimantan belowground carbon stock reach 1500 Mg per ha (Rahayu & Dariah 2019). The total carbon stock of Indonesian peatland is ranged 13.6 Gt C – 40.5 Gt C with the best estimate of 28.1 Gt C (Warren *et al* 2017).

Logging activity in the peatland forest directly impacts aboveground carbon stock and tree diversity due to losing big trees, which is stored a huge of carbon. Moreover, forest conversion to agriculture directly reducing both above and belowground carbon stock through losing forest cover and peat decomposition. Forest conversion to oil palm plantation will potentially emit 0.96 g CO_2 m^{-2} $hour^{-1}$ or 84 Mg ha^{-1} $year^{-1}$ based on a study in Kalimantan (Rumbang 2015) and reach up to 121 Mg ha^{-1} $year^{-1}$ in Sumatra (Khasanah & van Noordwijk 2018).

Maintaining peatlands in Indonesia can save up to 20 times the mineral soil carbon (Pantau Gambut, 2019). Moratorium on primary forest clearance and peatland conversion (President Instruction No. 5/2019) as one of the peatland management strategies. This makes the contribution of peatland to the target of reducing Indonesia's greenhouse gas emissions at 29% or 41% with international support by 2030. Peatland management in Indonesia divided by Peat Hydrological Unit (Kesatuan Hidrologis Gambut/KHG) referred to SK Menteri LHK No. 129/MenLHK/Setjen/PKL.02/2/2017. 865 KHGs are covering 24,667,804 ha in Sumatra, Kalimantan, and Papua. KHGs extend beyond peatland and covers areas with mineral soil located between two rivers as integral parts of peat hydrological units. There are 13 KHGs, that cover around 347,082 ha of area, in North Kalimantan laid in Tana Tidung and Nunukan District. The Provincial Government of North Kalimantan has defined clear climate and natural resource protection goals. These goals become part of the province's revitalization plan for the Kayan Sembakung Delta as well as through Governor's regulation number 7, 2019 concerning North Kalimantan Mitigation Action Plan to Reduce Green House Gases Emissions (Rencana Aksi Daerah Penurunan Emisi Gas Rumah Kaca/RAD GRK).

However, the basic data of emission factors (above and belowground carbon stock) in various land covers systems in North Kalimantan did not exist. The information on the exact peatland area within these KHGs is also limited. The aim of the project is to assess and provide data on the aboveground and belowground carbon stock at the plot level in the peatland of North Kalimantan. In particular, the assessment is focused on areas that are not under any concessions or permit for management (non-permit) of secondary forest and shrub. The data is crucial as the basis for estimating carbon emission from land use/cover and land use/cover changes.

Methods

Carbon stock measurement for peatland in this project followed closely the method outlined in “Petunjuk Praktis Pengukuran Cadangan Karbon Tanah Gambut” (Agus et al, 2011) for belowground carbon stock. As for the aboveground carbon stock assessment, we followed the method in “Petunjuk Praktis Pengukuran Cadangan Karbon pada Berbagai Tipe Penggunaan Lahan dari Tingkat Plot sampai Tingkat Bentang Lahan” (Hairiah et al. 2011). Tree diversity sampling and analysis also conducted during the assessment based on the method elaborated in “Pemantauan dan Evaluasi Keanekaragaman Hayati pada Bentang Lahan” (Rahayu et al. 2016).

The carbon stock assessment was focused in Tana Tidung and Nunukan District. The sampling was designed based on the land cover/land use map of Kayan Sembakung Delta, peat depth map and accessibility to reach the plot samples through desk study, as well as focused on non-concession land (Figure 1).

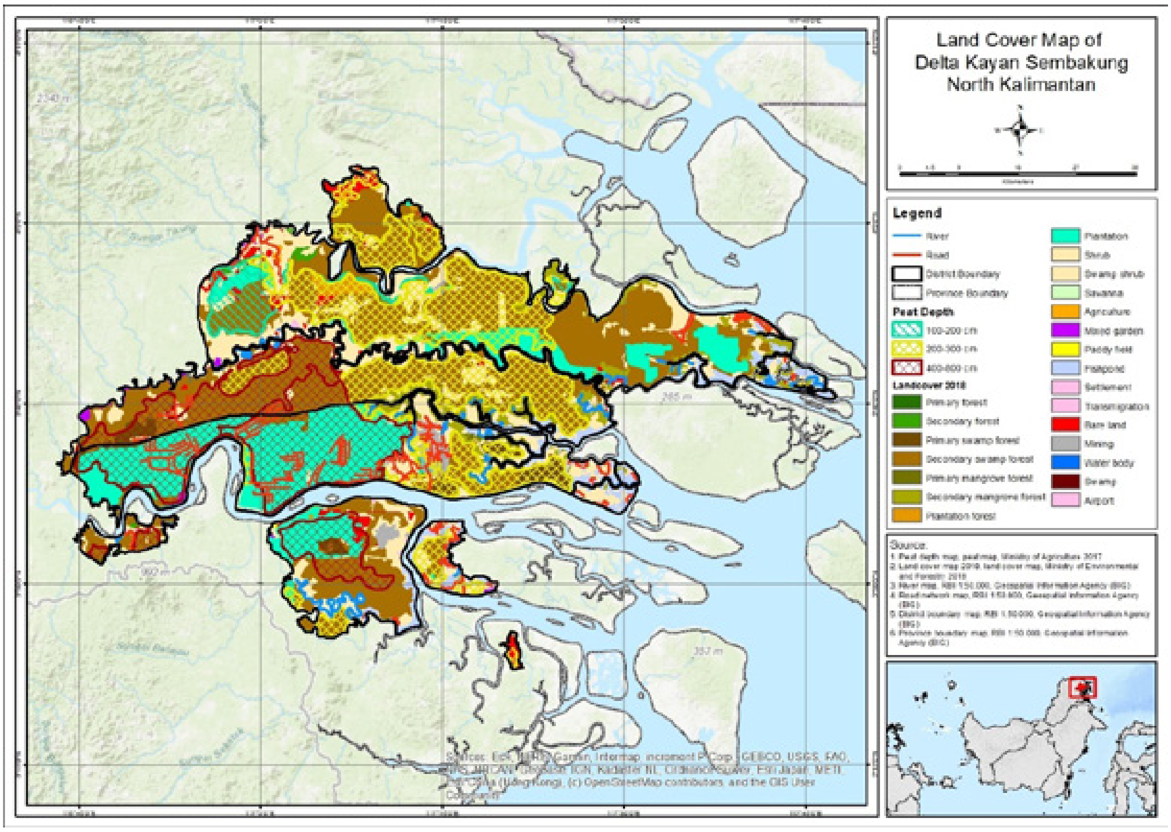


Figure 1. Land cover, peat thickness and potential access of rivers and roads in Delta Kayan Sembakung, North Kalimantan

Stratified random sampling was conducted during assessment through considering land cover (secondary forest and shrub) and peat thickness, while accessibility to reach the sample point (availability of road, river or stream) used as consideration on setting the plot. The sample plot focused in Kecamatan Sesayap Hilir, Tana Tidung District and Kecamatan Sembakung, Nunukan District (Figure 2).

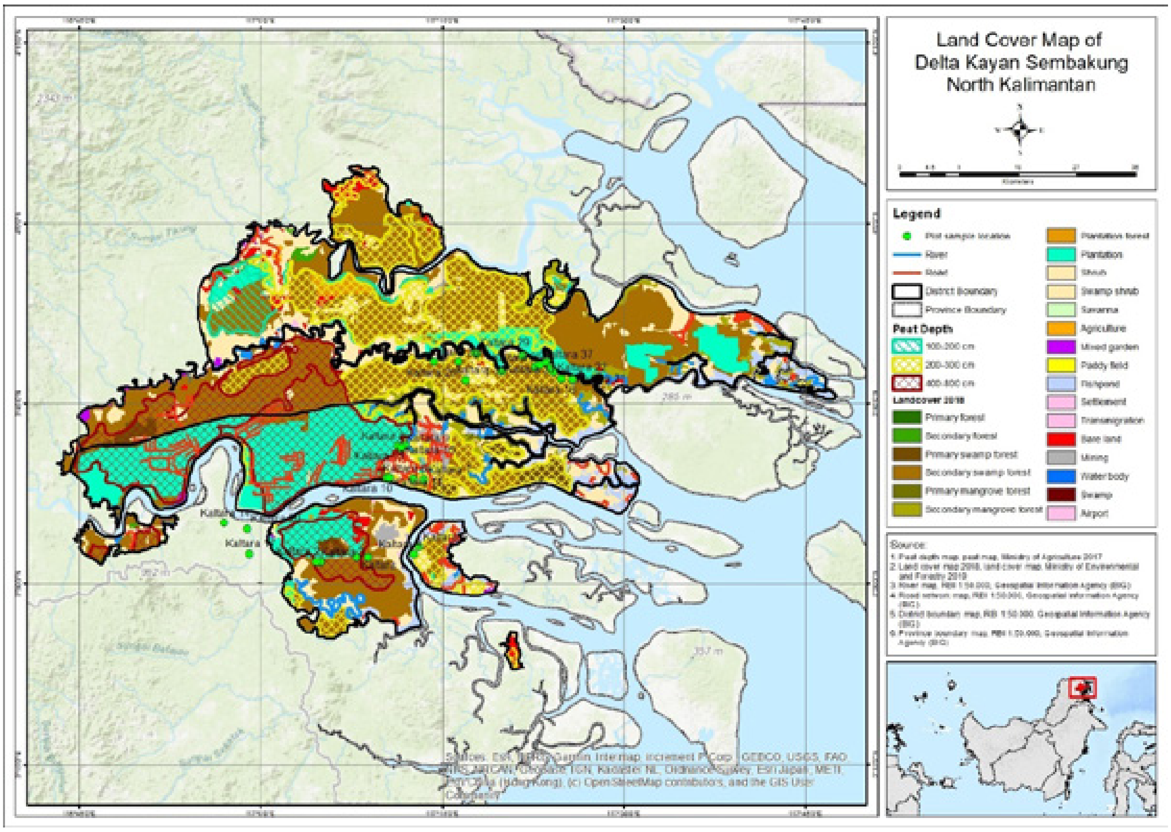


Figure 2. Plot samples position (green light dot)

2.1. Plot Design

Aboveground carbon stock was collected through tree inventory at nested plots of 40 m x 5 m for tree 5-30 cm DBH and plot of 100 m x 20 m for tree ≥ 30 cm DBH (Figure 3). Diameter breast height/DBH for all trees in each category of the plot was measured. Leaves specimen were collected during the inventory. Tree diversity was analyzed based on species inventory in 5 x 10 m x 10 m for the tree above 5-10 cm DBH; in 5 x 20 m x 20 m for tree 10 – 20 cm DBH; and in 100 m x 20 m for the tree above 20 cm DBH.

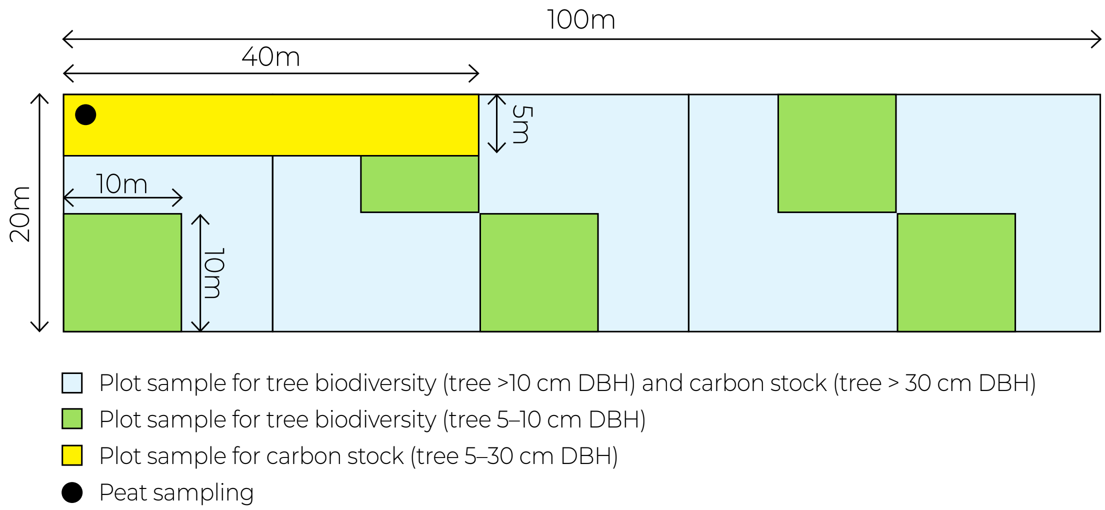


Figure 3. Plot sample design for carbon stock and tree biodiversity assessment

The basic activity on belowground carbon stock measurement in the peat area is peat sampling using peat auger in each 50 cm peat depth until reaching the mineral soil. The peat sample from peat auger then collected (Figure 4). Visual identification of peat maturity was directly made during peat sampling.

Figure 4. Peat sampling using peat auger

2.2. Supporting data collection

Plot level information included administrative information (name of the village, sub-district, district, forest unit management, etc.), GPS position, history of land use, management, the issue on forest fire, logging activity, restoration activity, hydrological condition, etc. was collected during the survey. Interviewing local people, local government, and other relevant key informants is a method to get the information.

2.3. Laboratory analysis

Laboratory analysis was conducted on the bulk density of peat, organic carbon content, and peat maturity. This was done in the Soil Research Institute, Bogor. Tree species identification was conducted in the Herbarium Bogoriense, Cibinong.

2.4. Carbon stock calculation

Aboveground tree biomass of general species was calculated using an allometric equation developed by Chave et al. (2005) for humid/moist topical forest stand with precipitation between 1500 mm-4000 mm/year:

$$ABG\ Biomass_{.est}(kg) = \rho * esp(-1.499 + 2.148\ ln(D) + 0.207(ln(D))^2 - 0.0281(ln(D))^3)$$

For palm species we use allometric equations developed by Brown (1997) that compiled in Hairiah et al. (2011):

$$ABG\ Biomass_{est} = \exp^{[-2.134+2.530 x ln(D)]}$$

Where: AGB $Biomass_{est}$ = estimation aboveground tree biomass, kg/tree; D = DBH, diameter at breast height, cm; ρ = Wood density, g cm^{-3} (available from: http://db.worldagroforestry.org/wd).

Semi destructive sampling through cutting the leaves and stalk, weighting fresh and oven-dried materials, remunerate the number of leaves in each stump, the number of stumps in a plot area applied for estimating biomass of Nipah (*Nipa frutican*). We used 46% carbon content in biomass (Hairiah *et al* 2011). To estimate understorey vegetation, deadwood, and litter, we used 15% (Rahayu et al. unpublished data) of biomass with considering visual observation in the field.

Belowground carbon stock was calculated based on peat thickness (cm) that was obtained from field measurement using peat auger multiplied by bulk density (gcm-3) and organic carbon content (%) from laboratory analysis.

2.5. Tree diversity analysis

Species richness and important value index (IVI) was analyzed. Species richness is the number of different species represented in an ecological community, landscape, or region (Colwell, 2009). Important Value Index (IVI) expressed dominance species in the unit area that calculate based on relative frequency, relative density and relative dominance (Curtis & McIntosh, 1950)

Site Description

Sampling for carbon stock assessment was conducted in Kecamatan Sesayap Hilir, Tana Tidung District and Kecamatan Sembakung, Nunukan District

3.1. Kecamatan Sesayap Hilir

Sesayap Hilir is one of kecamatan in Tana Tidung District that covered area of 1.317,53 km^2, divided by 8 kampung, with population density is 6 people per km^2. Administrative boundaries of Kecamatan Sesayap Hilir is Kecamatan Sembakung, Nunukan District in the north, Muara Sesayap, Kota Tarakan in the east, Bulungan District in the south and Kecamatan Sesayap in the west.

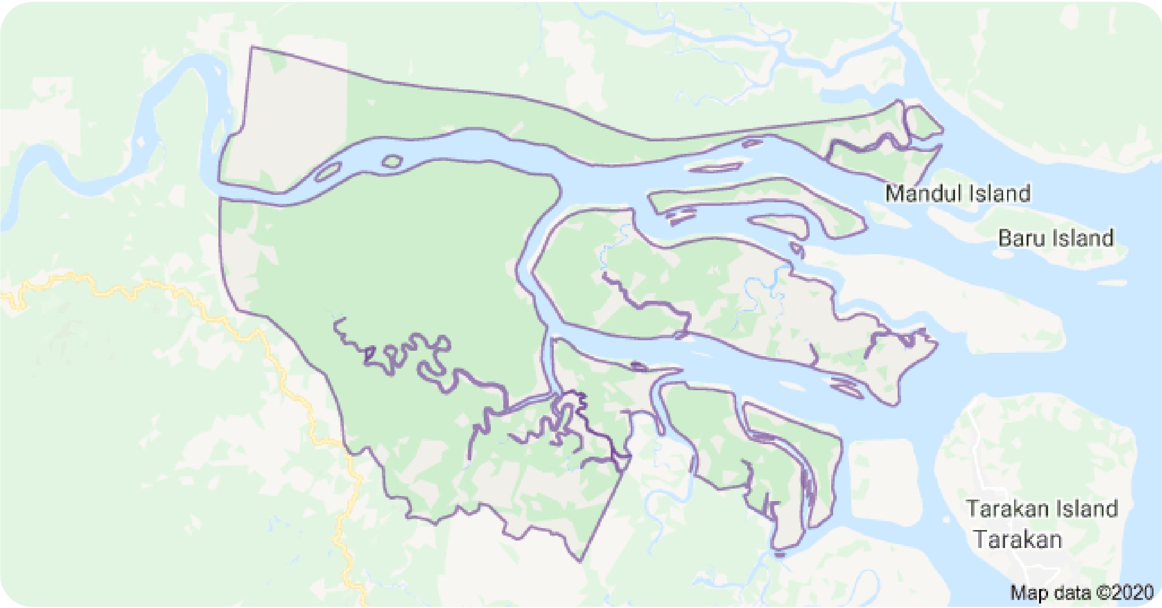


Figure 5. Kecamatan Sesayap Hilir, Tana Tidung District

Nineteen plots inventory was conducted in Tana Tidung. They are predominantly located in Bebatu (9 plots) and Menjelutung (8 plots) Kecamatan Sesayap Hilir; one plot in Kecamatan Sesayap and one plot in Kecamatan Sebawang. The dominant land cover class in Sesayap Hilir and Sesayap is secondary swamp forest and shrub (Figure 6). Logging activity by logging company operated up to 2005 in the area remaining secondary forest and shrub. Secondary forest in Bebatu represented secondary succession process from degraded forest after logging activities, no land clearing. Dense undestorey vegetation, such as *Pandanus* sp. found in the relatively open area in secondary forest.

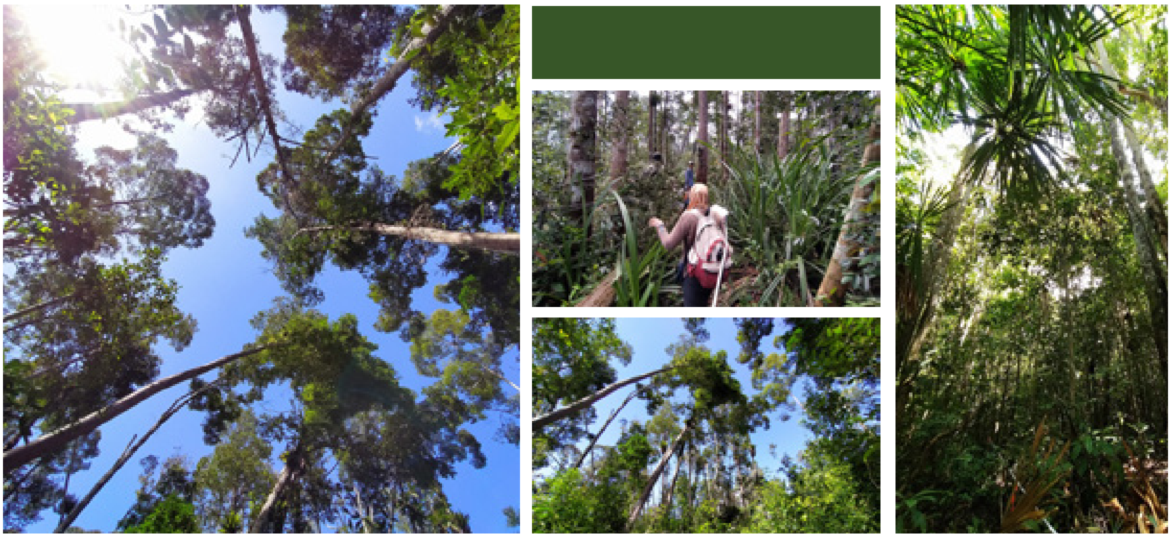


Figure 6. Secondary forest performance in Bebatu, Sesayap Hilir

Peat thickness in the area is dominated by deep peat above 400 cm where located in secondary forest. A 6 m wide canal was built along the road located in the boundary area between timber plantation and secondary forest. In some areas under secondary forest and shrub, peat deep is about 200 – 400 cm. Mineral soil and shallow peat found in Bebatu near the fishpond, which Nipah (*Nipa frutican*) and Nibung (*Oncosperma* sp.) as the dominant vegetation.

Different condition found in Menjelutung, where primary succession that categorized as shrub (Figure 7) found in the open area after logging and land clearing on 2005, due to forest fire or cleared for temporary building during the logging company operating period. This shrub is indicated by pioneer species of *Macaranga gigantea* and *Macaranga hypoleuca* as dominant vegetation.

Figure 7. Shrub performance in Menjelutung, Sesayap Hilir

3.2. Kecamatan Sembakung

Kecamatan Sembakung is one kecamatan in Nunukan District (Figure 8). Administrative boundaries of this kecamatan is Kecamatan Sebuku in the North, Kabupaten Tana Tidung in the east and south, Kecamatan Sembakung Atulai in the west. This kecamatan divided by 9 villages, are: Atap, Butas Batu, Labuk, Lubakan, Manuk Bungkul, Pagar, Plaju, Tagul, Tepian and Tujung. Sample plot for carbon stock assessment focused in Tepian and Plaju village. Secondary forest is dominant land cover along Sembakung river in Tepian and Plaju village, while shrub is located in about 1.5 – 2 km from the river. Peat thickness in the area is in medium 200 – 400 cm.

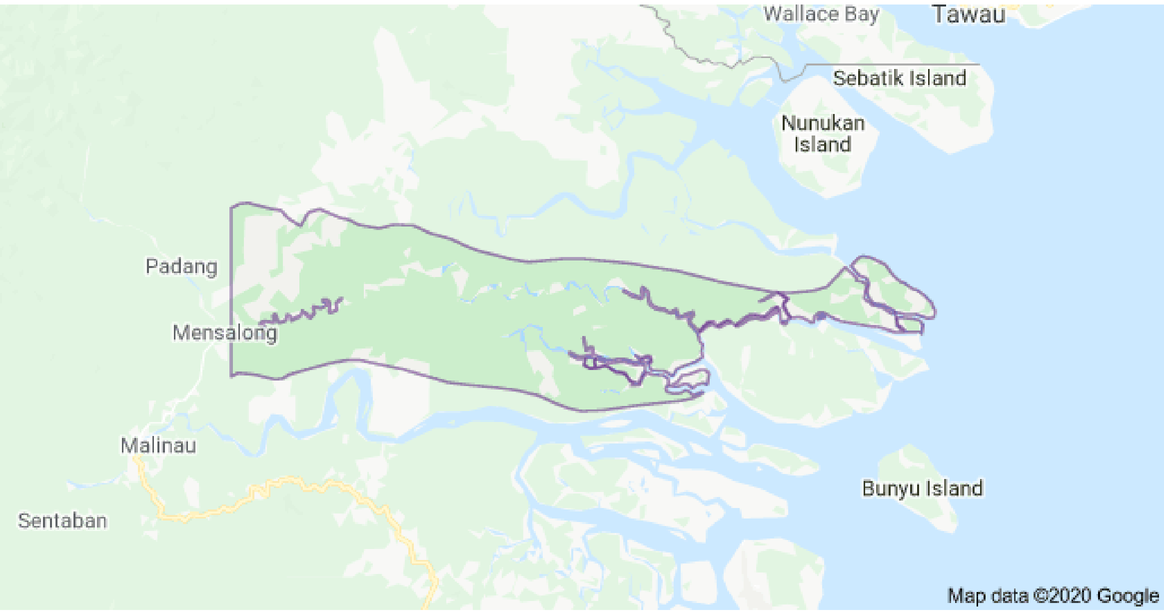


Figure 8. Kecamatan Sembakung, Nunukan District

Secondary forest cover in Tepian and Plaju mostly logged by community. Density of tree more than 30 cm DBH in Nunukan (Tepian and Plaju) is higher compared to Tana Tidung (Bebatu and Menjelutung) (Figure 9). Amount of 13 plots sample observed in Kecamatan Sembakung, 7 plots in Tepian and 6 plots in Plaju.

Figure 9. Secondary forest performance in Tepian and Plaju, Kecamatan Sembakung

Section 4.

Results and Discussions

4.1. Aboveground Carbon stock

Basically, there are two land cover classifications observed in the assessment, are secondary forest and shrub, but shrub only sampled in Tana Tidung District. Secondary forest in the assessment defined a secondary succession of the forest after logging activities where some primary species remaining in the system mixed with some pioneer species or development process of the existing seedling primary species. In comparison, the shrub is primary succession developed from the open area after logging and land clearing activities, mostly dominated by pioneer species.

Aboveground carbon stock at plot level is varied is ranged from 21.7 Mg ha^{-1} at minimum value to 349.4 Mg ha^{-1} at maximum value (Table 1). Average value aboveground carbon stock at the land cover level is 145.4 ± 74.1 Mg ha^{-1} for secondary forest and 41.0 ± 11.3 Mg ha^{-1} for shrub (Table 2).

Table 1. Aboveground carbon stock at plot level in Tana Tidung and Nunukan

Plot code	District	Land cover	Aboveground carbon stock (Mg ha^{-1})
Kaltara 1	Tana Tidung	Secondary forest	116.5
Kaltara 2	Tana Tidung	Secondary forest	107.6
Kaltara 3	Tana Tidung	Secondary forest	97.0
Kaltara 4	Tana Tidung	Secondary forest	205.4
Kaltara 5	Tana Tidung	Secondary forest	51.5
Kaltara 6	Tana Tidung	Shrub	44.1
Kaltara 7	Tana Tidung	Secondary forest	117.9
Kaltara 8	Tana Tidung	Shrub	53.5
Kaltara 9	Tana Tidung	Shrub	45.7
Kaltara 10	Tana Tidung	Secondary forest	141.9
Kaltara 11	Tana Tidung	Secondary forest	71.4
Kaltara 12	Tana Tidung	Shrub	28.3
Kaltara 13	Tana Tidung	Shrub	34.2
Kaltara 14	Tana Tidung	Shrub	34.1
Kaltara 15	Tana Tidung	Shrub	21.7
Kaltara 16	Tana Tidung	Secondary forest	164.4
Kaltara 17	Tana Tidung	Secondary forest	86.8
Kaltara 18	Tana Tidung	Secondary forest	271.3
Kaltara 19	Tana Tidung	Secondary forest	93.1
Kaltara 20	Tana Tidung	Shrub	23.3
Kaltara 21	Nunukan	Secondary forest	138.7
Kaltara 22	Nunukan	Secondary forest	240.1

Plot code	District	Land cover	Aboveground carbon stock (Mg ha^{-1})
Kaltara 23	Nunukan	Secondary forest	74.5
Kaltara 24	Nunukan	Secondary forest	137.2
Kaltara 25	Nunukan	Secondary forest	140.0
Kaltara 26	Nunukan	Secondary forest	276.3
Kaltara 28	Nunukan	Secondary forest	349.4
Kaltara 29	Nunukan	Secondary forest	80.7
Kaltara 30	Nunukan	Secondary forest	86.4
Kaltara 31	Nunukan	Secondary forest	175.7
Kaltara 33	Nunukan	Secondary forest	83.7
Kaltara 35	Nunukan	Secondary forest	158.6
Kaltara 37	Nunukan	Secondary forest	170.2

Average aboveground carbon stock at land cover level in both Tanah Tidung and Nunukan is 145.4 ± 74.1 Mg ha^{-1} for secondary forest and 35.6 ± 11.3 Mg ha^{-1} for shrub (Table 2).

Table 2. Aboveground tree carbon stock in Tana Tidung and Nunukan District

Land cover	Average aboveground carbon stock (Mg ha^{-1})	Standard deviation (Mg ha^{-1})	Number of observed plots
Tana Tidung and Nunukan			
Secondary forest	145.4	74.1	25
Shrub	35.6	11.3	8
Tana Tidung			
Secondary forest	127.1	61.5	12
Shrub	35.6	11.3	8
Nunukan			
Secondary forest	162.4	82.2	13

The average aboveground carbon stock in secondary forest is relatively higher in Nunukan compared to Tana Tidung, but not different statistically. High-density forest with some big trees above 60 cm DBH still found in secondary forest of Nunukan, particularly in Tepian and Plaju, Kecamatan Sembakung, where the sample plots were set up. No shrub sample plots took in Nunukan. According to the local community, shrub available in about 1.5 – 2 km distance from Sembakung river.

By integrating the estimated value of other aboveground carbon pools (dead wood, understorey vegetation, and litter) at 15% of tree biomass, we estimated a total aboveground carbon stock of **167.3 Mg ha^{-1}** for secondary forest and **41.0 Mg ha^{-1}** for shrub. The carbon store per area is higher than the secondary peat swamp forest in the buffer area of Lamandau Wildlife Reserve in Kotawaringin Barat, Central Kalimantan, which is 77 Mg C ha^{-1} with the same method assessment (Janudianto *et al* 2011). Different forest cover and vegetation structure is the main factor that affects aboveground carbon stock. Big trees above 30 cm diameter in Lamandau are rare, except jelutong trees (*Dyera poliphylla*), which maintained by the community to be tapped.

The aboveground carbon stock is lower than the average aboveground carbon stock in remaining peat swamp forest in Kalimantan, 211.8 ± 12.7 Mg ha^{-1} based on lidar estimation (Ferraz *et al* 2018). However, aboveground carbon stock is comparable to the average amount of carbon in the aboveground biomass of mature tropical rainforest, typically 130–240 Mg C ha^{-1} (Aalde *et al* 2006).

4.2. Belowground carbon stock

Belowground carbon stock pool in peatland is consist of peat carbon and root carbon. However, in this assessment, belowground carbon stock only generated from peat since it still lacks information on carbon stock of root in peatland.

Total carbon stock in peatland depends on peat thickness, peat maturity, and peat density. Both peat maturity and peat density are possible indicators to represent peat carbon content. Both in Sesayap Ilir and Sembakung, peatland characterized hemic and fibric, low bulk density, and high carbon organic content (Table 3). Maximum bulk density and minimum carbon organic content found in peaty clay, whereas boundary layer between peat and clay soil.

Table 3. Peat characteristic in Sesayap Ilir and Sembakung

	Bulk density (g cm^{-3})	$C_{organic}$ (%)
Minimum	0.03	10.20
Maximum	0.49	51.78
Average	0.12	47.27
Standard deviation	0.07	8.17

Average bulk density of 0.12 ±0.7 g cm^{-3} and carbon organic content of 47.27 ± 8.17% indicates that peat maturity in the area is mostly categorized as fibric (unmatured peat) referred to Agus *et al* (2011). This value is lower compared to the carbon density of Indonesian peatlands ranging from 54.5% for Jambi to 69.76% for Riau (Warren *et al* 2012).

Peat thickness in observed plots is 7 cm at minimum and 673 cm at maximum with a range of carbon stock is 27.1 – 4071.6 Mg ha^{-1} (Table 4). The peat carbon store in the area is comparable to the previous estimation in excess of 1000 Mg C ha^{-1} with values over 7500 Mg C ha^{-1} reported for exceptionally thick above 12 peat layers (Warren *et al* 2012). Peat carbon stock measurement in Lamandau Wildlife Reserve reached 1400 Mg C ha^{-1} at 150 cm peat layer (Rahayu & Dariah 2019).

Table 4. Peat thickness and carbon stock in Tana Tidung and Nunukan District

Plot code	District	Land cover	Peat depth (cm)	Belowground C stock (Mg ha^{-1})
Kaltara 1	Tana Tidung	Secondary forest	502	2150.4
Kaltara 2	Tana Tidung	Secondary forest	500	1274.1
Kaltara 3	Tana Tidung	Secondary forest	492	3954.4
Kaltara 4	Tana Tidung	Secondary forest	114	1138.6
Kaltara 5	Tana Tidung	Secondary forest	487	3506.4
Kaltara 6	Tana Tidung	Shrub	7	70.5
Kaltara 7	Tana Tidung	Secondary forest	25	870.7
Kaltara 8	Tana Tidung	Shrub	429	1765.4
Kaltara 9	Tana Tidung	Shrub	589	4071.6
Kaltara 10	Tana Tidung	Secondary forest	11	27.1
Kaltara 11	Tana Tidung	Secondary forest	195	197.5
Kaltara 12	Tana Tidung	Shrub	570	2021.2
Kaltara 13	Tana Tidung	Shrub	189	822.7
Kaltara 14	Tana Tidung	Shrub	384	2063.9

Plot code	District	Land cover	Peat depth (cm)	Belowground C stock (Mg ha^{-1})
Kaltara 15	Tana Tidung	Shrub	673	2744.9
Kaltara 16	Tana Tidung	Secondary forest	216	1387.0
Kaltara 17	Tana Tidung	Secondary forest	487	2198.0
Kaltara 18	Tana Tidung	Secondary forest	250	1169.8
Kaltara 19	Tana Tidung	Secondary forest	243	894.5
Kaltara 20	Tana Tidung	Shrub	288	1272.4
Kaltara 21	Nunukan	Secondary forest	300	1683.1
Kaltara 22	Nunukan	Secondary forest	185	1201.9
Kaltara 23	Nunukan	Secondary forest	297	1381.3
Kaltara 24	Nunukan	Secondary forest	140	843.1
Kaltara 25	Nunukan	Secondary forest	167	1135.0
Kaltara 26	Nunukan	Secondary forest	31	280.1
Kaltara 27	Nunukan	Shrub	164	1074.6
Kaltara 28	Nunukan	Secondary forest	179	876.5
Kaltara 29	Nunukan	Secondary forest	137	909.7
Kaltara 30	Nunukan	Secondary forest	513	2613.1
Kaltara 31	Nunukan	Secondary forest	286	1224.9
Kaltara 33	Nunukan	Secondary forest	174	879.1
Kaltara 35	Nunukan	Secondary forest	184	1015.8
Kaltara 37	Nunukan	Secondary forest	232	1178.3

Average value of belowground carbon stock classified based on peat thickness classes referred to Wetland International Indonesia classification at 0 – 100 cm, 100 – 200 cm, 200 – 400 cm and above 400 cm (Table 5).

Table 5. Average value of belowground carbon stock in peatland of Tana Tidung and Nunukan

Peat thickness range (cm)	Average carbon stock (Mg ha^{-1})	Standard deviation (Mg ha^{-1})	Number of observed plots
0 - 100	977.0	654.5	4
100 – 200	1328.5	659.3	12
200 - 400	1464.6	695.4	8
>400	1614.2	1408.2	10

4.3. Tree species diversity

Species richness

Total of 115 tree species found during the assessment, 74 species found in 20 plots of 2000 m^2 each (4 ha) in Tana Tidung and 92 species in 13 plots (2.6 ha) in Nunukan. Species richness in Nunukan higher than in Tana Tidung.

At the plot level, species richness of sapling (tree 5 – 10 cm DBH) and pole (tree 10 – 20 cm DBH) in Nunukan (Kaltara 21 – 37) is higher than in Tana Tidung (Kaltara 1 – 20) (Figure 10). The average species richness of sapling and pole in each plot area in Tana Tidung (Kaltara 1 - 20) is 8 and 14, while in Nunukan

(Kaltara 21 – 37) is 11 and 16 for sapling. Species richness in secondary forest in Tana Tidung (Kaltara 1 – 7, 10 and 11) and in Nunukan (Kaltara 21 – 37) is 15 for pole and 10 for sapling, but lower for shrub (Kaltara 8 – 9, 12 – 19), about 10 for pole and 5 for sapling.

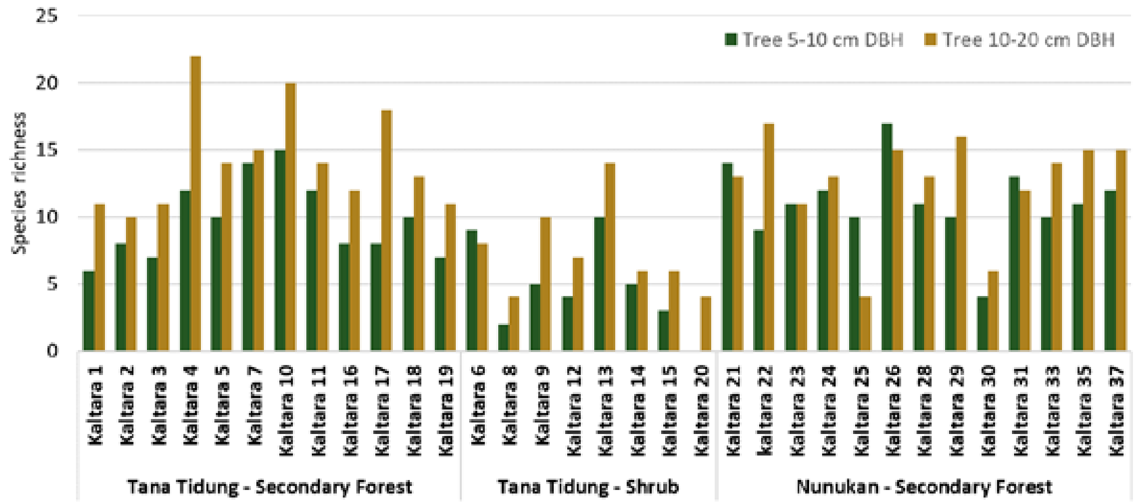


Figure 10. Species richness of sapling and pole in observed plots of peatland in Tana Tidung and Nunukan

Species richness of tree 20 – 30 cm DBH in Tana Tidung and Nunukan is similar, 9 species in average, but species richness of tree > 30 cm DBH in Nunukan (Kaltara 21 – 37) is higher than in Tana Tidung, with average value is 7 species and 5 species, respectively (Figure 11).

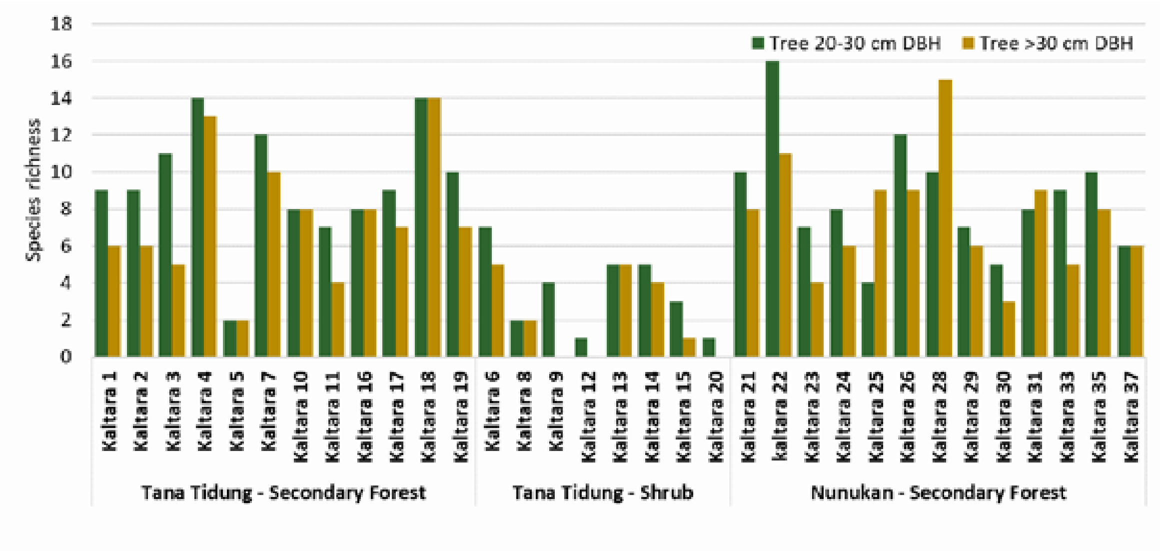


Figure 11. Species richness tree > 30 cm DBH in observed plots of pet land in Tana Tidung and Nunukan

Tree density

At the plot level, tree density sapling (tree 5 – 10 cm DBH) in Nunukan is higher than Tana Tidung but remain the same for pole (tree 10 – 20 cm DBH) (Figure 12). Average tree density of sapling is 33 trees in 100 m^2 (660 trees per ha) in Nunukan, 24 trees in 100 m2 (480 trees per ha) in Tana Tidung; average tree density of pole is 105 trees in 400 m^2 (525 trees per ha) in Nunukan and 101 trees in 400 m^2 (505 trees per ha) in Tana Tidung

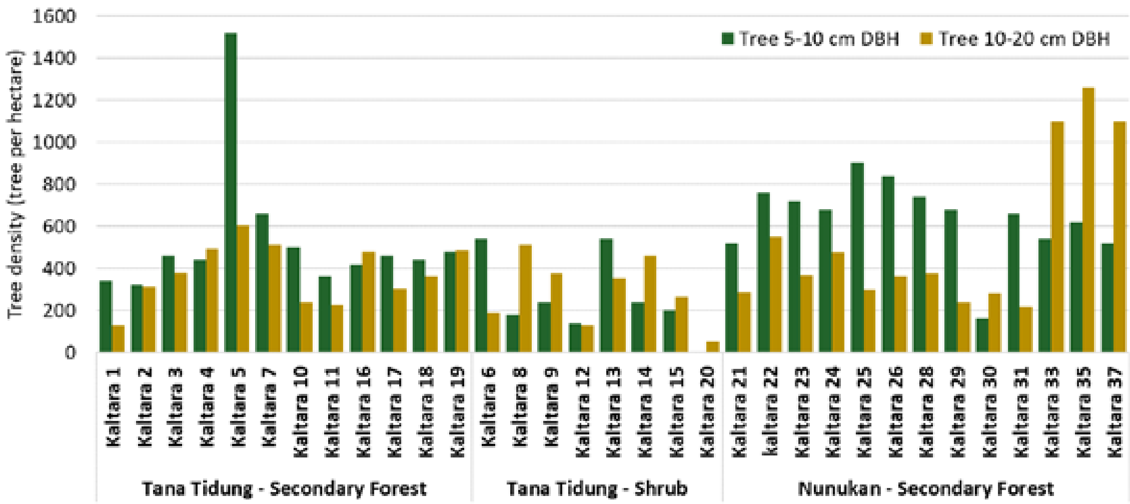


Figure 12. Tree density of sapling and pole in observed plot in Tana Tidung and Nunukan

Tree density of tree 20 – 30 cm DBH in Nunukan is higher than in Tana Tidung, 120 tree per ha and 109 tree per hectare, respectively. Tree above 30 cm DBH is varied from 0 to 33 in 2000 m^2 (Figure 13), with similar average value at 12 trees in 2000 m^2 (60 trees per ha) in Tana Tidung and 14 trees in 2000 m^2 (70 trees per ha).

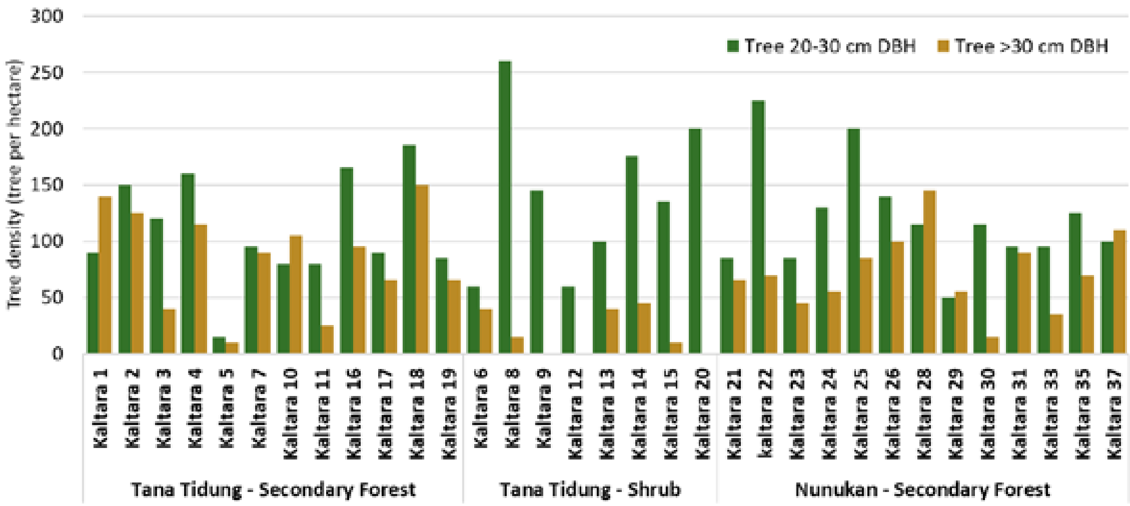


Figure 13. Tree density of tree 20 – 30 cm DBH and tree above 30 cm DBH in Tana Tidung and Nunukan

Higher tree density of pole stage (10 – 20 cm DBH) at 660 trees per ha than sapling stage (0 – 10 cm DBH) at 525 trees per ha occurred in Nunukan; while in Tana Tidung tree density of sapling is higher (505 trees per ha) than pole (480 trees per ha). This condition indicates a different succession stage between Tana Tidung and Nunukan.

Section 5.

Conclusions

The dominant land cover in the non-permit area in Sesayap Ilir (Tana Tidung) and the Sembakung (Nunukan) District are secondary forests, shrubs, and plantations. Peat thickness is ranged from 0 – 7 m. Total aboveground carbon stock is **167.3 Mg ha^{-1}** for secondary forest and **41.0 Mg ha^{-1}** for shrubs.

Peat condition in the secondary forest and shrub in the non-permit area in Sesayap Ilir and secondary forest in Sembakung is characterized as hemic and fibric in term of maturity with average bulk density is **0.12 ± 0.07 g cm^{-3}** and organic carbon content is **47.27 ± 8.17%**. Peat thickness is ranged from 7 – 673 cm. Average carbon content in peat is **977.0 ± 654.5 Mg ha^{-1}** for peat thickness 0 – 100 cm, **1328.5 ± 659.3 Mg ha^{-1}** for 100 – 200 cm, **1464.6 ± 695.4 Mg ha^{-1}** for 200 – 400 cm and **1614.2 ± 1408.2 Mg ha^{-1}** for > 400 cm.

Tree species richness in Nunukan is higher than in Tana Tidung, 92 species in 2,6 ha and 74 in 4 ha. Higher species richness found in diameter classes of 10 – 20 cm and 20 – 30 cm DBH. Tree density in secondary forests is dominated by pole (10 – 20 cm DBH), but in shrubs is dominated by sapling (5 – 10 cm DBH).

Section 6.

General Remarks

The value of aboveground carbon stock in secondary forest and shrub, as well as peat carbon stock in this assessment, was estimated from plot-level inventory. In this assessment, we observed 25 plots for secondary forest and eight shrub plots, which only covered 6.5 hectares. Compared to the total area of secondary forest and shrub in non-concession peatland in Kahayan – Sembakung Delta, the coverage area of the sample lacks representative due to high variability of canopy cover, tree species and peat thickness across the area. More plots inventory is better to meet the representativeness of the data.

However, with limited data available, we still possible to use the data for broader purposes by providing detailed information on the number of plot samples and standard error deviation of the data.

Otherwise, for future works, there are possible options to increase the representativeness of data: (1) combining other available data with similar survey methods, and (2) do additional plots samples with the same method.

References

Aalde H, Gytarsky M, Krug T, Kurz WA, et al. Chapter 4: Forestland. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. 2006. I*PCC Guidelines for National Greenhouse Gas Inventories*. Japan: IGES; 2006. p. 4.53.

Agus F, Hairiah K, Mulyani A. 2011. Pengukuran Cadangan Karbon Tanah Gambut. Petunjuk Teknis. Bogor, Indonesia: World Agroforestry Centre dan Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (BBSDLP). 58 p.

Chave J, Andalo C, Brown S, Cairns M A, Chambers JQ, et al. 2005. Tree allometry and improxed estimation of carbon stocks and balance in tropical forests. *Oecologia* 145:87-99. DOI 10.1007/s00442-005-0100-x.

Colwell RK. 2009. Biodiversity: Concepts, Patterns and Measurement. In Simon A. L. *The Princeton Guide to Ecology*. Princeton: Princeton University Press. pp. 257–263.

Curtis JT, McIntosh RP. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.

Ferraz A, Saatchi S, Xu L, Hagen S, Chave J, Yu Y, Meyer V, Garcia M, Silva C, Roswinti O. 2018. Carbon storage potential in degraded forests of Kalimantan, Indonesia. Environmental Research Letters, Volume 13, Number 9. https://iopscience.iop.org/article/10.1088/1748-9326/aad782

Hairiah K, Ekadinata A, Sari RR, Rahayu S. 2011. P*engukuran Cadangan Karbon: dari tingkat lahan ke bentang lahan*.Petunjuk praktis. Edisi kedua. Bogor, Indonesia: World Agroforestry Centre, ICRAF SEA Regional Office; Malang, Indonesia: University of Brawijaya (UB). 88p.

Hergoualc'h K, Verchot LV. 2011. Stocks and fluxes of carbon associated with land-use change in Southeast Asian tropical peatlands: A review. *Global Biochemical Cycles* 25(2):GB2001. DOI:10.1029/2009GB003718

Hergoualc'h K, Carmenta R, Atmadja S, Martius M, Murdiyarso D, Purnomo H. 2018. *Managing peatlands in Indonesia: Challenges and opportunities for local and global communities*. Info Brief No. 205. Bogor, Indonesia: Center for International Forestry Research. https://doi.org/10.17528/cifor/006449

Janudianto, Mulyoutami E, Joshi L, Wardell DA and van Noordwijk M. 2011. *Recognizing traditional tree tenure as part of conservation and REDD strategy: Feasibility study for a buffer zone between a wildlife reserve and the Lamandau river in Indonesia's REDD Pilot Province*. ASB Policy Brief No. 22. Nairobi, Kenya: ASB Partnership for the Tropical Forest Margins.

Khasanah N, van Noordwijk M. 2018. Subsidence and carbon dioxide emissions in a smallholder peatland mosaic in Sumatra, Indonesia. *Mitigation and Adaptation Strategies for Global Change* 24: 147–163.

Osaki M, Nursyamsi D, Nur M, Wahyunto, Segah H. 2016. Peatland in Indonesia. In: Osaki M and Tsuji N (eds.). *Tropical Peatland Ecosystems*. Sapporo, Japan: Springer. pp:49-58

Pantau Gambut https://pantaugambut.id/

Rahayu S, Dariah A. 2019. *Dapatkah kematangan gambut dijadikan proxy kandungan bahan organic dan bobot isi dalam penghitungan cadangan karbon gambut tropis secara cepat*? Technical Brief No. 103. Bogor, Indonesia: World Agroforestry (ICRAF) Southeast Asia Regional Program.

Rahayu S, Dewi S., Harja D, Hairiah K, Pambudi S. 2016. Keanekeragaman hayati pada bentang lahan: pemahaman, pemantauan dan evaluasi. Bogor, Indonesia: World Agroforestry Centre (ICRAF) – South East Asia Regional Program – Brawijaya University, 74p. ISBN 978-979-3198-83-5

Republik Indonesia. 2017. *Indonesian Third National Communication Indonesian Third National Communication under The United Nations Framework Convention on Climate Change*. Jakarta, Indonesia: Ministry of Environment and Forestry.

Rumbang N. 2015. A study of carbon dioxide emission in different types of peatland use in Kalimantan. *Ilmu Pertanian* 18 (1): 8–17

Warren M, Hergoualc'h K, Kauffman JB, Murdiyarso D, Kolka R. 2017. An appraisal of Indonesia's immense peat carbon stock using national peatland maps: uncertainties and potential losses from conversion. *Carbon Balance Management* 12. https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-017-0080-2

Warren M, Kauffman J, Murdiyarso D, Anshari G, Hergoualc'h K, Kurnianto S, et al. 2012. A cost-efficient method to assess carbon stocks in tropical peat soil. *Biogeosci Discuss* 9(6):7049–71.

World Agroforestry (ICRAF) Program Indonesia
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16115 | PO Box 161, Bogor 16001, Indonesia
Ph: +62 251 8625 415 | Fax: +62 251 8625 416 | Email: icraf-indonesia@cgiar.org
www.worldagroforestry.org | www.worldagroforestry.org/agroforestry-world