BIOMASS AND CARBON STOCK ASSESSMENT OF PEAT SWAMP FOREST ECOSYSTEM; A CASE STUDY IN PERMANENT FOREST RESERVE PEKAN PAHANG, MALAYSIA

Mohd Afzanizam, M.[1], E.Philip[2], Shahrul,A.B,[3] & Mohd Haniff, H[4]

[1]Research Officer, Forest Research Institute Malaysia (FRIM), Climate Change and Forestry Program, 52109 Kepong Selangor
[2] Head of Program, Forest Research Institute Malaysia (FRIM), Climate Change and Forestry Program, 52109 Kepong Selangor
[3]Research Officer, Forest Research Institute Malaysia (FRIM), Climate Change and Forestry Program, 52109 Kepong Selangor
[4] Head of Unit, Malaysia Palm Oil Board (MPOB), Tropical Peat Research Institute (TROPI), 6, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang Selangor

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Abstract-*Calculation of forest biomass is an ongoing requirement. It is in view of monitoring the changes that occur as one of the particular assessment in the forest especially in PSF Pekan. The study was conducted in Compartment 75. The results estimated the total biomass is 415.18 t ha-1, the value of which is almost the same compared to the Compartment 100 in another study which is 414.57 t ha^{-1}. This situation may change in the next 10 to 30 years, because in Compartment 75 indicates that trees with DBH Class 55.0-69.9cm contribute the highest carbon stocks by 87.16 C t ha-1 (36.9%) with basal area 4.47 m^2 ha^{-1}, compared with the Compartment 100 where the DBH class of 40.0-54.9cm as the highest biomass contributor with 153.22 C t ha-1 (37%) with a basal area of 11.13 m2 ha-1. Other studies; Compartment 156 and Compartment 200 reported biomass result as 399.21 t ha-1 and 328.14 t ha-1 respectively, shown that Compartment 75 may among the highest in this PSF. This study should be continued in future periods as a series of useful data.*

Keyword: **carbon stock, stand structure, stocking density, peat swamp, tree biomass**

1. INTRODUCTION

Forest ecosystem including peat swamps in their natural state play a role as an efficient carbon stores in terrestrial environment. The Intergovernmental Panel on Climate Change identified five carbon pools of the forest ecosystem involving biomass namely the aboveground biomass (AGB), belowground biomass (BGB), litter, woody debris or soil organic matter (SOM). Among all carbon pools, the aboveground biomass constitutes the major portion of the carbons storage in forest. Forest biomass estimation is very crucial for long term monitoring the amount of carbon that is emitted during deforestation and will also project forest's potential to sequester and store carbon in the forest. In Peninsular Malaysia alone, PSF coverage area is 255,080 ha [1]. From this total, 140,830 ha is located in Pahang. Table 1 extracted from Forestry Statistics show PSF coverage area under Permanent Reserve Forest by Forest type in 2014. No value recorded in other states.

Table 1: PSF coverage area in Johor, Pahang, Selangor in 2014 [1].

States	Peat Area (ha)
Johor	5,429
Pahang	140,830
Selangor	82,890
Terengganu	25,931* (*using digital satellite data)
Total	255,080

Among first extensive inventory of peat swamp forest (PSF) has been studied mostly in Sarawak and Brunei [2] and [3]. In this preliminary study, the two major carbon pool AGB and BGB will be discussed later. In Peninsular Malaysia, estimated carbon stock for PSF under logged and natural condition were 98 t/ha and 120 t/ha respectively [4].

Table 2 show carbon stock changes in PSF, Malaysia (tonne per hectare) [5].

Year / Type of Forest	1972	1983	2005
Natural/Undisturbed PSF	88.75	107	110-225
**Logged* PSF	61.8	89	90
Degraded PSF	54.7	135	

Note: * Study conducted at PSF in Johor and Selangor

According to values of various sources (Table 3), the AGB of logged-over and secondary peat swamp forest in tropical region ranges from 130-334 t/ha (~65-167 t C/ha) [6]. Estimated carbon content of biomass was assumed to be 50% of dry weight biomass (Table 3).

Two allometric functions are generally used in describing the standing biomass of a forest stand (i) aboveground biomass (AGB) (ii) belowground biomass (BGB). AGB biomass refers to the biomass of standing trees above the ground which includes the stems, branches, twigs and leaves of the trees. BGB biomass refers to the biomass of the roots of standing trees. The tree biomass is calculated based on the allometric functions developed by measuring the weights of the tree components (stems, branches, leaves and roots) from destructive sampling of trees. For PSF, existing allometric equation were adopted for biomass estimation based on a more similar type of forest in Sumatra [7]. The equations used in this study are as follows:

Table 3: Published values of aboveground biomass (AGB) and aboveground carbon (AGC) in logged-over or degraded peat swamp forest (PSF) [8].

PSF type	Province/State	AGB (tonne ha^{-1})	AGC (tonne C ha-1)	References
Logged-over	Kota Samarahan, Sarawak	244.28	122.14	[8]
Secondary PSF	Jambi	306	153	[9]
Secondary PSF	Central Kalimantan	130	65	
Secondary PSF	Sumatra	284	142	[10]
Secondary PSF	Papua	334	167	
Secondary PSF	Kalimantan	310	155	

In this preliminary study, tree biomass and carbon stock in Pekan FR has been determined. Sequestration or uptake refer to the process of increasing the carbon content of a carbon pool other than the atmosphere [11]. The objective of the study are :

1. To conduct biomass assessment studies and provide baseline data for peat swamp forest in natural/pristine condition.

2. To quantify carbon stock for tropical peat swamp forest.

2. MATERIAL & METHOD

The study site is located at Compartment 75, Pekan FR, in the Southeast of Pahang, Malaysia (Figure 1). The Compartment 75 is a 200-ha area under production forest.

2.1Ecological Plot Establishment

Ten plots of 20m x 20m were established for population profile assessments. It is important to acquire information and examine changes in forest structure and species composition through time, and to examine changes in stand density and basal area. All trees ≥10 cm dbh were measured for the stand structure and density.

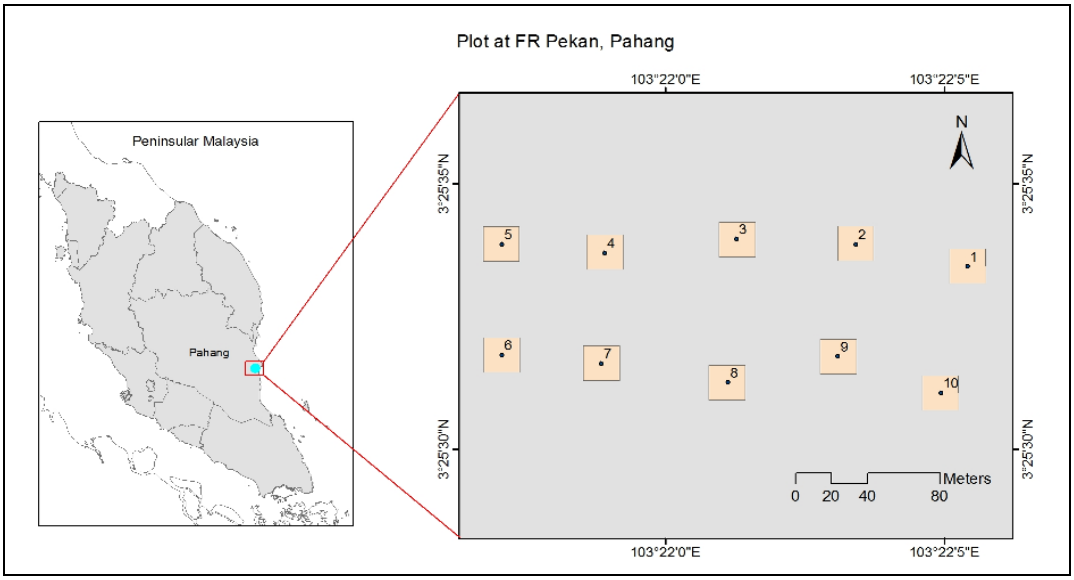

Figure 1: Permanent plot size establishment of 20 m x 20m in Compartment 75 Pekan FR for tree biomass assessment and carbon stock study.

2.2Tree species diversity and forest structure

All living trees and dead trees were enumerated in the plot. The merchantable height and dbh were recorded and metrics of abundance including basal area and stand density.

Tree basal area and tree volume was calculated as follows;

Basal area, ba =[π (dbh^2)/40000] (unit in m^2),

Tree volume, vol; = ba x mht x 0.65 (unit in m^3), where mht is merchantable bole height in meters. The 0.65 value is a presumed form factor that applies to all trees [12]. Only trees with ≥10 cm dbh were analysed

Maximum canopy height of these trees was obtained using a clinometers and their basal circumference (as close to the tree base as possible or immediately above stilt or buttress roots). Characteristics of the trees in each plot were noted to assist in their identification. Local names of trees were assigned; voucher specimens were collected and refereed to FRIM Herbarium and other prominent morphological features were cross-referenced to tropical peat standard works in Sarawak and Brunei [13,14],Peninsular Malaysia, Sabah and Sarawak [15-19].

2.3Tree biomass

Tree biomass is defined as the total amount of living organic matter in trees and express it as oven-dry per unit area, usually in tonne ha^{-1} [20]. In this biomass assessment studies, stem diameter which is the most common parameter measured in both permanent and temporary samples plots, has been used to calculate biomass of a tree as many allometric functions include stem diameter as one of the main predictors of above-ground biomass [7,21-23) and below-ground biomass [23]. Other equation developed for a rather generalized tropical wet forest and not specific to tropical

peat swamp [24]. Common equations used for estimating tropical tree biomass in Malaysia are generally suitable for dry inland forest [21].

Biomass(aboveground), AGB = 0.0145 (dbh^3) – 0.4659 (dbh^2) + 30.64 (dbh) -263.32 , dbh in cm, R^2 = 96

Biomass (belowground), BGB = 20.1% of AGB

Total Plant Biomass = Biomass(aboveground) + Biomass (belowground)

The standing biomass of a stand is the cumulative summation of the calculated tree biomass by the area (hectares). For multiplot assessment, the average value is calculated to represent the standing biomass for this compartment. In general, the basic allometric function of biomass equation includes the stem diameter at breast height (dbh) to establish height-stem dbh relationship [21]. Steps taken in calculating the aboveground biomass from a single tree measurement. This will give biomass carbon of one tree and converted to "per hectare basis" for one plot and up to the average value for standing biomass of an area [22].

2.4 Carbon stock

C estimation using suitable allometric equation were developed for tropical peat swamp forest based on carbon stock estimation study in Riau Indonesia [25]. The carbon stock is converted to a hectare basis by dividing the cumulative sum of the carbon stocks in each DBH class by the area (hectares).

C = $0.087*D^{2.470}$, D=dbh in cm, C in kg

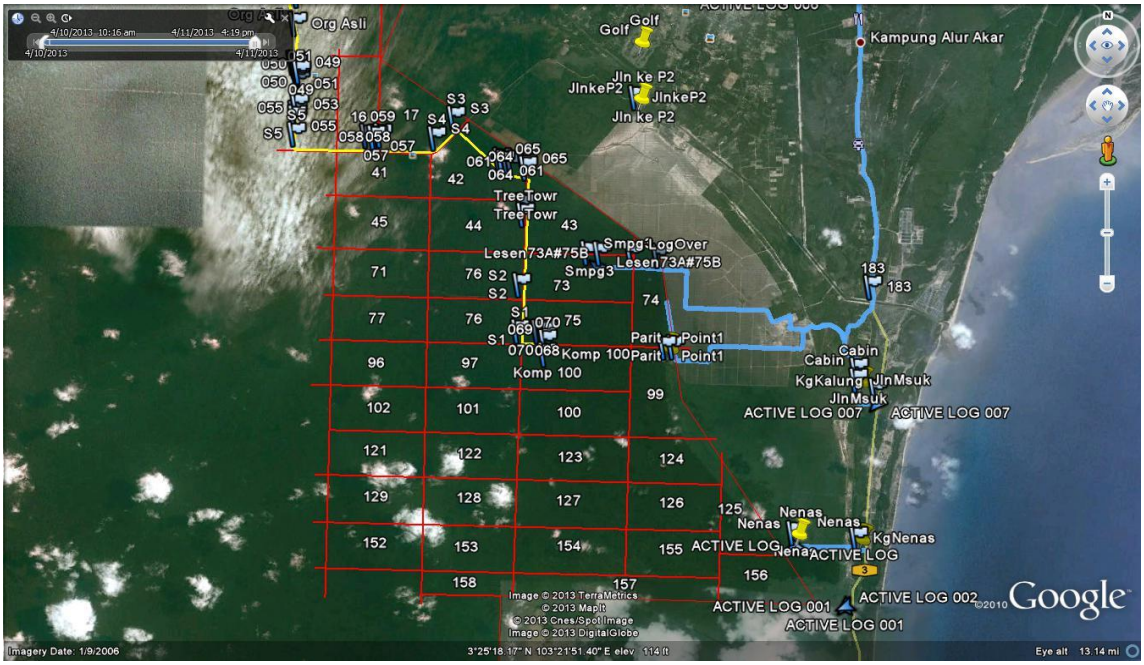

Figure 2: Location map shows Compartment 75 in PSF Pekan. Compartment size was 2000m x 1000 m.

3. RESULT AND DISCUSSION

Table 4 shows data on structure of trees ≥ 10 cm dbh in the plot. A total of 173 trees were enumerated in the plot and taxonomic composition for biodiversity assessment.

From field observation, the most abundant trees found in class height 10-19.9 m which is 76 trees that form the undercanopy/understorey layer. Almost 48% (85 trees) of make up the forest canopy layer also known as canopy coverage or crown cover. Average height of trees was 21.7 m. The tallest tree recorded across the plot were 42.4 m while the shortest trees were 4.4 m (Table 4).

Table 4 shows number of trees according to class height.

Forest layer	Class of Height (m)	Number of trees	Canopy coverage (%)
Undergrowth	0-9.9	7	4.05
Understorey/undercanopy	10-19.9	76	43.93
Canopy	20-29.9	56	32.37
	30-39.9	29	16.76
Emergent	40-49.9	5	2.89
	≥50	0	0
	Total	173	100.00

Based on the tropical lowland peat swamp forests in Sarawak, Malaysia and adjacent Brunei show lateral or horizontal changes in vegetation types from its periphery to the centre of the dome-shaped peat swamps and each of the six dominant lateral vegetation zone was previously designated as "Phasic Community'' [3]. Six distinct communities or successive lateral vegetation zones were recognized based on their floristic composition and structure of vegetation in each Phasic Zone [3, 26] and were numbered Phasic Community I at the margin to Phasic Community VI in the centre of the peat swamp.

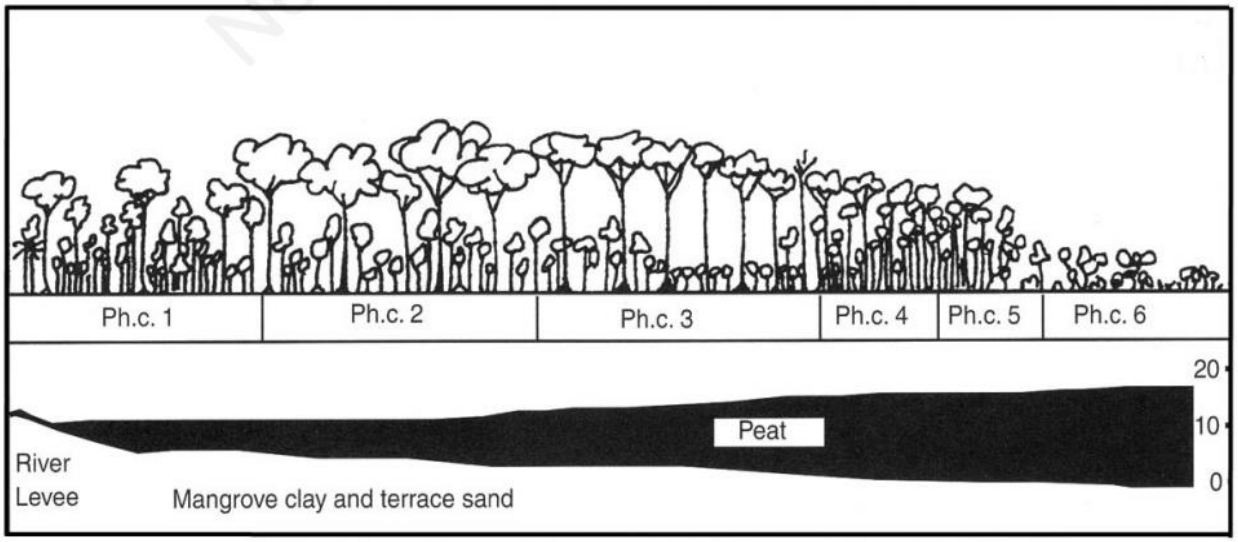

Figure 3: Six phasic communities, along a gradient, or catena, of decreasing soil fertility and increasing waterlogging, from the periphery (seaward) to the centre (landward). (Adapted from [3,27])

Compartment 75 of Peat Swamp Forest in Pekan classified as mixed peat swamp according to phase of vegetation [3,27,28] and referred to as phasic community 1. The main tree species association for mixed swamp forest are *Gonystylus-Dactylocladus-Neoscortechinia*. This phasic vegetation community closely resembles lowland dipterocarp forest. Prominent species observed in Compartment 75 are *Shorea sp., Calophyllum sp.* and *Gonystylus sp.* For example, *Shorea leprosula* (meranti tembaga) & *Shorea platycarpa (*meranti paya). The presence of one dominant species, *Shorea albida* or balau is absent from swamps outside Sarawak, western Brunei and northwest Kalimantan as it is commonly regarded as monoculture stand and very rare in tropical rain forests associated with its phenological characteristics and site condition of peat swamp.

In early 60s, a comprehensive study on the ecology of the lowland peat swamp forest in Sarawak and Brunei has inventoried 253 tree species that are mostly confined to the seaward or periphery of the swamp forest [3,27,29]. Most of the plant species that grow in the forests at the centre of the peat domes are usually found on nutrient poorer soils in the heath forest [27]. Table 5 show floristic inventory in Compartment 75 of peat swamp forest in Pekan Pahang.

Table 5: Flora inventory in Compartment 75, Peat Swamp Forest ,Pekan Pahang.

Family	Scientific name (Local name)	Number of species	Number of trees
Meliaceae	*Aglaia rubiginosa* (Bekak), *Sandoricum beccarianum* (Sentol)	2	7
Euphorbiaceae	*Blumeodendron tokbrai (*Gaham badak), *Neoscortechinia philippinensis, Pimelodendron griffithianum* (perah ikan)	3	3
Guttiferae	*Calophyllum ferrugineum* (Bintangor gambut), *Calophyllum molle (Bintangor), Calophyllum sclerophyllum (*Bintangor jangkang), *Garcinia parvifolia* (kandis), *Garcinia urophylla* (kandis)	2	23
Anacardiaceae	*Campnosperma coriaceum (*Terentang simpoh)	1	4
Ochnaceae	*Campylospermum serratum (*Mata ketam)	1	1
Rhizophoraceae	*Carallia brachiata* (Meransi), *Pellacalyx axillaris* (membuloh)	2	2
Guttiferae	*Cratoxylum formosum* (Geronggang)	1	1
Burseraceae	*Dacryodes macrocarpa (*Kedondong matahari), *Santiria laevigata* (kedondong kerantai licin), *Santiria rubiginosa* (kedondong kerantai), *Santiria tomentosa (*kedondong bulu)	2	16
Fabaceae	*Dialium indum* (Keranji paya)	1	2
Ebenaceae	*Diospyros lanceifolia (*Kayu arang), *Diospyros maingayi* (Kayu arang)	2	3
Rubiaceae	*Diplospora malaccensis*	1	1
Bombacaceae	*Durio carinatus* (durian paya)	1	2
Elaeocarpaceae	*Elaeocarpus floribundus*(Mendong)	1	3
Lauraceae	*Litsea grandis (*Medang daun lebar)	1	3
Thymelaeaceae	*Gonystylus bancanus* (ramin melawis)	1	8
Myristicaceae	*Gymnacranthera farquhariana* (Penarahan)	1	7
Fagaceae	*Koompassia malaccensis* (Kempas), *Lithocarpus ewckii* (Mempening)	2	4
Celastraceae	*Lophopetalum multinervium* (perupok)	1	2

Rutaceae	*Maclurodendron sp.* (Perupok)	1	2
Myristicaceae	*Myristica lowiana* (penarahan arang)	1	1
Sapindaceae	*Nephelium maingayi* (Redan)	1	10
Chrysobalanaceae	*Parastemon urophyllus* (Nyalas)	1	5
Pittosporaceae	*Pittosporum ferrugineum*	1	1
Sapotaceae	*Pouteria maingayi (*Nyatoh nangka merah)	1	5
Dipterocarpaceae	*Shorea leprosula* (meranti tembaga), *Shorea platycarpa (*meranti paya)	1	8
Stemonuraceae	*Stemonorus secundiflorus* (sampul keris)	1	11
Myrtaceae	*Syzygium cerinum* (kelat gelam), *Syzygium kiahii, Syzygium lineatum, Syzygium sp.*	1	35
Tetrameristaceae	*Tetramerista glabra* (punah)	1	2
Unidentified			2
Total		36	173

Prominent species observed in Compt .75 are *Gonystylus bancanus* (Ramin melawis), *Calophyllum ferrugineum* (Bintangor gambut), *Shorea platycarpa* (Meranti paya), *Tetramerista glabra* (Punah) and *Durio carinatus* (Durian paya), *Koompassia malaccensis* (Kempas). Stand characteristics of tree communities of Ramin-Bintangor forest subtype in Southeast Pahang peat swamp forest (SEP PSF) are rich with commercial timber species [30](Table 5)

Stocking density was the highest in the DBH class of 10.0-24.9, represented by 97 stems (56.07%). Both basal area and volume were the largest in the dbh class 55.0-69.9 with 4.47 m^2 ha^{-1} and 75.07 m^2 ha^{-1} respectively. The stocking density was relatively low at only about 1.73% (3 stems) out of the total. Basal area are useful measure for site occupancy and forecast future development of tree stand at a given time. Total basal area and volume was 14.02 m^2 ha^{-1} and 190.48 m^3 ha^{-1}respectively (Table 6).

Table 6: Stand structure of trees by dbh classes in Compartment 75, Pekan FR.

DBH class (cm)	Stocking density (stems ha^{-1})	Basal area(m^2 ha^{-1})	Volume (m^3ha^{-1})
10.0-24.9	97 (56.07%)	1.85	14.72
25.0-39.9	35(20.23%)	2.78	32.96
40.0-54.9	23(13.29%0	3.69	50.77
55.0-69.9	15(8.67%)	4.47	75.07

≥70	3 (1.73%)	1.22	16.96
Total	173 (100%)	14.02	190.48

Note; Number in parentheses denotes the percentage value

Table 7 show tree biomass for all trees in the plot at Compartment 75, Pekan FR. Biomass of trees with dbh ≥ 5cm for the Compartment 75 is shown below. The plot has a total tree biomass value 415.18 tonnes ha^{-1}. The dbh class with the greatest total plant biomass was 55.0-69.9 cm with 146.93 tonnes ha^{-1}, the smallest was 10.0-24.9 cm with 42.61tonnes ha^{-1} (10%) (Table 7). However, stocking density was the highest in dbh class 10.0-24.9 cm, represented by 97 stems (56.07%) (Table 6). The highest total biomass recorded in dbh class 55-69.9 (146.93 t/ha) due to high number of stems for site occupancy (Table 7). The highest stocking density were recorded for the same dbh class in Compartment 100 in Pekan FR (182 stems ha^{-1}, 48.4%) with total biomass of 342.62 tonnes ha^{-1}[30]. Highest stocking density also been recorded in Compartment 156 and Compartment 200 of Pekan FR at 358 stems ha^{-1} (64.3%) and 425 stems ha^{-1} (76.6%) respectively [31]; In other part of Pekan FR, the highest tree biomass recorded was in dbh class 40.0-54.9 [30]. In general, Compartment 75 has a high amount of tree biomass.

Table 7: Tree biomass for all trees in the plot at Compartment 75, Pekan FR

DBH class (cm)	Aboveground biomass (t/ha)	Below ground biomass(t/ha)	Total biomass (t/ha)	Percentage (%)
10.0-24.9	35.48	7.13	42.61	10%
25.0-39.9	63.54	12.77	76.31	18%
40.0-54.9	87.20	17.53	104.72	25%
55.0-69.9	122.34	24.59	146.93	35%
≥70	37.15	7.47	44.61	11%
Total	345.69	69.48	415.18	100%

Table 8 shows comparative biomass estimates between different compartment in Pekan FR at different study period. The total biomass of Pekan FR were gathered as follow ; Compt. 200 (328.14 t ha^{-1}), Compt. 156 (399.21 t ha^{-1}), Compt. 100 (414.57 t ha^{-1}) and Compt. 75 (415.18 t ha^{-1}). The population abundance shows a wide tree distribution in different DBH classes. The total tree biomass estimation of 280.12 tonnes ha^{-1} in the PSF Sumatra [9]; which was relatively lower than the total tree biomass gathered from this study in Pekan FR at different compartment.

Table 8: A comparison of biomass assessment study of Pekan FR in different compartment

DBH class (cm)	Total biomass (t/ha)			
	Compt. 200	Compt. 156	Compt. 100	Compt. 75
10.0-24.9	72.92	74.2	38.85	42.61
25.0-39.9	63.91	111.3	75.27	76.31
40.0-54.9	60.49	83.78	153.22	104.72
55.0-69.9	20.2	50.09	128.96	146.93
≥70	110.62	79.84	18.26	44.61
Total	328.14	399.21	414.57	415.18

The findings indicate the lowest carbon stock figure was in dbh class 10-24.9 cm (19.27 t C ha^{-1}) while the highest was in dbh class 55.0-69.9 (87.16 t C ha^{-1}). The total carbon stock quantified from this study was 236.51 tonnes C ha^{-1} (Table 8) which is slightly higher than previous study that indicated carbon stock between 110-225 t/ha under natural/undisturbed condition [5]. Compartment 75 mostly consist of undergrowth and understorey trees indicating a young swamp ecosystem but high potential biomass yield. Another study estimated the total carbon stock in Pekan FR was 205.74 t C ha^{1} [32]. Global data sourced on carbon stock estimation in undisturbed tropical peat swamp forest were between 182-306 t C/ha with the average of 243 t C ha^{-1} [33]. Carbon percentage of tree biomass in tropical peat ranged between 46% and 50% which is slightly underestimated [20,34,35]. This study quantify carbon percentage are slightly higher (~56%) of total biomass. Carbon content of biomass was assumed to be 50% of dry weight biomass which in this studywas underestimated [6]. A study conducted in different type of forest; hill forest of Gunung Stong, Gunung Basor and Bukit Bakar in Kelantan revealed the carbon stock estimation were 147.13, 156.43 and 169.36 t/ha respectively [36]. This indicates peat swamp forest are able to capture and store carbon efficiently under natural/pristine condition and therefore has high potential in carbon sequestration compared to other forest types.

4. CONCLUSION

Total tree biomass and carbon stock quantified peat swamp forest of Pekan FR under natural condition were 345.69 tonnes ha^{-1} and 236.51 tonnes C ha^{-1}respectively. Ecological plot for biomass assessment is important to monitor the forest stand dynamics under natural condition. Continuous carbon stocking in peat swamp forest is crucial to determine the carbon changes over time and justify the role of peat swamp as carbon sink or source under pristine/natural condition. Future works should also look into comparative biomass and carbon stock estimates caused by anthropogenic activities (human intervention/disturbance) under logged-over condition.

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