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CARBON STOCK EVALUATION AND ITS POTENTIAL CARBON MARKET VALUE IN CAREY ISLANDMANGROVE FOREST, SELANGOR,MALAYSIA

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Abstract

This study was carried out to examine the total carbon stock and its potential carbon market value at Carey Island mangrove forest, Selangor, Malaysia. Two sites were chosen: ODCC "by the sea" and Kg. Melayu "riverine" as they represent the dominant mangrove tree species, (Avicennia Alba, Rhizophoraapiculata, Rhizophoramucronata and Xylocarpusgranatum). Data collection was done across three seasons: Intermediate, dry and wet for both sites in order to get one year average. Sampled mangrove species were sorted out into leaves, stems, bark (aboveground), roots (belowground) and litter; sediment samples were collected at 0-10, 10-20 and 20-30 cm deep. Carbon organic content was determined using furnace (LOI) followed by a conversion factor of (1.724). Data obtained were utilized to compare the results between species, tree partitioning, soil depth, seasons and different settings. Results showed that carbon was more allocated in the dry season within the bark and 20-30 cm deep underground. In vegetations, results have revealed that carbon allocation was very similar (bark > stem > leaf >root) even *though both sites represent different species. Litter carbon allocation was in the order of: propagules > leaf > branch in ODCC and branch > propagules > leaf in Kg.Melayu. In sediment, results brought to light that carbon allocation increases with soil depth. The total carbon stock was estimated at 648.73 (t/ha/yr) in ODCC and (600.18) t/ha/yr in Kg.Melayu with soil carbon stock representing 98% and 99% of the total carbon stock in ODCC and Kg. Melayu respectively. The total coverage of mangrove forest is Carey Island was estimated 182.72 hausing Arc GIS 10.1. The potential carbon market value for Carey Island was in a range of USD0.6 – 21.8 million.*

Keywords
Mangrove, Carey Island, Biomass, Carbon Stock, Organic Carbon, Loss on Ignition, Carbon Market Value

1. Introduction

As highlighted by Hemati*et al.*, (2015) due to the accelerating growth of the economic power in developing countries and the indifference of man due to his ignorance in terms of mangrove functioning as key strategies to combat the global climatic changes, mangrove forests end up disappearing at a scary rate around the whole world.

The estimated total area (ha) of mangrove forests worldwide as illustrated in Table (1) in 1980s was about 19.8 million ha and less than 15 million ha (Malaysia alone contributes about 4% of the total mangrove area worldwide) in 2000s as stated by Aizpuru*et al.*, (2000) and Alongi (2002), which means that the world has lost about 5 million ha of its mangrove coverage in a period of 20 years. Logically, if this massive deforestation continued all of the mangrove forests would be disappeared by the year 2060. It is known that about 90% 0f the mangrove areas are located in 26 developing countries and those areas are targeted to be deforested due to the economical evolution. The importance of determining carbon stock in forest ecosystems comes due to the direct proportion between the continued shrinkage of mangroves worldwide and carbon stock declination. Not only that, but also only very few of those ecosystems are known and well addressed regarding their carbonstocks.

Moreover, human activities have affected mangrove forests state worldwide, which have led to an enormous increase in greenhouse gases (GHGs) in the atmosphere associated with global climatic change. It was reported by (Houghton *et al.*, 2001 Gullison*et al.*, 2007; van der Werf*et al.*, 2009) that deforestation and forest degradation contribute 12-20% of the annual

GHGs emissions. The study objectives are:

- To determine the total carbon stock in mangrove vegetation, litter, and sediment, on Carey Island across threeseasons.
- To determine the carbon market value of the ecosystemchosen.

Table 1: *Current and Past Mangrove Extent by Region (1980-2005)*

Region	Most recent reliable estimates		(1980)	(1990)	(2000)	(2005)
	X 1000 ha	Ref year	1000 ha	1000 ha	1000 ha	1000 ha
Africa	3.243	1997	3,670	3.428	3,218	3,160
Asia	6,048	2002	7,769	6,741	6,163	5,858
North and Central America	2,358	2000	2,951	2,592	2,352	2,263
Oceania	2,019	2003	3,181	2,090	2,012	1,972
South America	2,038	1992	2,222	2,073	1,996	1,978
World	**15,705**	**2000**	**19,794**	**16,925**	**15,740**	**15,231**

Source: (Lang'at, 2013).

The biomass estimation of the study area was reported by Saraswathy*et al.,* (2009) who have pointed out that *Avicennia Alba*, *Rhizophoraapiculata*, *Rhizophoramucronata*and *Xylocarpusgranatum*are the dominant species in Carey Island with the highest Importance Value Indexes (IVI), which were: 15.57%, 8.01%, 14.03% and 10.02% respectively and the highest total biomass. The first two species were present only in ODCC, while the other two were present in Kg. Melayu. So, only the above four species was targeted whensampling.

The significant function of mangrove forests comes due to that the total organic carbon (TOC) values in mangrove sediments were relatively similar to that of the mangrove vegetation parts as reported by Bouillon *et al.,* (2008). Terrestrial vegetation forms (litter) are one of the major sources of carbon in soils and sediments, where they represent nearly 75% of carbon stored in terrestrial ecosystems and approximately, 50% when carbon in soil is not excluded. Schlesinger & Andrews (2000) has pointed out that about 40% of the carbon is annually exchanged between the atmosphere and the terrestrial biosphere. Also Sitoe*et al.,* (2014) has found that around 73% of the soil content was a stored carbon. Lewis *et al.,* (2009) has reported that these processes are totally influenced by the climatic and the environmental changes.Hence,mforest ecosystems play an important role in regulating carbon dioxide (CO_2) concentrations in the atmosphere and mitigating the climate changes (Luyssaert*et al,* 2007).

According to *Santilli et al., (2005) "The current annual rates of deforestation in Brazil and Indonesia would equal four-fifths of the emission reductions gained by implementing the Kyoto Protocol in the first commitment period, Jeopardizing the goal of Protocol to avoid (dangerous anthropogenic interference) with the climate system"*. Hereby, the several countries that have signed the Protocol are currently trying to integrate CO_2 inventories by ecosystem and region which is called emissions trading or carbon trading/value.

The formation of carbon market was a result of national and international attempts to mitigate the concentration of GHGs emissions and to prove that the value of tropical and subtropical forests extends beyond their economic value as commodities. The purpose of establishing such a scheme is to reduce carbon emissions either by getting the permission to emit certain amounts of GHGs (buying) or by the reduction of those emissions (selling) (Angelsen*et al.,* 2009; Ullman *et al.,* 2013).

Globally, the total carbon market in 2008 was traded nearly 5 billion tones for GHGs emission reductions in both regulated and voluntary markets and only 65 million tons of them were traded voluntarily and it is advised not to rely on voluntary markets alone in order to make progress in GHGs reduction (Bayon*et al.,* 2012; Alekseev & Anger, 2015).

2. Methodology

2.1 Study SiteDescription

This study was conducted at Carey Island, Selangor that is the largest island among 8 islets of the west coast of Peninsular, Malaysia with an area of about 15,000 ha. About 78% of the island is planted with oil palm and managed by Sime Darby Sdn. Bhd and also some private holders. Carey Island is located about 70 km away from the south west of Kuala Lumpur, the south of Port Klangand north of Banting town and separated from the Selangor coast by the Langat River, connected by a bridge from Chodoiand TelukPanglimaGarangnear Banting. ODCC (02.49192° N, 101. 21285° E) and Kg.Melayu (02.49410° N, 101.21567° E) werethetwo sites chosen owing to the availability of the targeted species and the easy accessibility.

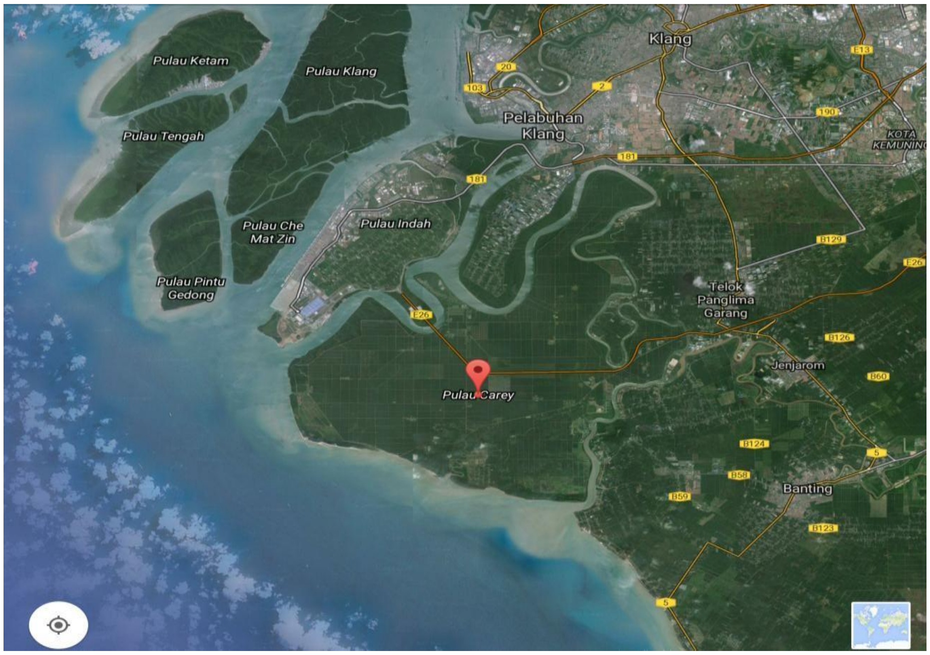


Figure 1: *The location of the study area (Carey Island, Selangor, Malaysia).*

2.2 SamplingMethods

2.2.1 LivingParts

Four trees of each of the targeted species were chosen while sampling (bark, leaf, stem and root) during the three seasons. The bark of the targeted trees was removed via a keen knife at about 1.5 m height (Figure 2). Stem samples were collected by drilling the stem until the center (Figure 3). Collection of the leaf samples was done using the leaf cutter (Corona TP 32-6) (Figure 4). Roots were collected from living trees. All of the collected samples were put into labeled plastic bags and weighed then oven-dried at 65 ^{o}C until the weight remained constant. All samples were pulverized using (A10 manufactured by 1 KA-Labortechnik) then kept in labeled plastic containers before beingfurnaced.

Figure 2: *Collecting Bark Samples*

Figure 3: *Collecting Stem Samples*

Figure 4: *Collecting Leaf Sample*s

2.2.2 Litter StandingCrop

According to Cummings *et al.*, (2002) twigs, propagules, leaves, and flowers form the litter layer, which also defined as the decomposition of the topsoil organic matter. The plot size used in such studies ranges from 30x30 cm to 1 m² while sampling. In this study the plot size used was 1x1 m. Where, every vegetation part is picked up into labeled plastic bags and transferred to the lab for further processing.

A total number of ten (1m x 1m) plots, were randomly established to collect the forest floor litter during each season of the three seasons (seasonal sampling): intermediate (April & May 2015), dry (July & August 2015) and wet (October & November 2015), in order to estimate one year litter total carbon stock. All litter compositions (twigs, leaves, fruits, and propagules), were collected in labeled plastic bags and transferred to the laboratory then washed properly to remove the stuck dirt. After the litter being air-dried, it was oven-dried at 65 ^{o}C until the weight remained constant. The oven-dried litter was then sorted out into different groups (twigs, leaves and propagules). The sub-samples were pulverized and placed in labeled plasticcontainers before beingfurnaced.

Figure 5: *Collection of the Standing Crop*

2.2.3 Soil

Soil sampling was done through the three seasons, a total number of four samples were randomly collected in each single fieldtrip using 5cm PVC pipe. The samples were collected from three depths, which are: (0-10 cm), (10-20 cm) and (20-30 cm) due to that the variation of carbon content is very little as the depth exceeds 30 cm (Kauffman *et al.*,2011).

After the samples were collected, they were transferred to the laboratory for further processing. Soil samples were dried at room temperature for few days then sieved via 2mm sieve and kept into labeled plastic containers before being furnaced (Bernard *et al.,* 1995; Kauffman & Donato, 2012). Soil carbon storage was estimated using the following formula:

Soil Carbon $(Mg\ ha^{-1})$ = *bulk density* $(g\ cm^{-3})$ * *Soil depth interval (cm)* * *%C*(1) Where, % C is the carbon concentration expressed as a whole number

2.3 Carbon StockEvaluation

2.3.1 Vegetation Biomass and CarbonPool

According to Kauffman and Donato (2012), the total carbon stock/pool of the vegetation biomass can be calculated multiplying the mean organic carbon content of the highest two vegetation parts in percentage (%) by the total biomass for each season as follows:

$$\text{Organic Carbon Content } \left(\frac{t}{ha}\right) = \text{the mean organic carbon content of the highest two vegetation parts (\%)} * \text{total biomass } \left(\frac{t}{ha}\right) \quad (2)$$

2.3.2 Litter CarbonStock

Litter total carbon stock can be determined by obtaining the mean carbon storage in percentage (%) of the litter parts and multiply it by the oven-dry mass (Kauffman & Donato, 2012).

$$\textit{Organic Carbon Content } \left(\frac{t}{ha}\right) = \textit{the mean organic carbon content of litter } (\%) * \textit{totaloven dry mass } \left(\frac{t}{ha}\right) \quad (3)$$

2.3.3 Soil CarbonStorage

Based on Kauffman & Donato (2012) carbon stored in soil can be estimated by obtaining the mean total soil carbon storage for each season and then obtaining the average total soil carbon storage (t/ha) for one year using equation(1).

2.3.4 Total Ecosystem CarbonStock

Based on Howard *et al.*, (2014) the total carbon can be obtained by summing up the mean organic carbon content of the vegetation parts, litter and the average total soil carbon storage for the targeted year expressed in (t/ha C yr^{-1}), then the total carbon stock (Blue Carbon) of the investigated site (Mg) can be calculated as follows:

$$\textit{Total Ecosystem Carbon Stock(Blue Carbon) of projected area(Mg)} = \textit{total carbon (Mg ha-1)* Area (ha)} \quad (4)$$

2.4 Converting to CO_2 Equivalents ($MgCO_2$)

According to Howard *et al.,* (2014) the total carbon stock of the ecosystem investigated can be expressed into CO_2 equivalents as stated below:

$$\textit{Total potential CO2 emossions per hectare } \left(Mg\frac{co2}{ha}\right) \textit{ or CO2e} = \textit{total carbon stock of the ecosystem * conversion factor of 3.67} \quad (5)$$

As greenhouse gas emissions (GHGs), are usually reported in carbon dioxide units CO_2 equivalents or CO_2e simply since CO_2 is the most common form of carbon in the atmosphere. Total carbon stock, can be converted to CO_2e by multiplying carbon stock of the ecosystem investigated by a conversion factor of 3.67 (Kauffman & Donato, 2012).

2.5 Carbon MarketValue

There are two essential market sources in terms of evaluating the emitted/stored carbon which are: the regulated or certified emissions reductions (CERs) and the voluntary market or voluntary emissions reductions (VERs). The difference between these two markets is that the regulatory market is certified, traded on official markets such as: (EU ETS), and more organized, unlike the voluntary market, which is traded freely among individuals and organizations (Tavoni*et al.,* 2007; Bayon*et al.,* 2012; Ullman *et al.,* 2013).

The total carbon stock in a forest ecosystem can be estimated by multiplying the total carbon of the projected area (t/ha C yr^{-1}) by the size of the projected area (ha) which will provide us with an estimation of the buried carbon content which will be multiplied by the price of carbon unit to get its potential carbon marketvalue.

2.6 StatisticalAnalysis

The results were expressed as the amount of organic carbon stored in the vegetative parts and soil layers in both sites during the three seasons. ANOVA was used to determine the degree of standard deviation and Statistical Package for the Social Sciences (SPSS) was utilized to compare the results. Between species, tree partitioning, soil depth, and seasons.

3. Results andDiscussion

3.1 Mangrove Forest Structure and Biomass of ODCC and Kg. Melayu

It is well known and of logic, that forest organic carbon density goes in parallel with biomass growth and mangrove forest age (Wang *et al.,* 2013). According to a case study in KienGiang Province conducted by Wilson, (2010), tree size and density are the main determinant of stand biomass and hence, wood density highly affects carbon content of the plant. In this study, *Avicennia alba* and *Rhizophoraapiculata*were the two dominant tree species in ODCC with a total biomass of 3.40 t/ha and 5.99 t/ha respectively while *Rhizophoramucronata*and *Xylocarpusgranatum*werethetwodominanttreespeciesinKg.Melayuwithatotalbiomassof 12.45 t/ha and 9.40 t/ha respectively. According to the above values, the total biomass of Kg.Melayu is approximately two times higher than it is in ODCC (Saraswathy*et al.,* 2009).

3.2 CarbonPools

Organic carbon allocation in the living parts (vegetative carbon) recorded the highest in the bark recording 55.77% ± 2.77 in ODCC and 55.44% ± 3.86 in Kg. Melayu and the lowest was recorded in the roots 49.16% ± 3.76 in ODCC and 48.52% ± 3.98 in Kg. Melayu in the order of bark > stem > leaf > root (Figure 6). The average carbon content was equal to 52.68 ± 4.07 and 52.53 ± 4.27 in ODCC and Kg. Melayu consecutively. The order of carbon across seasons was in the order of dry > intermediate > wet for both study sites. Similar trends can be seen in studies conducted by Hemati*et al.,* (2015); Mitra*et al.,* (2011) and Rodrigues *et al.,*(2015).

The total vegetation biomass was divided into aboveground and belowground and it was in the order of aboveground > belowground (Figure 7). Total biomass carbon stock (aboveground and belowground) in ODCC has recorded 5.03 (t/ha/yr) and 9.24 (t/ha/yr) in Kg. Melayu which explained by that total biomass in Kg. Melayu is approximately twice as much as it is in ODCC which similar to several publication's findings including findings reported by Chen *et al.*, (2012) and Hemati*et al.*,(2015).

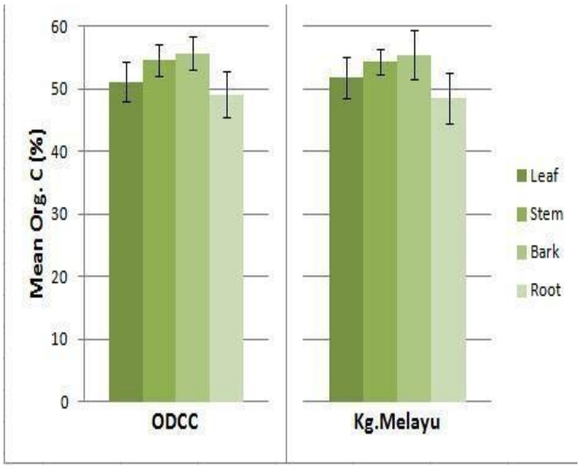


Figure 6: *Organic Carbon Distribution in Mangrove Tree Parts*

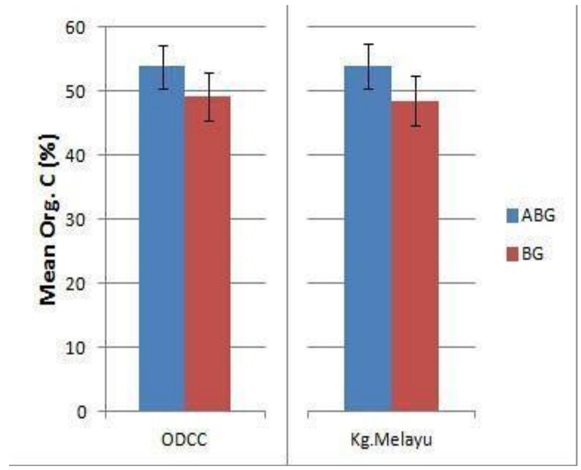


Figure 7: *Distribution of Organic Carbon Content in Tree Biomass*

Litter standing crop was the second pool estimated and it has showed that the propagules part has recorded the highest value in terms of carbon storage (53.13%) in ODCC in the order of propagules > leaf > branch. In Kg. Melayu, branch part has recorded the highest amount of carbon storage (53.31%) in the order of branch > propagules > leaf (Figure 9). Such trends could be explained by that, different standing crop parts act differently to the biochemical activities that take in place. The highest carbon storage in terms of seasons was in the dry season recording 55.41% and 54.90% in ODCC and Kg. Melayu respectively in the order of dry > intermediate > wet. The total carbon stock in litter standing crop was valued to 0.77 (t/ha/yr) in ODCC and 1.06 (t/ha/yr) in Kg.Melayu, which is interpreted by that Kg. Melayu was higher than ODCC in terms of tree biomass and that makes it higher in terms of litter standing crop production. Not only that, but also ODCC is more exposed to tidal waves that wash standing crop away as it is by the sea than Kg. Melayu that is more protected as it a riverinearea.

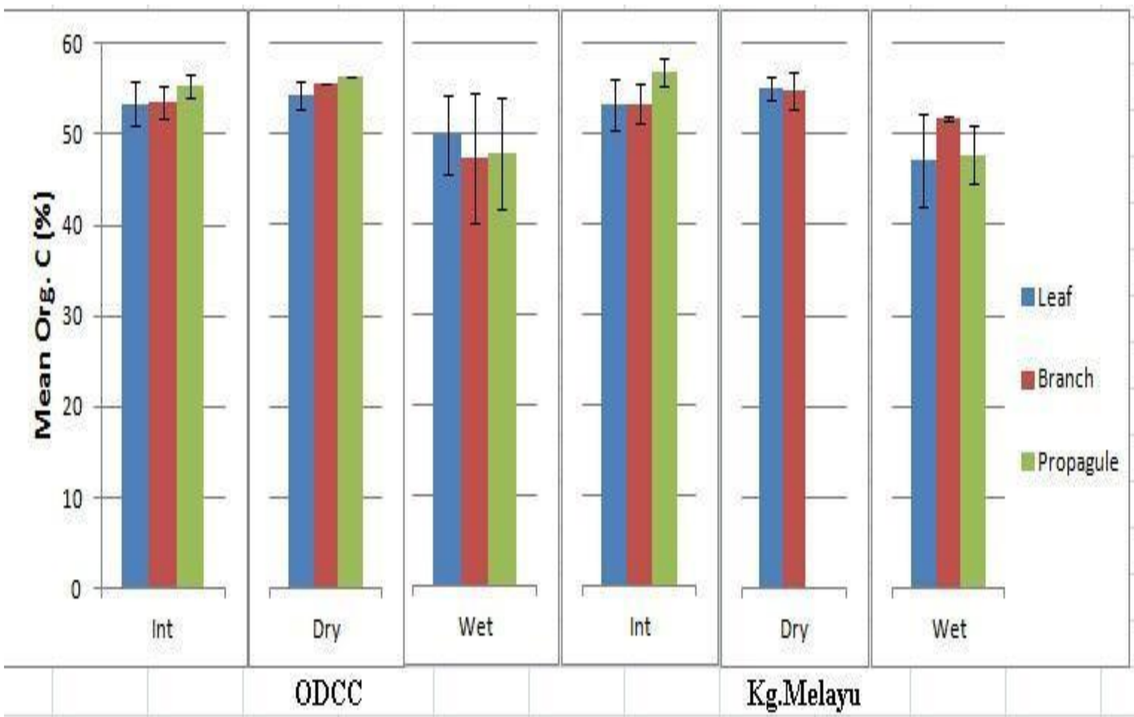


Figure 8: *Organic Carbon in Litter Standing Crop at ODCC & Kg. Melay*

Soil Carbon stock is the highest ecosystem carbon pool contributing 50-90% of the total ecosystem carbon stock as indicated by Donato et al., (2011). This study has found that about 99% and 98% of the total carbon stock in ODCC and Kg. Melayu was stored in the soil regardless the health status in the forest as the biomass in both study sites is considered low as highlighted by Saraswathyet al., (2009). The third layer (20-30 cm) has achieved the highest carbon storage in both study sites in dry season, which has increased with the soil layer depth which is a common trend in tropical forests (Orihuelaet al., 2004) in the order of dry > intermediate > wet (Figure 9). Soil carbon stock was equal to 642.93 (t/ha/yr) and 589.88 (t/ha/yr) in ODCC and Kg. Melayu respectively (Figure 10). Although, Kg. Melayu was slightly higher in terms of soil carbon storage values but it has recorded lower total carbon stock as it has lower bulk density (0.59 g/cm³) as soils that have low bulk density are richer in organic matter and vice versa as reported by Huber *et al.*,(2008).

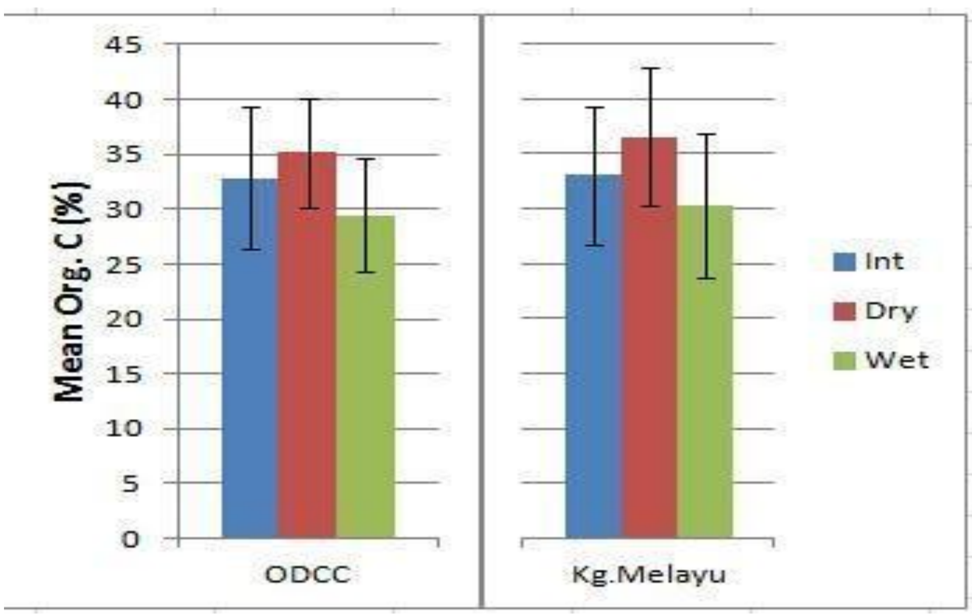
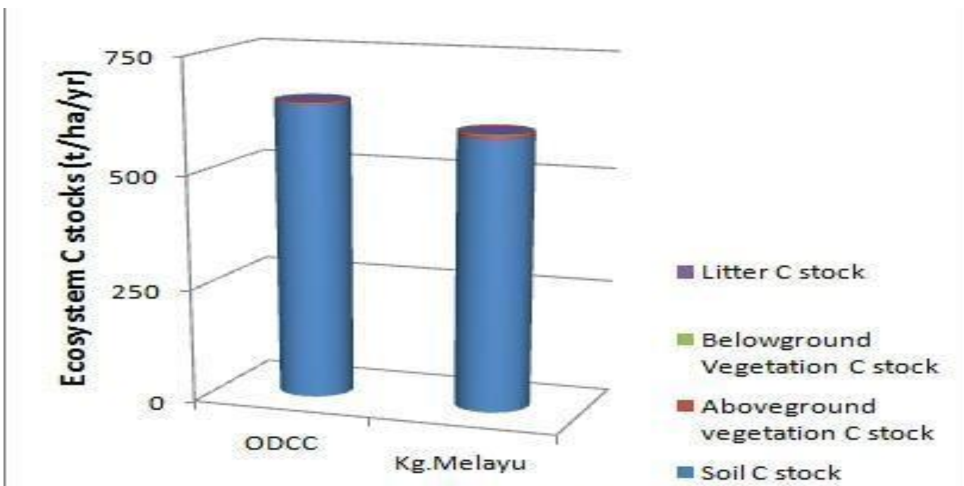


Figure 9: *Organic Carbon Content (%) in Soil Sediment across Seasons*



	ODCC	Kg.Melayu
Litter C stock	0.77	1.06
Belowground Vegetation C stock	0.91	1.65
Aboveground vegetation C stock	4.12	7.59
Soil C stock	642.93	589.88

Figure 10: *Ecosystem Carbon Stocks in ODCC and Kg.Melayu*

3.3 Carbon Stock Economic Evaluation and Carbon DioxideEquivalents

As highlighted by Ullman et al., (2013) there are two market sources that put value on the emitted carbon which are the voluntary market and the regulatory market. The voluntary market is mainly for individuals, companies, and governments who are wishing to buy/sell their carbon credits while the regulated market is more organized as it requires buyers to have implemented policy before allowing them to participate. Not only that, but also regulated market provides higher amounts which will have a positive reflection on global wetland conservation.

Potential carbon market value determination for an ecosystem can be conducted by multiplying the total carbon stocks with the price of the market price. In Carey Island, the potential carbon market value was in a range of 0.6 - 21.8 million USD (Table 2) as the buried carbon content in Carey Island mangrove forest based on the mangrove coverage (182.72 ha) was 114,099.50 T C yr^{-1}.

Table 2: *Estimated Price of Carbon Stocks in ODCC and Kg. Melayu Based on Different Global Market Sources*

	Ecosystem C Stocks (Tg)	Market →	Voluntary	EU ETS	CDM	GHGs initiative	Kyoto assigned allowance
		Price/T (USD) →	6.00	191.80	15.68	9.69	13.95
ODCC (648.73 t/ha/yr * 182.72 ha)	118,535.94		711,215.64	22.7 mil	1.8 mil	1.1 mil	1.6 mil
Kg.Melayu (600.18 t/ha/yr * 182.72 ha)	109,664.88		657,989.28	21.0 mil	1.7 mil	1.0 mil	1.5 mil

Carey Island (624.45 t/ha/yr * 182.72 ha)	114,099.50	**684,597.0**	**21.8 mil**	1.75 mil	1.05 mil	1.55 mil

Howard et al., (2014) has indicated that environmentalists usually report the amount of GHG emissions as CO_2 as it is the most common gas in the atmosphere. The amount of carbon dioxide equivalent (CO_2e) for an ecosystem means the amount of CO_2 that would have be the equivalent to the global warming effect (Change, 2007). CO_2 equivalents can be simply calculated by calculating Blue Carbon "carbon stored in biomass and top 1 m of soil in an ecosystem." the multiplying the Blue Carbon value by a conversion factor of 3.67 following Kauffman & Donato, (2012). According to this study, one hectare of Carey Island mangrove forest was equal to 2,291.73 CO_2e.

4. Conclusion

In a nut shell, "refer to Table (3)"

- Carbon allocation in vegetation parts was not significantly different P value > 0.05 in the order of (bark > stem > leaf > root) even though both sites represent differentspecies.
- Carbon storage was greater in aboveground biomass for bothsites.
- Litter standing crop carbon stock in Kg.Mealy was significantly higher than it is in ODCC as Kg.Melayu has higher biomass and more protected "riverine area" and ODCC is more exposed to tidalwaves.
- Seasonal changes did not influence organic carbon distribution in vegetation parts and it was in the order of dry > intermediate >wet.
- Soil biomass has contributed about 98% of the stored ecosystem carbon stock regardless the healthy status with more carbon allocated in 20-30 cmlayer.
- The potential carbon market value of Carey Island was in a range of 0.6 – 21.8 million USD.

Table 3: *Summary of carbon Content in Vegetation at both Study Sites*

Vegetation	ODCC	Kg.Melayu
Averagecarboncontent (%)	52.68 ± 4.07	52.53 ± 4.27
Order of C (%) based on species	*A.alba>R.apiculata*	*X.granatum>R.mucronata*
Order of vegetation tree parts	bark > stem > leaf > root	bark > stem > leaf > root
Order of biomass Partitioning	Aboveground > belowground	Aboveground > belowground
Order of seasonal Changes	Dry > intermediate > wet	Dry > intermediate > wet

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