Estimating Above-Ground Biomass of the Mangrove Communities in the Muthurajawela Wetland, Sri Lanka

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Abstract: ***Muthurajawela wetland is the largest saline coastal peat bog in Sri Lanka, contains a high diversity of both flora and fauna. In Muthurajawela wetland, mangrove forests are scattered along the Gampaha District of Western Sri Lanka, and are dominated by the Rhizophora mucronata, Bruguiera cylindrica, Annona glabra. This paper presents the results of the above-ground biomass (AGB), carbon stocks and CO_2 content of mangrove communities in Muthurajawela wetland, in order to gather better information to support the improved management of mangrove forests in this region. 36 plots were set up and 60 samples tree (Rhizophora mucronata, Bruguiera cylindrica, Annona glabra and Other woody species) was collected. Then, analyzing, processing data, setting the correlation equation between DBH and biomass. The results showed that average green biomass of Bruguiera gymnorrhiza was 31.29 kg/tree (equivalent average dry biomass of 17.21 kg/tree). Annona glabra 20.60 kg/tree (equivalent to 10.90kg/tree dry biomass). Rhizophora mucronata was 42.91kg/tree (average dry biomass was 24.03 kg/tree, not including roots). Other woody species (Sonneratia caseolaris, Hibiscus tiliaceus, Excoecaria agallocha, Cerbera manghas, Syzygium caryophyllatum, Dolichandron spathacea, Pandanus tectorius.) averaged 29.50 kg/tree (equivalent to 15.90kg/tree dry biomass).The total biomass of the mangrove population in Muthurajawela wetland was 447,357.48 tons (245,174.07 tons dry biomass). The total amount of carbon was 115,231.81 tonsC (22.05 tonsC/ha), equivalent 422,516.64 tons CO2 (80.86 tons CO2/ha).***

Keywords: Carbonstocks; Rhizophora mucronata; Bruguiera cylindrica, Annona glabra, Mangroves; Above-ground biomass

1. Introduction

Mangrove ecosystems thrive along coastlines throughout most of the tropics and subtropics. These intertidal forests play important ecological and socioeconomic roles by acting as a nutrient filter between land and sea, contributing to coastline protection [13], providing commercial fisheries resources and nursery grounds for coastal fish and crustaceans [25].However, over the last half-century, the area of mangroves has decreased by 30-50% due to coastal development, aquaculture expansion and over-exploitation [5], [9]. The loss of mangroves in the last half century has led to the fear that they might no longer be able to provide ecological functions within the next 100 years [21], [2]. Rapid sea level rise in the 21st century is seen as a major threat to mangroves [8], although mangroves have been responding to sea level changes by traveling towards land or to higher places [4].

Mangroves are also the largest reservoir of carbon, which plays a particularly important role in balancing O_2 and atmospheric CO_2, so it has a great influence on the climate of each country, each region and greatly affects the temperature of the Earth through the process of regulating greenhouse gases, especially CO_2. Every year, about 100 billion tons of CO_2 is fixed by photosynthesis carried out by trees and a similar amount is returned to the atmosphere by the respiration of the organism. With such an important role, and in the present context, the area of mangroves is shrinking, research into and quantification of the value of mangroves involves carbon accumulation in plant biomass is very necessary.

As all other natural ecosystems, mangrove forests in Sri Lanka too provide many extractive and non-extractive uses for the beneficiary of mankind. But many extractive uses such as shrimp culture, House construction work cause extensive damages to forests at present. Also increasing utilization of its resources severely affects its stability. Mangroves in Sri Lanka are one of the most abused ecosystems in the country [17]. Many mangrove ecosystems in Sri Lanka have been, and to a large extent are, indiscriminately exploited for commercial, aquacultural, agricultural, residential, tourism, mining and industrial development. They are also being used as dumping grounds for domestic, agricultural and industrial waste thus posing as imminent threats to the mangrove habitats. Studies conducted to evaluate the loss by the tsunami have found that the areas with dense mangrove forests have reduced the damage to properties by absorbing the tidal waves [12].

Last time, the area of mangrove forest decreased significantly, especially in Puttlam-Kalpitiya Lagoon, approximately 34 % of mangrove forests were converted to industrial shrimp farms in that area [14]. This caused the deterioration and destruction of the ecosystem and also creation of other issues such as lack of clean water and loss of jobs by the local fishermen.Similarly, the Muthurajawela wetland-Negombo lagoon wetland system is being rapidly degraded by inadequately planned development activities and other detrimental activities related to growing human population pressure. Because this wetland is located in a rapidly developing urban area, it is an extremely vulnerable ecosystem [17].

Although humans have traditionally used both the direct and indirect benefits offered by the mangrove ecosystem, humans throughout the world often sacrifice long-term hidden benefits and capital wealth for the sake of immediate monetary returns. The consequence of this attitude is that humans will suffer in the future, if we do not act soon and in unison, to protect and restore mangrove forests [23]. Therefore with continuing degradation and destruction of mangroves, there is a critical need to understand them better [16]. The importance of management of mangrove resources on a sustainable basis is very significant and needs to be implemented seriously. Mismanagement of mangroves will affect negatively not only the mangrove ecosystem proper but also adjoining coastal ecosystems, particularly sea-grass beds and coral reefs as well as the entire coastal system. This is because mangroves are a major component of the tropical coastal belt, with a very important role in the intensive physical, chemical, and biological dynamism of the coastal area. At present activities towards mangrove forest conservations in Sri Lanka have been launched by different organizations in the country such as rural communities, government agencies, international organizations like IUCN and nongovernmental organizations. Mangrove forests are very important to rural communities for their livelihood. Therefore local communities of fishers in mangrove forest areas are very actively participating in mangrove conservation. However existing conservation measures are inadequate comparatively to the decline rate of mangrove forests [17]. Recently, there are many studies [6], [7], [19] conducted to describe the ecology and biology of mangroves in SriLanka. However, there are no specific studies on biomass estimations of mangroves in the country [1]. Research on biomass in Sri Lanka is still a very new issue, the number of studies is small, and the content and approach are limited. For these reasons, we conducted a study estimating the biomass and carbon storage capacity of Muthurajawela wetland, Sri Lanka mangroves with the aim of estimating the biomass and CO_2 content of Muthurajawela wetland to contribute to the enrichment of understanding of the biomass of mangroves; develop the argument and quantifying the economic and environmental values that mangroves bring; and provide basic information for the management, conservation and development of mangrove forest here.

2. Methodology

2.1. Characteristics the study area

Muthurajawela wetland is the largest saline coastal peat bog in Sri Lanka located on the west coast ($70^0$3'N, $79^0$55'E) between the Negombo lagoon and Kelani river and spreading inland up to Ragama and Peliyagoda in the Gampaha District (Figure1). The marsh, together with the Negombo lagoon, forms an integrated coastal wetland ecosystem. The marsh-lagoon complex is estimated to have originated in about 5000 years BC [3]. The main water source to the marsh is Dandugan Oya which drains a catchment of 727 km^2 and discharges at the interface of the lagoon and the marsh, while the marsh is traversed by a navigational canal constructed during the Dutch colonial period. The area receives an annual average rainfall of 2000-2500mm, while the average annual temperature is 27^0C [15]. According to historical evidence, Muthurajawela wetland was subjected to extensive cultivation of paddy rice, more than 500 years ago [10]. The soil is a uniform, potentially acidic sulphate, and the land is poorly drained with a peaty substrate which is saturated for almost the whole year. The marsh receives water from the Kelani river and the Dandugam oya stream.

Muthurajawela wetland receives and retains high loads of domestic and industrial wastes and sediment from both surrounding and upstream areas. Wetland plants facilitate sediment deposition, before water enters Negombo lagoon. The plants also act as a filter for through-flowing waters, and assist in the removal of nutrients and toxic substances. During the rainy season the wetland acts as a retention area for run-off from surrounding higher grounds and floodwaters from Dadugam Oya, Kalu Oya and Kelani Ganga.

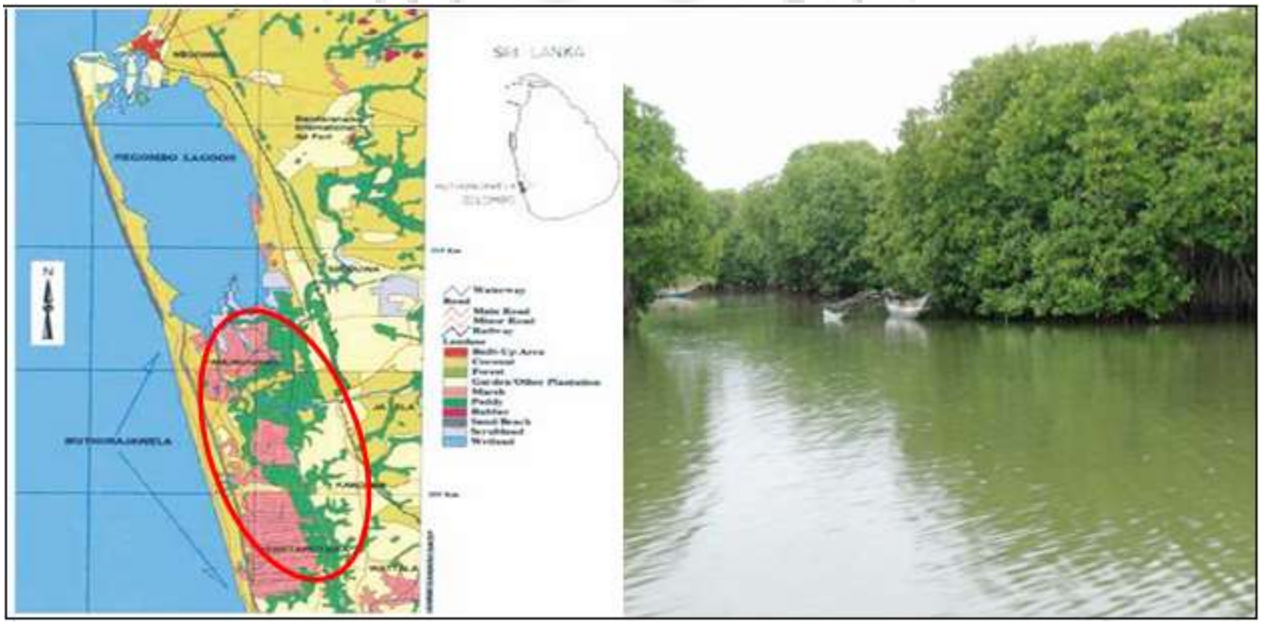

Figure 1: Location of the Muthurajawela wetland

The Muthurajawela wetland is situated South of Negombo and cover an area of approximately 6,232ha. The daily high tide brings in seawater from the ocean into the wetland, and the continuous mixing of these two waters over thousands of years has led to a brackish, integrated coastal ecosystem that is biologically diverse and teeming with life. According to the result of the present study total of 157 plant species belonging to 62 families were recorded. Out of which, 16 aquatic weed species, 91 grass species, 23 liana species, 17 shrub species, 10 woody species. Due to the high level of human activity within the Muthurajawela wetland (such as growing pressures from urban, residential, recreational and industrial development), the flora composition at Muthurajawela wetland seems to be changing rapidly.

2.2 Data collection

Based on the forest status map combined with field surveys 36 plots each with a size of 1,600m^2 (40x40m) decided to set up for the study area (Figure 2). Global Positioning System (GPS) to determine the coordinates used, and direction of the standard plots. In each main plot 1,600m^2 (40x40m) and in each plot 5 sub-plots of 100m^2 (10x10m) were established. In each plot the information as density, height, DBH and identify all the woody trees present were collected.

Based on the collected DBH data, 45 branches samples was taken for the with DBH series from smallest to largest, of three main species: *Rhizophora mucronata*, *Bruguiera cylindrica and Annona glabra*and others woody species (*Sonneratia caseolaris*, *Hibiscus tiliaceus*, *Excoecaria agallocha*,*Cerbera manghas*, *Syzygium caryophyllatum*, *Dolichandron spathacea* and *Pandanus tectorius*).This was done by with the collected samples to the laboratory. First the volume of the main stem was calculated by using the equation 1. The volume of the average branch which was brought to the laboratory was calculated in the same manner

$$\frac{\text{Stem}}{\text{branch}}\ volume = \frac{\pi * d^2 * h}{12} \qquad (1)$$

Then a known volume of the sample brought to the laboratory was oven dried at 80^0 C for 72 hours and the weight measurement was taken. Then the biomass of stem/branch was determined by equation 2

$$\frac{\text{Stem}}{\text{branch}}\ biomass = \frac{sample\ \ biomass}{sample\ \ volume}\, x\, \frac{stem}{branc\ h}\ volume \qquad (2)$$

Leaf biomass was measured by oven drying a known number of leaves at 80^0 C for 72 hours and measuring its weight. Finally it was converted to leaf biomass per tree by convert to the total number of leaves in the tree. For this work, average size tree species was selected from each plot for each tree species and the stem diameter and stem height measured. Then number of branches were counted and the base diameter and length of the average size branch was measured number of leaves in each branch was counted. Set the K ratio of the dry and fresh biomass of the individual tree. Based on data collected from standard trees, building correlation equation between green biomass with DBH to determine the biomass of plots and population. The dry biomass of plots and populations are green biomass multiplied with K coefficient. From the results of remote sensing interpretation, the area of the vegetation cover according to three levels of tree dense: high density, medium density and low density. Then per hectare biomass calculated by equation 3:

$$\text{Biomass per ha} = \text{biomass of one tree} \times \text{trees per ha} \qquad (3)$$

The biomass of the mangrove population at each density level = the total biomass of the species present in each ha x of the area of each density level respectively.

(4)

Finally, the total biomass of population in Muthurajawela wetland is equal to the total biomass of each density class. The amount of above-ground carbon is calculated from dry above-ground biomass multiplied with the carbon conversion factor of 0.47 [11]. The CO_2 was calculated by using equation 5.

$$CO_2\ \text{content} = Cx\frac{44}{12} \qquad (5)$$

Estimation of the CO_2price based on the purchase price of CO_2 on the market, was calculated by using equation 6.
The cost of CO_2 = unit price USD/tons CO_2 x total of CO_2 content

(6)

Figure 2: Layout of sample plots in Muthurajawela wetland

3. Results

3.1. The growth parameters of mangroves forests

Muthurajawela wetland is the largest coastal peat bog of the island located on the West coast. Edaphic factors such as physiography, land form, soils, salinity, and hydrological conditions, appear to be the primary factors which govern the organization of different vegetation types within the Muthurajawela wetland.

On the medium flooded tidal areas of the Muthurajawela wetland, soil is clay-mud with organic humus and dominant plant species were *Rhizophora mucronata* and*Bruguiera cylindrica*. Sometime, there were *Aegiceras corniculatum*, *Sonneratia caseolaris*, *Excoecaria agallocha* species were also present. However, in the high flooded tidal areas, two species that dominated and developed well were *Bruguieracylindrica* and *Rhizophora mucronata*. *R. mucronata*populationshad an average density of 261 tree/ha in the area with mean height of 8.19±3.69 m, DBH was 9.54±2.8 cm, and a strong root system *B. cylindrica*population, which dominates the competition for light and nutrients, has gradually eliminated other species to form a pure populations with an average density of 1,208.33 tree/ha with the DBH of 9.05±3.95 cm, and average height of 8.81±4.14m.In the highlands, along the dyke, the dominant tree species was *Annona glabra* with an average density of 1,375 tree/ha and average height of 6.50±2,29m and DBH7.66±2.82cm (Table 1) which grows together with other herbaceous species, i.e.,*Acrostichum aureum* and *phragmites karka*.

Table 1: The growth parameters of mangroves trees

Species name	N(tree/ha)	DBH (cm)	H (m)
Rhizophora mucronata	261.11	9.54±2.87	8.19±3.69
Bruguiera cylindrica	1,208.33	9.05±3.95	8.81±4.14
Annona glabra	1,375	7.66±2.82	6.50±2,29
Others woody species	247.22	9.05±3.37	7.27±2.40

Note: Average ± standard deviation; N:the density of mangroves; DBH: Diameter at breast height; H: the average height of tree. **Others woody species:** *Sonneratia caseolaris*, *Hibiscus tiliaceus*, *Excoecaria agallocha*, *Cerbera manghas*, *Syzygium caryophyllatum*, *Dolichandron spathacea* and *Pandanus tectorius*.

3.2 Build correlation equations

Each individual tree is part of the population. Therefore, individual tree biomass is the basis for determining population biomass. Studying biomass takes effort, time and cost. To overcome this disadvantage, we constructed the correlation equations between biomass and DBH. From that model, we can identify population biomass accurately, quickly, simply and inexpensively.

Calculated results showed that the average biomass of 15 standard *Rhizophora mucronata* trees was 36.76 kg/tree, ranged from 5.48-144.81 kg/tree (average dry biomass was 20.59 kg/tree, notincluding roots). Green biomass of 15 standard *Bruguiera cylindrica* trees averaged 31.56 kg/tree ranged from 3.79-121.74 kg/tree (average dry biomass of 17.36 kg/tree). Green biomass of 15 *Annona glabra* trees was 25.40 kg/tree ranging from 3.19-72.99 kg/tree (equivalent to 13.44kg/tree dry biomass). Other woody species was 34.24 kg/tree (equivalent to 18.45kg/tree dry biomass).

The results in Table 2 showed that the dry biomass structure of the parts of individualtrees was arranged in the following order: stems > branches > leaves. The average dry stem biomass of *Rhizophora mucronata*, *Bruguiera cylindrica*, *Annona glabra* were 79.64%, 77.97%, 78.72%. The average dry branches biomass of *Rhizophora mucronata*, *Bruguiera cylindrica*, *Annona glabra* were 13.25%, 12.68% and 12.28% respectively and the lowest are dry biomass of leaves: 9.11% for *Rhizophora mucronata*, 9.35% for *Bruguiera cylindrica* , 9.00% for *Annona glabra*. The ratio of dry biomass to green biomass of *Annona glabra*, *Bruguiera cylindrica*, *Rhizophora mucronata* and others mangrove species is 0.529, 0.55, 0.56 and 0.539 respectively in the Muthurajawela wetland. The structure of green and dry biomass parts of the mangrove trees are shown in Table 2.

Table 2: The above-ground biomass of individual mangrove trees

Name's plant	Green biomass (kg/tree)				
	DBH (cm)	Stems (kg)	Branches (kg)	Leaf (kg)	Total (kg)
Rhizophora mucronata	4.46-19.97	29.13	4.76	2.87	36.76
Bruguiera cylindrica	3.60-15.93	24.96	3.78	2.82	31.56
Annona glabra	3.20-14.33	20.08	3.13	2.19	25.40
Others woody species	4.33-16.56	27.06	4.14	3.04	34.24
Name's plant	**Dry biomass (kg/tree)**				
Rhizophora mucronata	4.46-19.97	16.31	2.67	1.61	20.59
Bruguiera cylindrica	3.60-15.93	13.73	2.08	1.55	17.36
Annona glabra	3.20-14.33	10.62	1.66	1.16	13.44
Others woody species	4.33-16.56	14.58	2.23	1.64	18.45

From the green biomass results of the standard trees, we established four correlation equations (Table 3) for *Rhizophora mucronata*, *Bruguiera cylindrica*, *Annona glabra*, and other woody species (*Sonneratia caseolaris*, *Hibiscus tiliaceus*, *Excoecaria agallocha*, *Cerbera manghas*, *Syzygium caryophyllatum*, *Dolichandron spathacea*, *Pandanus tectorius*), because these trees are present in very small numbers in the population, so we grouped them into one group). The results showed that all four equations have the exponentiation form $y = ax^b$ with very high correlation coefficient (R^2>0.96) (Figure 3). This means that the green biomass is closely related to the diameter factor. Or, in other words, as the diameter of tree increases, the biomass also will increase according to the exponential function.

Table 3: List of allometric equations applied to estimate biomass of the mangrove trees inMuthurajawelawetland

Species name	Allometric equation	R^2
Rhizophora mucronata	$W_{above}=0.1359DBH^{2.4025}$ (Equation 7)	0.97
Bruguiera cylindrica	$W_{above} = 0.1328DBH^{2.3686}$ (Equation 8)	0.962
Annona glabra	$W_{above} = 0.1637DBH^{2.2864}$ (Equation 9)	0.967
Others woody species	$W_{above} = 0.1466DBH^{2.3369}$ (Equation 10)	0.995

Wabove=above-ground biomass (kg/tree),DBH=diameter at breast height (cm).

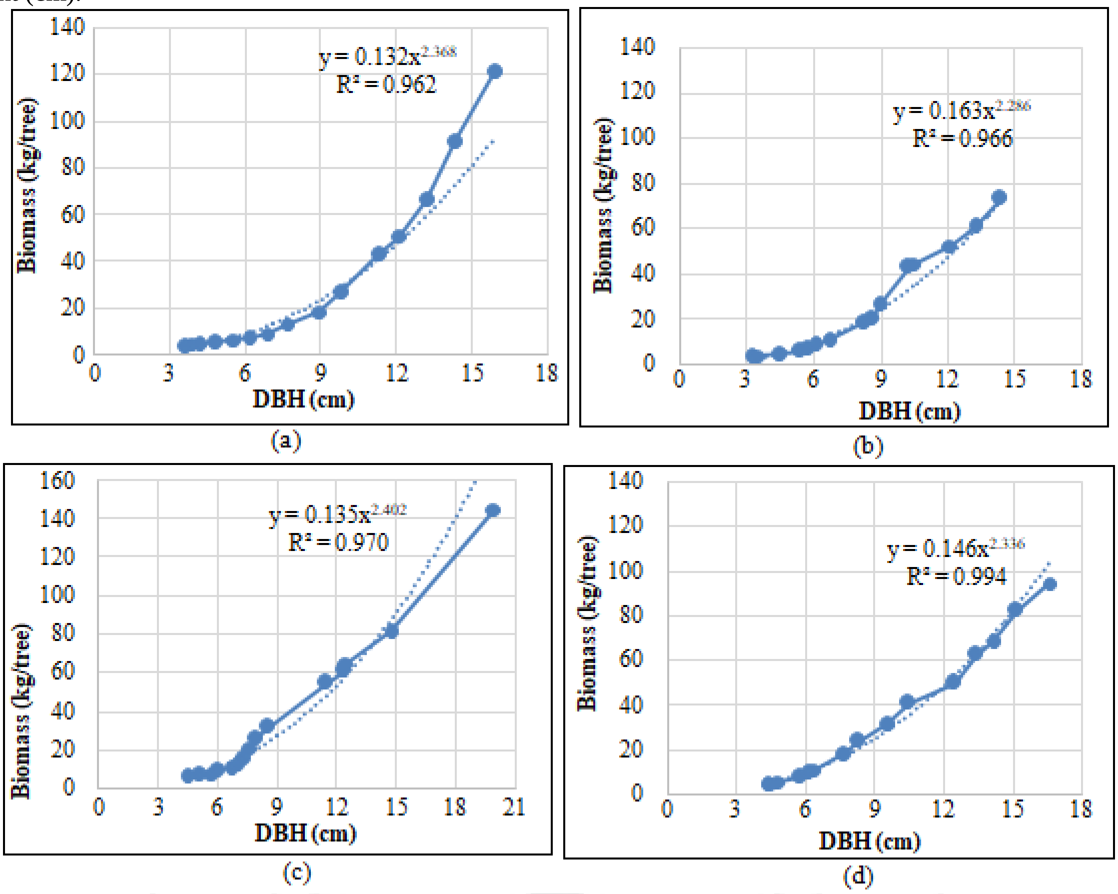

Figure 3: The correlation equation between above-ground biomass and DBH for *Bruguiera cylindrica* (a), *Annona glabra* (b); *Rhizophora mucronata (c);* others woody species*:(d)*

The above-ground biomass of mangrove populations

From the correlation equation,the above-ground biomass of vegetation for 36 plots estimated. The results showed that average green biomass of *Bruguiera cylindrica* in Muthurajawela wetland was 31.29 kg/tree, equivalentdry biomass 17.21 kg/treeand ranged from 2.09 to 186.04 kg/tree, and average green biomass of *Annona glabra* 20.60 kg/tree, equivalent dry biomass 10.90 kg/tree, ranges from 2.02-86.22 kg/tree. Others woody species (*Sonneratia caseolaris, Hibiscus tiliaceus, Excoecaria agallocha, Cerbera manghas, Syzygium caryophyllatum, Dolichandron spathacea* and *Pandanus tectorius*) averaged 29.50 kg/tree (dry biomass 15.90 kg/tree), fluctuating 2.06-102 kg/tree. *Rhizophora mucronata* was 42.91 kg/tree (dry biomass 24.03 kg/tree) fluctuating 4.93-220.83 kg/tree. Using the Duncan test in ANOVA analyses to compare the mean biomass values of *Rhizophora mucronata*, *Bruguiera cylindrica*, *Annona glabra*. Results showed that,there were significant differences about green biomass between three this species. But, there is no significant difference between *Bruguiera cylindrica* and other species group at 5% significance level. (Table 4).

Table 4: Estimated the total biomass of mangrove populations

Name of Plant	Densities (tree/ha)			Green biomass (kg/tree)	Green biomass (tons/ha)	Dry biomass (tons/ha)
	Low	Medium	High			
Rhizophora mucronata	150	308	325	42.91^{c}	33.60	18.82
Bruguiera cylindrica	775	1,150	1,700	31.29^{b}	113.43	62.39
Annona glabra	916.67	1,300	1,908.33	20.60^{a}	84.97	44.95
Others woody species	133.33	241.67	308	29.50^{b}	20.15	10.86
Total	$1,975^{a}$±263.2	$2,999.67^{b}$± 195.4	$4,241.33^{c}$± 03.3	---	252.15	137.02

Note: *a,b,c,d: In the same column, the letters (a, b, c, d) following the numbers are significantly different at 5% by Duncan's test*

Comparing the average number of trees per hectare of the three groups of low, medium and high tree density, the results showed that there was a statistically significant difference between three levels of density at a 95% confidence level (Table 4). This means that the distribution of tree density at each level was appropriate. This is the scientific basis for us to use these densities to calculate the biomass of the mangrove populations according to the area of three vegetation cover classes which were interpreted from the remote sensing image (Figure 4).

The area of Muthurajawela wetland in 2015 was 6,232 ha (Landsat image interpretation), was dividedinto 6 major classes: Bare soil, water, marshes, low dense forest, medium dense forest and high dense forest (Figure 4; 5). This comprised 5,225.28 ha of forest land (83.84%), and 1,006.72 ha of non-forest land (16.16%). The area of three vegetation classes (low, medium and high tree density), interpreted from the remote sensing image, was 1,464.27 ha, 2,020.60 ha, and 1,740.41 ha, respectively (Figure 4; 5). The results showed that there were green biomass differences (tons/ha) between the three density groups at a 95% confidence level.

Figure 4: The vegetation cover map of the Muthurajawela wetland

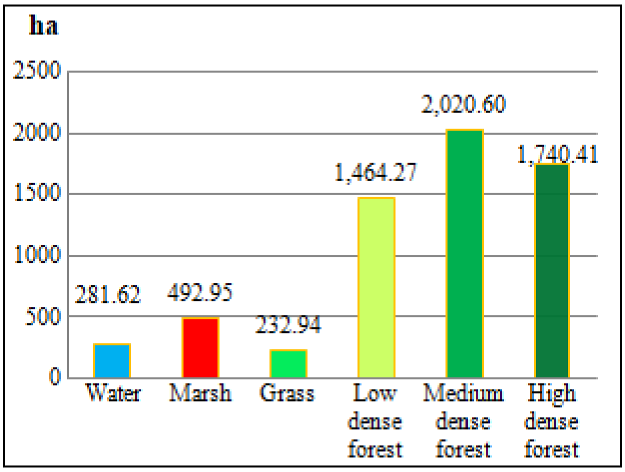

Figure 5: the area of vegetation classes of the Muthurajawela wetland

The total biomass of the mangrove population in Muthurajawela wetland was 447,357.48 tons (245,174.07 tons dry biomass) (Table5) through the area of vegetation cover classes by interpretation of Landsat images (Figure 4).

Table 5: Estimated the total biomass of mangrove forests in Muthurajawela wetland

	Green Biomass (tons)			Dry Biomass (tons)		
	Low dense	Medium dense	High dense	Low dense	Medium dense	High dense
Area (ha)	1,464.27	2,020.60	1,740.41	1,464.27	2,020.60	1,740.41
Biomass(tons/ha)	53.50[a]	83.11[b]	115.54[c]	29.21	45.63	63.32
Biomass (tons)	78,338.44	167,932.07	201,086.97	42,771.33	92,199.98	110,202.76
Population biomass (tons)	447,357.48			245,174.07		

The total amount of carbon of the mangrove forests in the Muthurajawela wetland was 115,231.81 tonsC (22.05 tonsC/ha), equivalent 422,516.64 tons CO_2 (80.86 tons CO_2/ha).

Scientists are today certain that up to 90 percent of climate change is man-made through the massive emissions caused by industrialization. The question now is whether we should consider a highly effective solution for improving the environment? "Global carbon prices" are a solution many economists support in terms of its effectiveness. According to the European carbon market in 2017, the cost of 1 ton of CO_2 was around €6. The price of 422,516.64 tons CO_2storage in the Muthurajawela wetland is €2,535,099.84.

A new report today by analysts Reuters Thomson Point Carbon estimates that by 2020, the reforms could nudge carbon prices up to €20 per ton. The price of CO_2 stored in Muthurajawela wetland will be €8,450,332.8.

4. Discussion and Conclusion

The method developed in this study for Muthurajawela wetland, using stem DBH and tree height to estimate biomass of mangrove trees produced acceptable results. However, due to difference in morphology of different mangrove trees, a single equation is not suitable for biomass estimation for all mangrove trees. Therefore, to obtain more accurate estimations, different indices of growth should be chosen to estimate biomass for these mangrove trees with different morphology. The four equations developed for the four mangrove species in Muthurajawela wetland are of the general form $y=ax^b$. Through regression analysis, it was found that there was a strong relationships between above ground biomass with DBH, height for each of the mangrove species, with a level of significant correlation, with $R^2 > 0.96$. To check the reliability of the correlation equation above, we conducted comparing the biomass deviation between the measured values and simulated values. The results showed that the simulated biomass value was generally lower than the survey biomass value because the difference percentage in biomass of mangrove species (between survey biomass and simulated biomass) was almost negative and less than 10%. Several diameter classes had a deviation of more than 10%. However, the average error was < 10%. This value was still acceptable in the forestry sector.

The average above-ground biomass was observed as 63.04 tons/ha for mangrove species in Muthurajawela wetland which varied from 20.15 tons/ ha for the pioneer stages to 113.43 tons/ ha for mature coastal mangroves. However, large variations were observed depending on the structural characteristics at each site.The results of the present study is similar to the results of Gunawardena (65 tons/ha, ranging 28-135 tons/ha) estimated for Muthurajawela wetland [1]. The total above green biomass of in Muthurajawela wetland (252.15 tons/ha) was also similar with the results of Ni in Ong Trang wetland, Vietnam (233.56 tons/ha) [18], as well as Aksornkoae's result 243.75 tons/ha [22] and Hirata's result (ranges 91.3 ton/ha to 497.6 ton/ha) in mangrove forest in Thailand [26]. The total amount of carbon of the mangrove forests in the Muthurajawela wetland to be 115,231.81 tonsC (22.05 tonsC/ha), equivalent 422,516.64 tons CO_2 (80.86 tons CO_2/ha), while the carbon amount of Sahu (2016) for Mahanadi mangrove wetland, East Coast of India 89.4 tonsC/ha [24]. Eskil (2012) observed the biomass carbon mangroves in Northwestern coastal zone of Sri Lanka as 35-149 tons/ha estimated using inventory data [20]. The results indicated that carbon content in Muthurajawela wetland was much lower than Sahu's (2016) and Eskil's (2012) reports. Such carbon content variability can be attributed to differences in floristic composition, climatic conditions, hydrology, geomorphology, successional stage and disturbance history. Among reason which discuss above, biophysical parameters of the mangrove vegetation, inundated water levels, soil exposure levels and associated plants are directly affected to backscatter coefficient of the remote sensing image. Muthurajawela wetlands is among the most important natural resources in Sri Lanka. They are sources of cultural, economic and biological diversity. With their wealth of stored carbon of 115,231.81 tonsC, wetlands provide a potential sink for atmospheric carbon, but if not managed properly could become sources of greenhouse gases (GHGs) such as carbon dioxide and methane. These are global wetland areas and the amount of carbon stored in it. Compilation of relevant databases could be useful in setting up a long-term strategy for Muthurajawela wetland in Sri Lanka. The following are some recommends:

It is anticipated that if required and pending any further collection of new harvest data, the model and methodology for uncertainty propagation presented in the current study could be used to produce estimates of mean above ground biomass for use in future up-scaling exercises.

During this study only vegetation types were identified via vegetation mapping. However a proper forest inventory and biodiversity investigation together can be done in to arvine more comprehension information.

All types of data collected in Muthurajawela wetland should be converted to a GIS database for the development of better management strategies for further conservation activities.

It is important to study the significant environmental and the sociological effects for the study site. For this reasons, information on the distribution and activities of the human population and its landcover of Muthurajawela wetland are essential for development of realistic conservation strategies.

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