Biomass and Carbon Stock Estimation of Udawattakele Forest Reserve in Kandy District of Sri Lanka

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Abstract

Carbon dioxide has gained lot of attention in recent past as a greenhouse gas, and therefore it has a potential to affect the climate pattern of the world. Several anthropogenic activities are known to be responsible for the increased level of carbon in the atmosphere and disruption of the global carbon cycle. However, nature has its own mechanism of sequestering and storing the carbon in its “reservoirs”. Forest has the ability to sequester carbon in their biomass and reduce the rate of increase of atmospheric carbon dioxide. The carbon sequestered in the forest trees are mostly referred to as the biomass of a tree or a forest. It has been identified five carbon pools of the terrestrial ecosystem, involving biomass. The study was designed to estimate biomass stock and then the carbon stock of the Udawattakele Forest Reserve (7°17'58 "N, 80°38'20’’E) in Kandy, Sri Lanka. Allometric equations were used to calculate biomass of trees. The total biomass stock was estimated to be 9475.56 t ha^{-1} (Mega gram-Mg) and the total carbon stock was estimated to be 4,453.55 t ha^{-1} (Mg) in the Udawattakele Forest Reserve (UFR). This amount is equivalent to 16,344.52 Mg of carbon dioxide in the atmosphere. UFR holds a moderate amount of biomass/carbon stock and the total carbon density of natural forest and plantations was found to be 36.55 Mg ha^{-1} and 44.89 Mg ha^{-1} respectively.

Keywords: climate change, tree diameter, allometric equation, biomass

1. Introduction

The assessment of carbon in the forest areas is a subject of global concern, since carbon stock is an important criterion of Sustainable Forest Management (SFM) and in addition, it is required for greenhouse gas inventories needed in the Land Use, Land Use Change and Forestry (LULUCF) sector, for the United Nations Framework Convention on Climate Change (UNFCCC) reporting. Plant biomass, including aboveground and belowground biomass is the main channel for CO_2 removal from the atmosphere.There are two key policy-related reasons for measuring carbon in forests. Commitments under the United Nations Framework Convention on Climate Change (UNFCCC), signed by more than 150 countries, require that all parties to the Convention commit themselves to develop, periodically update, publish, and make available to the Conference of Parties (COP), their national inventories of emissions by sources, and removals by sinks of all GHGs. Potential implementation of the Reducing Emission from Deforestations and Degradation (REDD) as it is aiming to create financial benefits to countries whom an age their forests in a sustainable manner, while increasing the absorption of greenhouse gasses which will ultimately result in reduction of global warming Greenhouse gases, including CO_2 play an important role on Earth’s climate (Kiehl and Trenberth, 1997).

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The climate change occurring throughout the globe is a serious issue that affects both biotic and abiotic systems of the Planet Earth. (Climate change 2001, three most powerful long lived greenhouse gases in the atmosphere are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide. Therefore these can be considered as primary agents of global warming (Kiehl and Trenberth, 1997).

Atmospheric CO_2 is utilised by the plants during the process of photosynthesis and stored as plant biomass and carbon fixation through forestry is a function of biomass accumulation and storage. Carbon sequestration can be achieved by establishment of new forests and by improving the growth rates of existing forests (Ranasinghe, 2010).

Carbon (C) is one of the most abundant elements on Earth and it is a naturally occurring component of the Earth's atmosphere. Atmospheric carbon is found in the form of chemical compounds, carbon dioxide (CO_2) and methane (CH_4), which are two key greenhouse gases that occur naturally in the atmosphere. Through the process of photosynthesis, forests absorb CO_2 from the atmosphere and storing the biomass of trees. According to the IPCC, there are five carbon pools of terrestrial ecosystem involving biomass: (a) above ground biomass, (b) below ground biomass, (c) dead mass of litter, (d) woody debris and (e) soil organic matter. The aboveground biomass of a tree constitutes the major portion of the carbon pool. It is the most important and visible carbon pool of the terrestrial forest ecosystem. The below ground biomass, which constitutes all the live roots, also plays an important role in the carbon cycle by transferring and storing carbon in the soil. A variety of methods have been developed to estimate biomass in forests and in other vegetation types. These methods differ in procedure, complexity and time requirement depending on the specific aim of the estimation operation (Gunawardena, 2014).

The most common approach to estimate the aboveground biomass is to establish an equation for the particular location that relates the biomass with tree variables such as DBH (Diameter of Brest Height) and height. This is done by measuring representative samples of trees belonging to a particular population. These equations are then used to estimate the biomass that is applicable to the population from where the sample is taken (Saint-Andre et al., 2004). The most widely used method for estimating biomass of forest is through allometric equations. The allometric equations are developed and applied to forest inventory data to assess the biomass and carbon stocks of forests.

Our study aim is to estimate the carbon stock in Udawattakele forest reserve which will help establishing a reference level of carbon stock. The information will later useful to compare the increase or decrease (emission or removal) the carbon stock of Udawattakele especially due to human intervention.

2. Materials and Methodology

2.1 Description of the study site

Udawatthakele Forest Reserve (UFR) (Figure 1) is situated within the city limits of Kandy, in the Central Province of Sri Lanka (7°17'58"N, 80°38'20"E and 635 m above mean sea level).

The total area of the forest is ~113 ha (Forest Department, 2013). Annual mean rainfall is more than 2,000 mm and the annual mean temperature is around 20^{o} C. This was declared a Forest reserve in 1897.10.15 under the gazette number 35/04. The vegetation of UFR is comprised of dense forest, abundant forest plantations of *Swietenia macrophylla*, *Myroxylon balsamum*, *Alstonia macrophylla*, *Mesua ferrea* and Sapu *Michelia champaca*, (Nyanatusita and Dissanayake 2013).

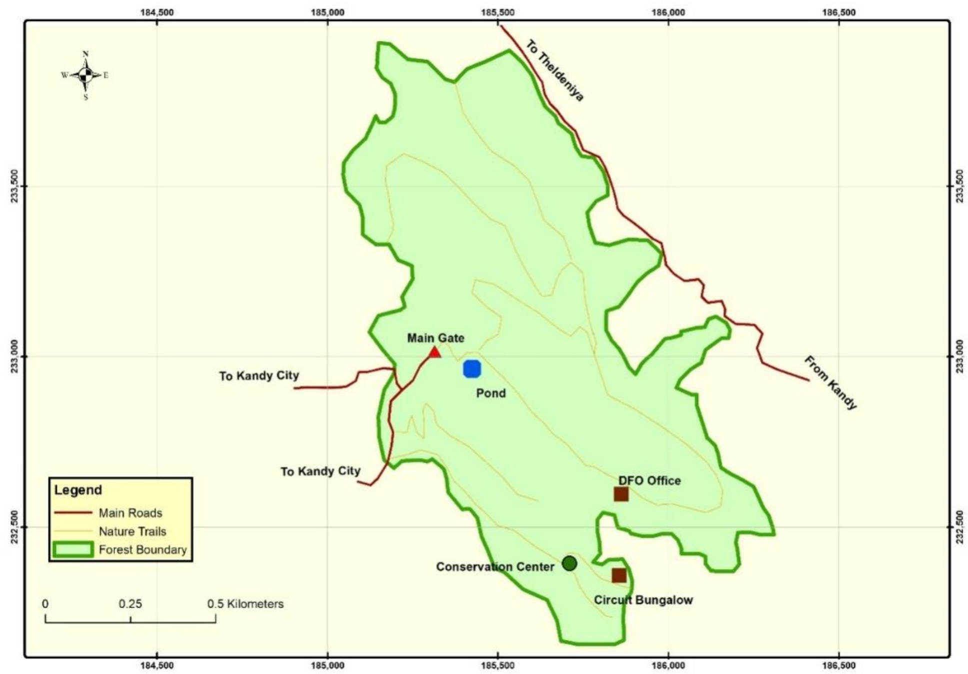


Figure 1: The map of Udawatthakele forest reserve (study site).

2.2 Biomass/carbon measurement methods

A variety of methods have been developed to estimate biomass in forests and in other vegetation types. These methods differ in procedure, complexity and time requirement depending on the specific aim of the estimation operation (Gunawardena, 2014). Energy balance of a system is nowadays used by many researchers to estimate biomass content. Single representative value of carbon content for broad forest categories are applied in the biomass average method (Gibbs et al., 2007). Another widely used method is conversion of measured volume estimates to biomass density using appropriate tools (Brown and Lugo, 1992). Destructive or nondestructive method use to estimate the biomass, Destructive method use to full tree harvest, cutting and weighing, or cutting, drying and weighing of the whole tree or its parts, is a simple procedure to estimate fresh and dry biomass. This method is time consuming, costly and above all destructive (Vann et al., 1998).

In non-destructive method trees are not felled for taking measurements (Stewart et al, 1992; Montas et al., 2000). This is mainly applied when the trees of interest are rare, protected or not possible to destructively sample to construct allometric relationships (Brown, 1997, Stewart et al, 1992, Montas et al., 2000) Non-destructive method takes the measurement without felling trees. So that measurements are done by climbing trees. Successive measurement on stem and branches are taken along with limited sampling of branches. Then the volumes are computed using the measurements taken. Finally, tree densities already available are used to convert measured volumes into biomass estimates.

2.3 Allometric equations for biomass estimation

Allometric equations need to be used when destructive estimations are not done. Biomass equation relates growth parameters such as DBH, height and crown parameters to biomass. The most important variable used in these models is (DBH) (Yen et al, 2010). Biomass equation developed by Brown (1997) was used to estimate biomass of live trees as it was a general equation developed for the areas receiving

1,500-4,000 mm of average annual rainfall. Allometric equations developed for the estimation of above ground biomass and carbon in tropical evergreen forests Shown in table 1.

Table 1: Allometric equations developed for the estimation of above ground biomass and carbon in tropical evergreen forests.

No	Equation	Author
1	TAGB =exp(-2.134+2.53*LN(DBH))	(Brown, 1997)
2	TAGB =r*exp(-1.499+2.148*ln (DBH)+0.207 * $(\ln(DBH))^2$-0.0281*$(\ln(DBH))^3$)	(Chave et al., 2005)
3	TAGB = rr^{avg} $(DBH)^{2+C}$ c=0.397, r= 0.604g/cm^3 , r=0.11	(Ketterings, 2001)
4	Y= exp(-1.996+2.32*ln(DBH))	(Brown, 1997)
5	Y= exp(-2.134+2.53*ln(DBH))	(Brown, 1997)
6	Y= 10^(-0.535+$\log_{10}$((p*r^2)) p=3.1415927, r=Radius	(Brown, 1997)
7	B_{tot}= 21.297022-6.952649*(DBH)+0.7403*$(DBH)^2$	(Brown & Iverson, 1992)
8	B_{tot}= 13.2579-4.8945(DBH)+0.6713$(DBH)^2$	(Brown, 1989)
9	Y= exp(-2.23927+2.49596*ln(DBH))	(Bao HUY et al., 2012)
10	ln(TAGB)= c+aln (DBH) a=2.196 c= -1.201	(Basuki et al.,2009)
11	Y = ln(TAGB)= c+aln (DBH)+bln(H) a=1.981 b= 0.541,c=-1.935	(Basuki et al., 2009)
12	C_AGB_kg= exp (-2.97775+2.49711*ln(DBH_cm))	(Bao HUY et al., 2012)
13	BGB_kg=exp(-3.73686+2.32102*ln (DBH_cm))	(Bao HUY et al., 2012)
14	C_BGB_kg = exp (-4.91842+2.41957*ln (DBH_cm))	(Bao HUY et al., 2012)
15	AGB = 0.0509 x q D^2 H	(Basuki et al., 2009)
16	BGB_kg = exp -3.73686+2.32102 ln (D)	(Brown et al., 2004)

(Source: Gunawardena, 2014)

Y, TAGB, AGB=above-ground tree biomass [kg] q=wood specific gravity [g cm^{-3}], D, DBH=tree diameter at breast height [cm], H=tree height [m], C_AGB=above ground carbon C, BGB=below ground carbon, BGB=below ground biomass.

2.4 Sampling design

The study site (UFR) was divided into homogeneous strata, based on the image characteristics of the image in the Google earth software which represent the study area. Accordingly two strata were identified. Homogenous areas was delineated using the image characteristics of Google satellite image of the study area.

2.5 Sample plots

Cluster sampling technique was used to prepare sample plots for data collection. A total of 12 plots were selected randomly to represent all the vegetation types of UFR. One plot was consisted with series of three circular sub plots in a single array. These plots have been selected using a map prepared from Google image. Each plot consisted of three circular sub plots. Each circular subplot was 20 m in diameter, and each located 10m apart from each other (Figure 2). The size and shape of the plot is a trade-off between accuracy, precision, time, and cost for measurement (Pearson et al., 2005). Sample plots containing smaller subunits of various shapes and sizes are cost effective depending on the variables to be measured. For example, for afforestation, all trees are measured in the entire sample plot, whereas data on non-tree vegetation, litter, and soil are collected in a smaller sub-plot. The Forest Inventory and Analysis (FIA) standard plot consists of a cluster of four subplots, each containing smaller nested plots for sampling understory vegetation and soils, of relatively small radius. (Pearson et al., 2005).

Nested plots are a practical design for sampling for discrete size classes of stems. They are well suited to stands with a wide range of tree diameters or stands with changing diameters and stem densities. In this study nested plot consisting with 3 m, 4 m, and 10 m subplots were used. (Figure 3)

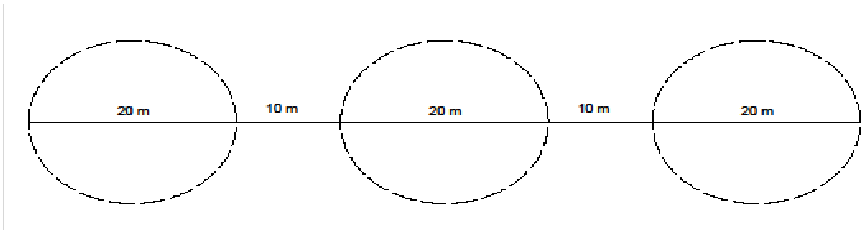
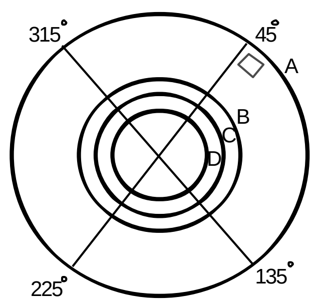


Figure 2. Cluster sampling design



A, r=10 B, r=4 C, r=3 D, r=2 E=30 cmx30 cm micro plot(r=Radius)

Figure 3. Sample plot design.

2.6 Calculation of carbon stock

The most widely used method for estimating biomass of forest is through allometric equations. The allometric equations are developed and applied to forest inventory data to assess the biomass and carbon stocks of forests. The allometric equations for biomass estimation are developed by establishing a relationship between the various physical parameters of the trees such as the diameter at breast height, height of the tree trunk, total height of the tree, crown diameter, tree species, etc. Methodology used in this study considered the guidelines laid in the ‘Good Practice Guidance for Land Use, Land Use Change and Forestry’ by IPCC (2003) and the methodology suggested by Pearson et al., (2005) was also used in this method to estimate the carbon stock in trees outside forests systems of Nuwara Eliya District in Sri Lanka.

2.7 Estimation of above ground biomass (ABG)

Live Trees

The equation developed by Brown (1997) was used in the study.

$$X = exp\,(-2.134 + 2.53 * ln\,(DBH) \quad (1)$$

$$X1 = X * .10{,}000\,/A \quad (2)$$

Palm trees

$$\mathrm{X} = 4.5 + 7.7 * \mathrm{H} \quad (3)$$

$$\mathrm{X1} = \mathrm{X} * 10{,}000\,/\mathrm{A} \quad (4)$$

Liana

$$\mathrm{X} = \mathrm{DBH} \wedge 2.657 * \exp\,(0.968) \quad (5)$$

$$\mathrm{X1} = \mathrm{X} * 10{,}000\,/\mathrm{A} \quad (6)$$

Dead trees

There may be different types of dead trees in a forest. They are, recently dead trees which retain small branches and twigs, resembling a live tree except for the absence of leaves. The other one is old dead trees which have only the conical shape of the main stem as branches have been fallen over the years. In this study only the recently dead trees were found. Therefore the same equation that was used to calculate biomass of trees was used here, however, subtracting 5 percent for the fallen leaves.

$$\mathrm{X} = \exp(-2.134 + 2.53\ln(\mathrm{DBH})) * 0.975 \quad (7)$$

Saplings

$$\mathrm{X} = \exp(-2.134 + 2.53 * \ln\,(\mathrm{DBH}) \quad (8)$$

$$\mathrm{X1} = \mathrm{X} * 10{,}000/\mathrm{A} \quad (9)$$

Seedlings

Twenty to 30 seedlings were cut at the ground level and weighed. A sub sample from each seedling was taken and weighed. Samples were oven dried at 105º C to a constant mass. Then the ratio between wet and dry mass of the sub sample was used to get the dry mass of entire seedlings. Finally, mean biomass of seedlings was calculated by averaging the estimated value of all the seedlings. These values were used to scale up counts of seedlings in the system (Pearson et al., 2007).

$$\mathrm{X} = \mathrm{Y} * \mathrm{N} * 0.001 \quad (10)$$

$$\mathrm{X1} = \mathrm{X} * 10{,}000\,/\mathrm{A} \quad (11)$$

Litter

$$\mathrm{X} = (\mathrm{R} * 10{,}000/0.785)/1000 \quad (12)$$

Woody debris (dead wood)

$$V = A1 + 4A + A\,2\,/6 * L \quad (13)$$

$$X = V * 0.7 \quad (14)$$

$$X1 = X * 10{,}000\,/A \quad (15)$$

Where;

X= ABG biomass (kg)
DBH = diameter at breast height (cm)
X_1 = ABG biomass (kg/ha)
A = Area of the plot
H = height (m)
10, 000 = Constant
N = Number of live seedlings
0.001= Constant
Y = average weight of a seedling (g)
R = dry weight/fresh weight
A_1=Diameter of small end of dead wood (cm)
A_2 = Diameter of large end of dead wood (cm)
L = Length of the stump (m)
V=Volume

2.8 Estimation of below ground biomass

The most efficient way to estimate below ground biomass is to apply the widely accepted general model of Pearon et al., (2009). In estimating belowground biomass, an equation is applied to total above ground biomass as a whole and not to individual tree biomass (except litter and downed wood).

$$BBD=\exp(-1.0587+0.8836 \times \ln(ABD)) \quad (16)$$

Where;

ABD = above ground biomass density (Mg/ha)
BBD = below ground biomass density (Mg/ha)

Mega gram (Mg) is the international reporting unit of above ground biomass which is equal to tons/hectare (t/ha).

2.9 Total biomass

Total biomass density was calculated by summing up mean carbon density of each component of carbon pool.

$$\text{Total biomass Density} = BtAG + BtBG + BdtAG + BdtBG + BspAG + BspBG + BsdAG + BsdBG + BWdb + Bl \quad (17)$$

Where;

B_{tAG} =Above ground biomass of live trees
B_{tBG} =Below ground biomass of live trees
B_{dtAG} =Above ground biomass of dead trees
B_{dtBG}=Below ground biomass of dead trees
B_{spAG}=Above ground Biomass of saplings
B_{spBG}=Below ground biomass of saplings
B_{sdAG}=Above ground Biomass of seedlings

B_{sdBG}=Below ground biomass of seedlings
B_{Wdb}=Biomass of wood debris
B_{l}=Biomass of Litter

2.10 Total carbon density

In this study total biomass was converted to total carbon by multiplying by 0.47. (Premakantha et al., 2014)

$$\text{Total carbon density}(\text{Mg/ha}) = \text{Biomass} \quad (\text{Mg/ha}) * 0.47 \tag{18}$$

2.11 Total carbon stock (Mg)

Total carbon stock of UFR was calculated by multiplying average carbon density of all the carbon pool by the area of UFR using the method suggested by Kauffman and Donato (2012).

$$\text{TC} = \text{Total carbon density (Mg/ha) x Area (ha)} \tag{19}$$

TC-e = Total carbon dioxide equivalents (Mg)

Total carbon stock was multiplied by 3.67 to obtain the CO_2 equivalents (Mg) as the ratio of molecular weights between carbon dioxide and carbon is 3.67 (Kauffman and Donato, 2012).

3. Results and Discussion

Total carbon density of natural forest and plantations was found to be 36.55 Mg ha^{-1} and 45.06 Mg ha^{-1} respectively. This result is too low when compared to the study by Costa and Suranga (2012). According to the results, live trees provided the major contribution for carbon sequestration in UFR and 16,344.5 Mg carbon equivalents are stored. This value can be used as a reference level for future studies.

3.1 Tree density in UFR

Table 3 shows the tree density of two vegetation types in UFR. Tree densities of natural forests and plantations were found to be 1,757 individuals per hectare and 1,006 individuals per hectare, respectively.

Table 3: The abundant species and their densities in the two vegetation types

(Note: some plantation species can be observed in high density in natural vegetation due to closeness of the two vegetation

Natural forests		Forest Plantations	
Species	Tree density (Individuals /ha)	Species	Tree density (Individuals /ha)
Mesua ferrea	223	*Sweetinia macrophylla*	234
Crayota urens	127	*Myroxylon balsamum*	127
Sweetinia macrophylla	121	*Mesua ferrea*	127
Symplocos cochinchinensis	104	*Alstonia macrophylla*	110
Myroxylon balsamum	93	*Pongamia pinnata*	64
Theobroma cocao	64	*Filicium decipiens*	53
Micromelum minutum	64	*Artocapus nobilis*	52
Artocapus nobilis	61	*Phyllanthus indicus*	48
Acronychia pedunculata	61	*Neolitsea cassia*	32

Diplodiscus verrucosus	48	*Calophyllun spp.*	32
Cryptocaryamembranacea	48	*Berrya cordifolia*	32
Filicium decipiens	48	*Gmelina arborea*	32
Alstonia macrophylla	47	*Terminalia belarica*	32
Semecarpus coriacea	42	*Nothopegia beddomei*	32

Tree densities and species composition of two vegetation types are important because they directly affect biomass estimations. *Sweetinia macrophylla, Myroxylon balsamum, Alstonia macrophylla, Mesua ferrea, Crayotaurens, Theobroma cocao, Micromelum minutum, Artocapus nobilis, Acronychia pedunculata* are the most abundant species found in both vegetation types. Of each species, there are more than 50 individuals per hectare.

The amount of biomass and the carbon stock differs between species, both in the case of trees and shrubs (Elias and Potvin 2003; Lamlom and Savidge 2003), as well as herbs and mosses (Tutersky, 2003). Species composition and community structure had significant impacts on biomass carbon density. Results show that the tree density in the UFR falls far below, compared to other natural forests. Therefore, there is a possibility of inclusion of more trees into both vegetation types and thereby increasing the carbon/biomass stock in the UFR. On the other hand, it was observed that number of seedlings is inadequate in terms of regeneration.

3.2 Frequency distribution of tree diameter classes

Frequency distribution of tree diameter classes in natural forests in UFR shows a reverse J shape curve similar to that of other natural forests. The curve illustrates that 42% of the trees are in between 10-19 cm. Figure 4 and Diameter class distribution of plantations also shows a reverse *J* shape curve unlike other plantations, (Figure 5) due to the presence of non-plantation species.

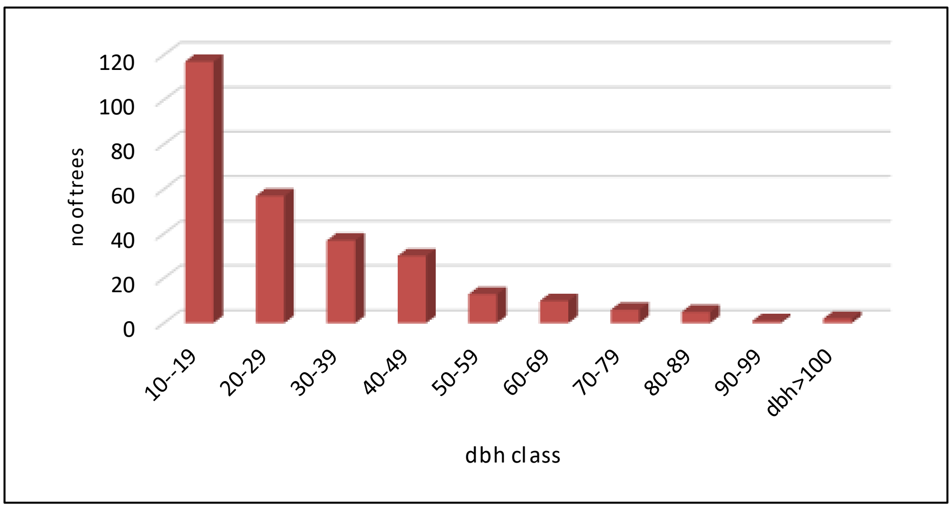


Figure 4. Diameter class distributions of Natural forests.

Frequency distribution of tree diameter classes for both vegetation types showed a reverse J shape curve. Diameter distribution of trees in both vegetation types showed that the percentage of number of trees in smaller diameter classes is more than the larger diameter classes. The amount of biomass contained in different tree diameter classes showed opposite pattern to that of tree diameter class distribution. Therefore, mature trees contain large amount of biomass in natural vegetation of the UFR. Plantations also showed the same pattern of increasing biomass density with the increase of size of diameter class. (Figure 4 and Figure 5) The ratio of carbon stock/growing stock decreases with tree size, indicating that the contribution of stem biomass becomes increasingly large as trees grow in size (Lehtonen et al., 2004; Kauppi et al., 2006).

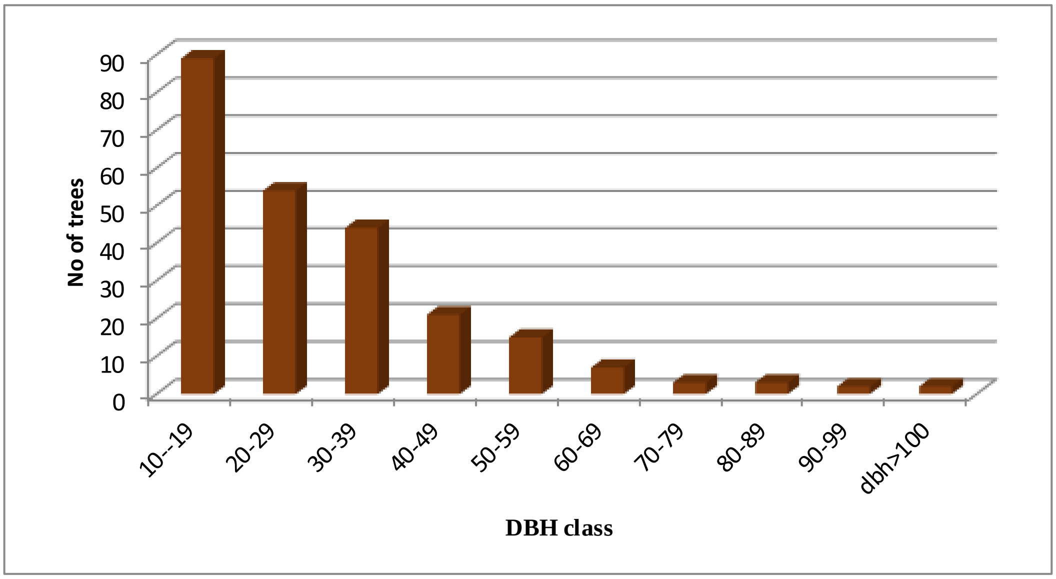


Figure 5. Diameter class distributions of Forest plantation.

Large trees have significant benefits, for example, they can constitute a large proportion of the carbon stock and affect greatly the carbon density of forests. Large trees usually have deeper roots and long lifetimes. They affect forest structure and function and provide habitats for other species.

Land management has been a key driver in the change in the stocks of large trees. It is also observed that at times the trees are in clusters hindering the potential growth of them due to competition among them. Thus, it is proposed to carry out field based inventories and to perform scientific studies prior to implementing silvicultural programmes in the plantations and make decisions in thinning and inclusion of more trees.

3.3 Biomass content in different diameter classes

Figure 6 illustrates the biomass density by different diameter classes in the natural forests of UFR. The lowest biomass density is shown in the 10-19 cm diameter class. It also shows that biomass density increases with the size of diameter class. Therefore, that larger diameter classes contain higher amount of biomass. Figure 7 illustrates the biomass density by different diameter classes in plantations. Similar to natural vegetation of UFR, 10-19 cm diameter class holds the least biomass density. Plantations too show the pattern of increasing biomass density with the increase of size of the diameter class.

Figures 8 and 9 show the contribution of each component to the total density of natural forests indicating that biomass partitioning of two vegetation types differ greatly. However, trees are the major contributor to biomass in both vegetation types.

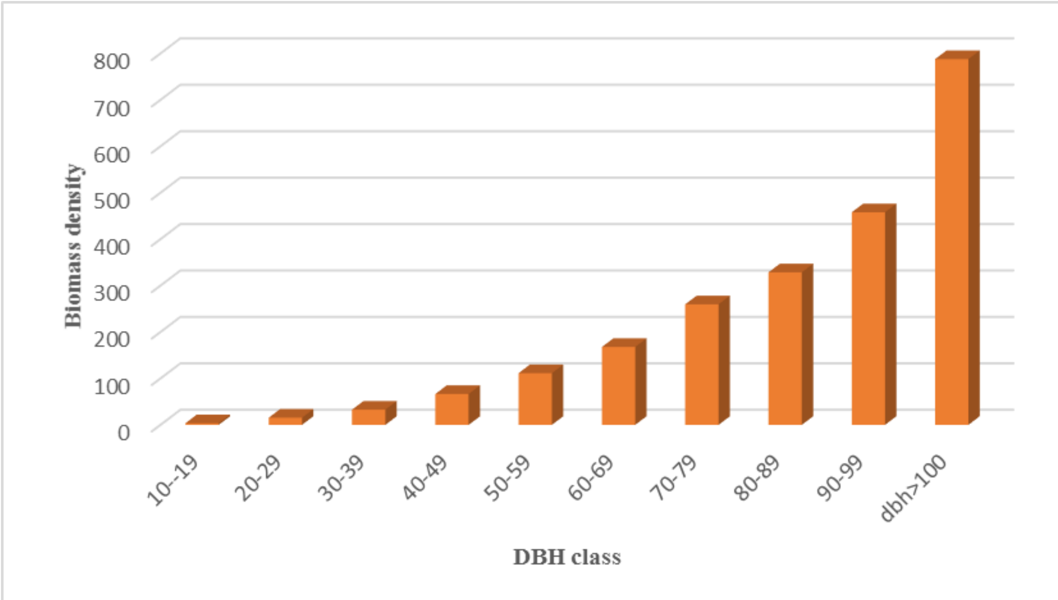


Figure 6: Biomass densities in different diameter classes of trees of Natural forests.

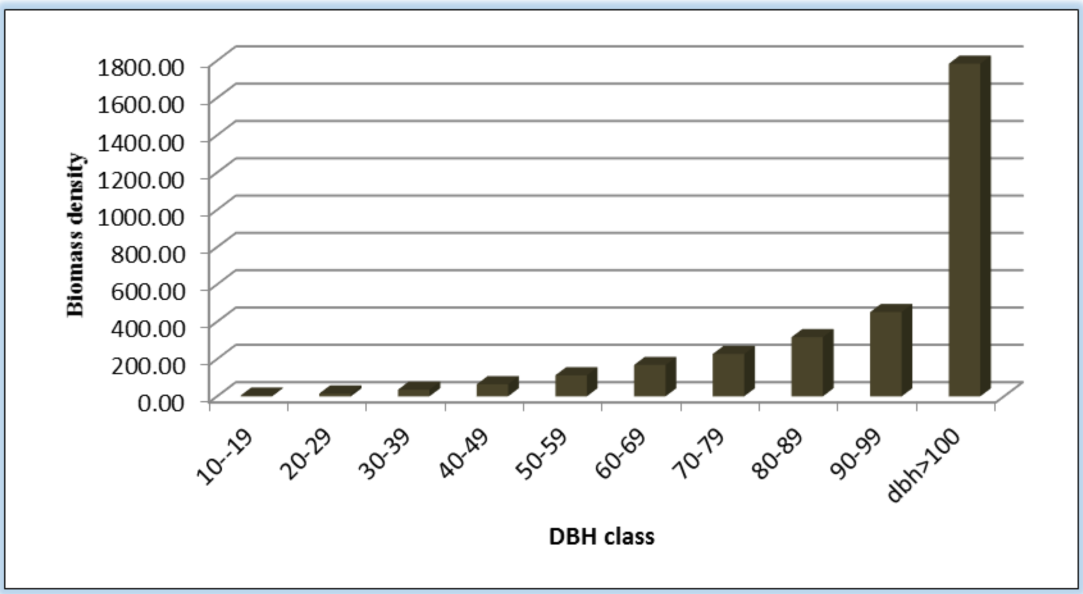


Figure 7: Biomass densities in different diameter classes of trees of forests plantation.

Biomass partitioning among components showed the contributions of different components towards the total biomass contents. Therefore it is apparent that the trees are the largest contributor to biomass production similar to other natural forests (Lago, 1992). However, very low contribution for carbon by seedlings and herbaceous vegetation in the UFR Similar to other tropical forest (Yanqiu et al., 2015).

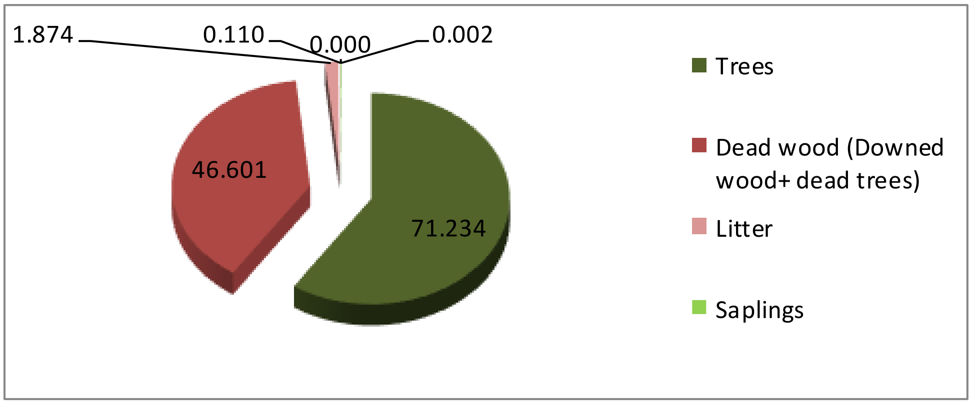


Figure 8: Biomass partitioning among different components of Natural forests in the UFR.

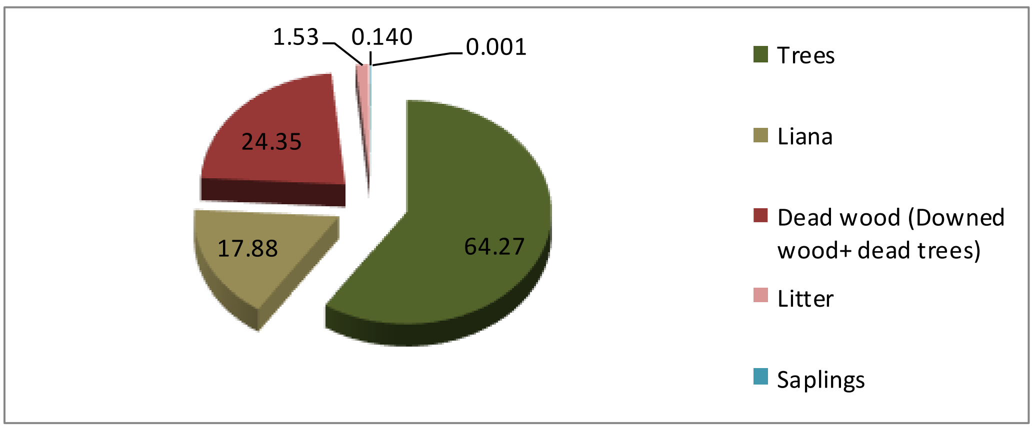


Figure 9: Biomass partitioning among different components of forest plantation in the UFR.

Similar to the results of this study, results of the estimation of carbon stock in Tankawati natural hill forest of Bangladesh revealed that the total carbon stock of the forest was 283.80 Mg ha^{-1} whereas trees produce 110.94 Mg ha^{-1}, undergrowth (shrubs, herbs and grass) 0.50 Mg ha^{-1}, litter fall 4.21 Mg ha^{-1} and soil 168.15 Mg ha^{-1} (up to 1 m depth). Lugo (1992) mentioned that the amount of biomass in undergrowth shrubs, vines, and herbaceous plants can be variable but it is generally about 3% or less of the total biomass of more mature forests.

3.4 Total biomass stock in the UFR.

Table 4: Total biomass stock of UFR

Component		Natural forests (Mg)	Plantations (Mg)
Trees		3,923.84	2013.00
Liana		0	596.15
Seedlings		0.14	0.034
Saplings		7.26	5.37
Dead wood	Dead trees	2,077.72	646.12
	Down	0.049	0.042
	Litter	83.55	41.61

Table 4 gives the total biomass stock in each component of both natural forests and plantations. Total biomass stock of the UFR is 9,475.56 Mg. Out of that, 64.3% of biomass is from natural forest and the rest is from the plantations. Total biomass mainly consists of two components, namely the live tree component and dead wood component. Contribution for total tree biomass from natural forests and plantations was 65.33% and 34.67% respectively. Out of 2847.98 Mg of deadwood biomass stock, 75.89% was from natural forests while 24.11% was from plantations.

Clear vertical stratification of the forest canopy layer could not be identified in the field work stage where measurements were taken from trees and other components. It indicates that vegetation has dissimilar structure to that of other natural forests. Due to this non storied nature in the canopy, light penetration to lower levels may be less, hindering the growth of plants in lower layers contributing to poor biomass accumulation from them.

3.5 Total carbon stock in the UFR

Total carbon stock is a function of the area and the carbon density, and hence the total biomass stock was more in natural forests compared to plantations as the natural forests extent is higher (Table 5).

Table 5: Carbon stock of UFR

Vegetation type	Extent (ha)	Total Carbon density (Ma/ha)	Carbon stock (Mg)
Natural forest	78.35	36.55	2,863.47
Plantation	35.28	45.06	1590.06

Carbon stock of the UFR was fairly low compared to the aboveground carbon stock of natural forests in different Asian countries. For example, Thailand (98.76 Mg ha^{-1}), Malaysia (100 Mg ha^{-1}) and Philippines (86 Mg ha^{-1}) (Pibumrung et al., 2008). In Sri Lanka Costa and Suranga (2012) estimated an above and belowground carbon density at 157 Mg ha^{-1} of monoculture and mixed plantation forests in Nuwara Eliya district in 2008. Mattson's carbon estimate of six forest types in Sri Lanka has given an average value of 120 to 130 Mg ha^{-1}. When compared to those carbon densities in both systems, carbon densities of plantation and natural forest in UFR were significantly low. This can be due to several factors, such as illegal felling, inappropriate management, impact of climate change, destruction of under growth because of over visitation to the park.

3.6 Total carbon dioxide equivalent stock in the UFR.

Table 6: Amount of carbon dioxide stored in UFR

Vegetation type	Carbon stock (Mg)	CO2-e (Mg)
Natural forest	2,863.49	10,508.99
Plantation	1590.06	5835.53

Table 6 shows the amount of carbon dioxide equivalent stored in UFR. Both vegetation types in the UFR had stored a total of 16,321.77 Mg carbon equivalents at the time of study. However there is no universally accepted methodology in estimating biomass/carbon stock either in forests or in other vegetation. However various methods are available but none is technically precise and accepted by all the scientists. Estimation of total organic carbon requires a complete enumeration of the entire ecosystem components is difficult lengthy, tedious and expensive. Because of that, only a very small number of studies have been done based only on samples, even so they may not be comparable as the methodology and the materials used are different.

4. Conclusion

It is clear that UFR holds a moderate amount of biomass/carbon stock and it contributes to mitigate climate change which is a prime global issue at present. Either keeping the forest reserve as it is or by increasing biomass/carbon stock through changing species composition and the structure, is the major challenge ahead of us. In line with this, assessing biomass/carbon stock is a pre-requisite. It can be concluded that this methodology used in this study can be successfully applied for assessment of Biomass/carbon stock in the natural forests and plantations in the Kandy District Sri Lanka.

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