ABOVE GROUND CARBON STOCK ESTIMATION OF INTERMEDIATE ZONE TEAK (*Tectona grandis*) GROWN IN SRI LANKA

***W.M. Jinadari[1*], W.J.S.K. Weerakkody[1], W.V.T.D. Amarasinghe,[2]
C.K. Muthumala[2]***

[1]*Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka*
[2]*Research Development and Training Division, State Timber Corporation, "Sampathpaya", Sri Lanka*

INTRODUCTION

Forests are the biggest carbon pool on the earth. Accordingly, it has the potential to establish a leading unit in mitigating global warming and adapting to climate change (Vashum and Jayakumar, 2012). Therefore, it is important to estimate the carbon stock of forests in order to assess the potential for climate change mitigation by estimating the amount of loss during deforestation or by estimating the amount of carbon that forests can store (Anup, *et al*., 2013).

Except for natural forests, many countries establish planted forests as an alternative. They can take over most, though not all functions that those natural forests can provide. In Sri Lanka, commercially planted forests are important to address timber and fuel-wood production that helps to reduce logging pressure on natural forests. Teak (*Tectona grandis*) is the major forest plantation species in Sri Lanka, where approximately 30000 m^3 is harvested annually from state-owned plantations. It is one of the most valuable timber yielding species not only in Sri Lanka but also worldwide due to its durability and workability (Palanisamy, *et al.*, 2009). Most of the teak plantations in Sri Lanka are mainly located in the dry zone. Even so, teak in the intermediate zone also plays a major role in the Sri Lankan market. Among other areas, Kurunegala is the major area of the intermediate zone having a majority of teak plantations.

Sri Lanka is divided into forty-six (46) agro-ecological zones based on monthly rainfall regime, topography, main soil type, land use and vegetation. Therefore, each agro-ecological region represents a uniform agro-climate, soils, and terrain conditions (Punyawardena, 2015). Due to these specific variations, this study was focused to determine the variation in the carbon stock of the teak plantations based on their respective agro-ecological regions.

METHODOLOGY

Study Area

This study was carried out in the selected teak plantations located in the Kurunegala district (Table 1). Two plantations located in Intermediate Zone Low country 1 (IL1) and Intermediate Zone Low country 3 (IL3) were mainly used for data collection. The study was carried out by selecting only two plantations located in IL1 and IL3 due to the reason of selecting even-aged plantations for proper comparison. Nevertheless, the slope percentages and the soil types of those plantations are varying. Respectively IL1 has 8%-6% slope averagely and red-yellow podzolic soil type (Mapa,2020), IL3 has a non-calcic brown soil type (Mapa,2020) and 13%-11% slope averagely.

Table1.Details of selected plantations

Agro-ecological region	Plantation	Age (years)	Location	Extent (ha)
IL1	Alawwa	60	7°21`46N 80°12`37E	94
IL3	Athgaala	60	7°37`25N 80°20`25E	68

Data Collection

Field data were collected following the random sampling method. From each plantation, sixteen sampling plots (each of 10m x 10m) were selected. ArcGIS v.10.7 software was used to demarcate the locations in a random manner. The Diameter at Breast Height (DBH) and total tree height of all trees in each sampling plot were measured by using DBH tape and Clinometer. DBH of any tree or coppice lower than 10cm was not accounted for in the carbon estimation.

Data Processing

The stem volume of each tree was calculated by collected ground data by using Equation 1 (Phillips, 1995).

$$V = \exp(-9.7327+2.055\times L_n d+0.773\times L_n h) \ \ldots\ldots.. \ (1)$$

Where V is stem volume (over bark) in m^3, exp is e^x, when e is the base of natural logarithms (≈2.718282) and x is the value of the expression in brackets, L_n is the natural logarithm, d is the diameter at breast height in cm, h is total tree height in m

By computed stand volume above ground carbon (AGC) extent was estimated by using Equation 2. (IPCC, 2006)

$$AGC = [V\times BCEF] \times CF \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \ (2)$$

Where, AGC is Above Ground Carbon in Kg, V is stem volume in m^3, BECF is biomass conversion and expansion factor, CF is carbon fraction of dry matter in tones C (0.49).

BECF factor was derived by using equation 3. (IPCC, 2006)

$$BECF = BEF \times D \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.... \ (3)$$

Where BECF is biomass conversion and expansion factor, BEF is biomass expansion factor (1.3) (Subasinghe and Erandaka, 2015), D is basic wood density in kg/m^3: at 12% moisture level, 720 kg/m^3); at oven dry mass, 596.16 kg/m^3 (Equation 4) (Ruwanpathirana, 2014).

To get Oven dry mass density at 12% moisture level (720 kg/m^3) it needs to be converted to oven-dry mass by using Equation 4.

$$D_{DM} = \quad D_{12} \times \text{Density at 12\% moisture} \ldots\ldots\ldots \ (4)$$

Where D_{DM} is Density at oven-dry mass (g/cm^3), D12 is conversion factor (0.828), D_{DM} = 596.16 kg/m^3

Statistical Analysis

To authenticate the statistical comparison of AGC stock and stem volume in different agro-ecological regions, a two-sample t-test was performed using Minitab (version 15.0). To verify the statistical significance of all parameters, mean values ±SD were calculated.

RESULTS AND DISCUSSION

Descriptive statistics of DBH, height, elevation and number of trees are shown in Table 2. Accordingly, the mean DBH value in the IL3 plantation is greater than the IL1 plantation. The highest number of trees per hectare is shown in the IL3 plantation. However, in terms of the mean height, the selected plantation in IL1 shows the highest.

Table 2. Descriptive statistics of selected plantations

AER	DBH (cm)	Height (m)	Elevation (m)	Number of Trees /ha
IL1	27 ± 1	17.3 ± 1.2	133.4 ± 7.2	186 ± 86
IL3	29 ± 1	14.2 ± 0.6	95 ±1.9	292 ± 185

Values of variables are shown as Mean value ± Standard deviation, Agro-ecological regions are denoted as AER

Five (5) classes were generated according to the DBH of the teak trees and Figure 1 graphically represents the frequency of each class based on the plantation. The highest frequency of the number of trees is observed in class, which ranges from 20-30cm in both agro-ecological regions and the lowest frequency is observed in class, which are having DBH greater than 41cm. When considering the IL3, the majority of trees are distributed in the highest DBH ranges than the IL1.

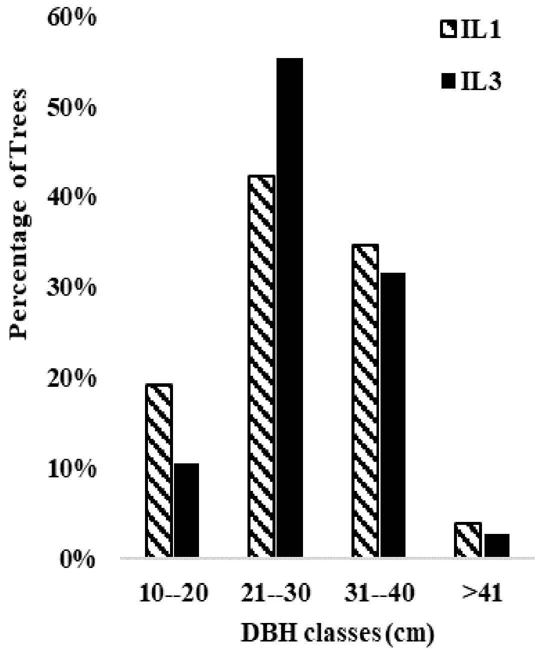

Figure 1. Percentage of Number trees distributed in different DBH classes

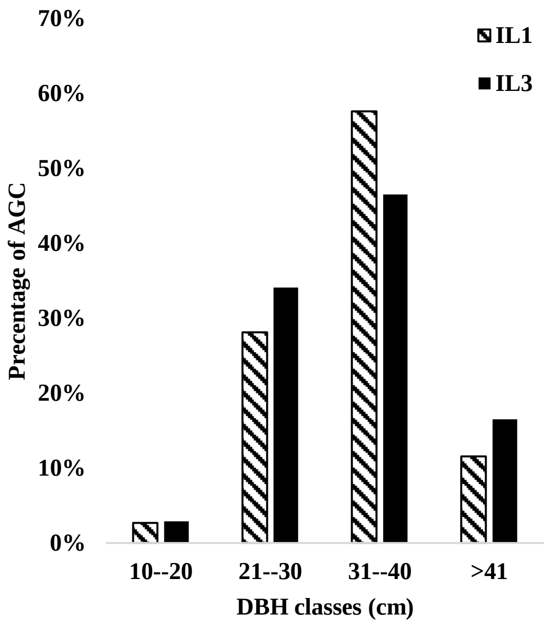

Figure 2. Percentage of Above Ground Carbon distributed in different DBH classes

Figure 2 shows the distribution of mean AGC in different DBH classes. The highest AGC is observed in class having DBH range from 31-40cm in both agro-ecological regions and the lowest in class 10-20cm. These results show that lower number of trees with higher DBH stores a greater amount of AGC over a higher number of trees with less DBH.

Results obtained from the t-tests conducted for the studied plantations are summarized in Table 3. According to the results, there is no significant difference between the plantations in IL1 and IL3 for per hectare mean stem volume. However, plantation in IL1 has a higher mean stem volume per tree compared with the plantation in IL3. The mean of AGC per tree in IL1 is greater than the IL3. It is observed the AGC of selected plantations in both agrological regions is highly varied from one sampling point to another. The reason might be the uneven ground condition within the plantations.
According to Subasinghe and Erandaka (2015), the annual biomass increment from 4 to 8 years was 13.5 kg. Since the plantations selected for the present study were 60 years, the mean annual biomass increment was 6.8 kg.

This is an expected change, as plantations are in the growth stage between 4 to 8 years, showing a high biomass increase, because, biomass increment is higher in younger growth stage than the mature stage. The plantations used in the present study show relatively less biomass increment due to their mature stage of growth.

Table 3.Comparison of above-ground carbon and stem volume

AER	Stem Volume /tree (m^3)	Stem Volume /ha(m^3)	AGC/tree (kg)	AGC/ha (tones)
IL1	0.583± 0.468	94.8 ± 90.7[a]	221 ± 178	36 ± 34.4[a]
IL3	0.478 ± 0.249	109.5 ± 96.9[a]	181.4 ± 94.7	43.1 ± 35.5[a]

Values of variables are shown as Mean and Standard deviation. Mean denoted by the same letter in a column represent a non-significant difference (p<0.05). AER- Agro-ecological regions

CONCLUSIONS/RECOMMENDATIONS

No significant difference ($p<0.05$) was found between AGC stock of selected plantations in IL1 and IL3. Similarly, there is no significant difference between the stem volume of selected plantations at $p<0.05$. The highest mean DBH was found in IL3 while the highest mean height was observed in IL1. In terms of the distribution of AGC stock with DBH, trees with higher DBH show higher AGC stock in selected agro-ecological regions. Carbon calculations will be more precise if calculation is done not only for AGC but also for total biomass and soil carbon pool with species-specific parameters. An increase in sampling number and replication will also ensure results that are more reliable. Selection of study sites was difficult due to time limitation and a limited number of appropriate plantations with similar conditions.

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