Height and Diameter Relationship of *Tectona Grandis* L. in Mullaitivu District of Sri Lanka

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Abstract— The study was carried out at different forest plantation sites of the teak (*Tectona grandis* L.) namely Mulliyawalai, Theravil, Mankulam and Karripatammuripu in Mullaitivu district of Sri Lanka. The study aims to interpret the relationship of tree height and canopy diameter over stem diameter at breast height. Teak plantation from Mankulam site was 13 years old young plantation and Karripatammuripu site was 35 years age old plantation. Theravil and Mankulm sites were 22 medium and even age old plantation. A total of 757 individuals of teak were assessed to determine relationship between height and diameter. Even aged planation of Mulliyawalai and Theravil sites showed a polynomial and linear curves relationship, respectively. High regression value (r^2) was value found in tree height over stem diamter (dbh) in Karripatammuripu site compared to other teak plantation site, showed that Karripatammuripu was found to be superior and clear site variation to others. In this fitted curves, Mulliyawalai, Theravil and Mankulam had lower regression (r^2) values. Polynomial curve was best fitted in Mulliyawalai and Mankulam sites. Linear and logarithmic curves were fitted to Theravil and Karripatammuripu sites. Similarly, the Mulliyawalai site showed a clear site variation in canopy diameter over stem diameter. The site Mulliyawalai was found to be superior to others in canopy diameter over stem diameter. Liner curve was fitted to canopy diameter over stem diameter in Mankulum site. The behavior of the curves showed in different pattern and models due to variation found on age, spacing, and other factors at forest plantation sites of the district in Sri Lanka

Keywords— Canopy, Diameter, Forest-Plantation, Height, Teak, Mullaitivu, Sri Lanka

INTRODUCTION

   Plantation forests in tropics can significantly aid the socioeconomic and livelihood development of the rural people [1]. *T. grandis* is one of the most well-known timber of the world [2]. Teak was probably introduced around 400-600 years ago in Sri Lanka. The district Mullaitivu in Sri Lanka consist vast areas of forest land covers approximately 8.6 % of forest vegetation [3]. In this district, dominant forest plantation is Teak which account about 90 % of the forest plantation [4] with other commonest plantation such as Halmila and Eucalyptus, Casuarina and Khaya in Mullaitivu district, and it was established in Northern Province of Sri Lanka since 1960's [4]. Teak can be grown successfully in low elevations of wet, dry and intermediate zones of Sri Lanka [5]. Establishment and renovation of teak plantation forest in these areas are becoming important with increasing population and demand of people [6]. The relationship between the height and diameter is important and commonly used to estimate the height of the tree by using dbh [7], [8]. The relationship between tree height and diameter is fundamental in determining community and ecosystem structure as well as estimates of biomass and carbon storage [9]. Objective of this study was to find out relationship between the canopy height and diameter with stem diameter (dbh) of teak plantation in Mullaitivu District, Sri Lanka.

I.   MATERIALS AND METHODS

   The research was conducted at the selected Teak plantations distributed in Mullaitivu district falls under dry zone low country agro ecological zone (DL_2) of Sri Lanka. The experiment was conducted in Teak plantation forest in Mullaitivu district falls under dry zone low country agro-ecological region of Sri Lanka with coordinates of 09°14′N 80°32′E, has bimodal rainfall pattern. Average annual rainfall varies from 1300 mm to 2416 mm and temperature ranges from 23^0C to 39.3^0C. The district has Kilinochchi district on its Northern border, Trincomalee district and Vavuniya district and part of the Mannar district in the south, Mannar district in the West and the sea in the East. It covers land area approximately 251,690 ha (including forest area excluding large inland water). This district accounts for 3.8% of the country's total area. Approximately 167,850 hectares

which is 64.1% of the total land area consist of forest within that 2,740 hectares (1.6 % of total forest) of plantation forest occurred [6].

Sampling was done in four sites of Mullaitivu district, which were chosen according to the density and age of teak plantations. Spacing of the different teak forest plantation was not same in all sites. Randomly selected 15×15 m^2 of square plot was sampled for height and dbh. A minimum of two sampling units were chosen for each stand. Diameter tape was used to measure the tree diameter at 1.3 m from the base of the tree. In a forest, easily measurable stand structure is the tree diameter which reflects the aspect of the basic stand structure, which is commonly used in both natural and plantation forest [10, 11] A Sunnto clinometer is used to measure the tree height and the heights were taken up to the tip of the tree height. Canopy diameter was measured directly using measuring tape from each and every tree within the sampling unit. The width of a crown can be measured by projecting the edges of the crown to the ground and measuring the length along one axis from edge to edge through the crown centre. The crown diameter was calculated as the average two values measured along to perpendicular directions from the location of each tree top by fitting a fourth-degree polynomial on both profile. Secondary data was collected from the forest department of Mullaitivu district to identify the sites of teak plantation. Field measurement was entered and tabulated into an Excel spreadsheet. Data analysis was done using Minitab (Minitab 2014) and Micro Soft Excel 2007.

II. RESULTS AND DISCUSSION

Plantation site of Karipattammurippu shows the highest value for tree height, canopy diameter and stem diameter due to its age old plantation. Similarly, Mankulam site shows the lowest value for tree height, canopy diameter and stem diameter due to its young age plantation. Maximum and minimum tree height of teak were recorded around 34.7 m in Karipattammurippu site and 9.7 m Mankulum site. Maximum and minimum stem diameter of teak were recorded around 52.8 cm in Karipattammurippu site and 9.16 cm Mankulum site. Maximum and minimum canopy diameter of teak were recorded around 9.8 m in Karipattammurippu site and 1.7 m Mankulum site (Table 1).

A. Tree height and stem diameter (dbh)

Teak tree height in relation to stem diameter in different sites namely Mulliyawalai (Figure 1.), Theravil (Figure 2.), Mankulam (Figure 3.) and Karripatammuripu (Figure 4.) of the forest plantation were given. High regression value was found between height and the dbh in Karripatammuripu site compared to other teak plantation site, shows that Karripatammuripu was found to be superior and clear site variation to others. In this fitted curves, Mulliyawalai, Theravil and Mankulam had lower regression values. However, Theravil and Mankulum had more or less similar value of regression value.
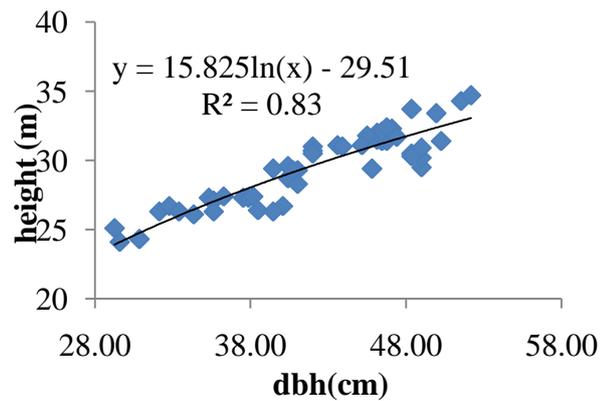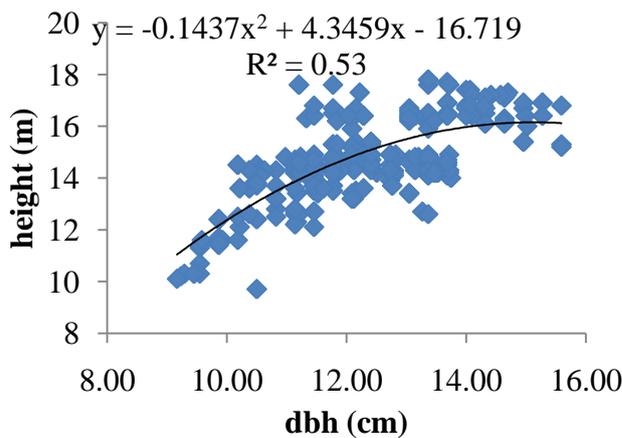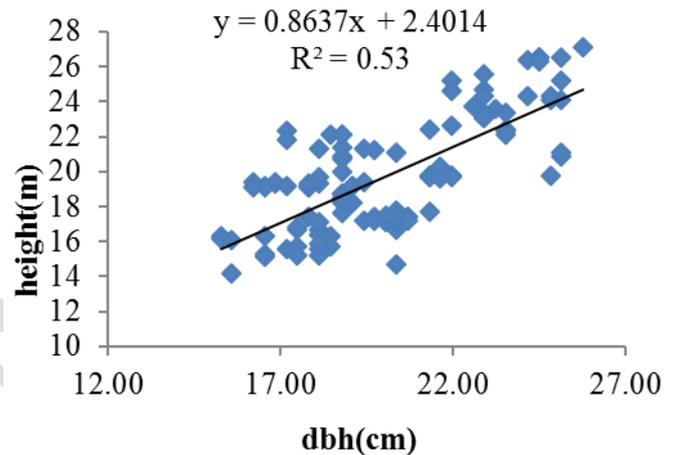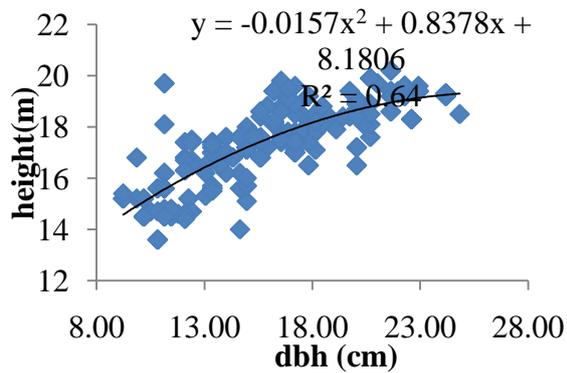
Polynomial curve was best fitted in Mulliyawalai and Mankulam sites. Linear and logarithmic curves were fitted to Theravil and Karripatammuripu sites. Polynomial and linear curves were fitted to Mulliyawalai and Theravil sites, respectively. It may be due different spacing used in the plantation sites, about 1.75 and 3 square meter used in Mulliyawalai and Theravil sites, respectively even both sites were in same age old plantation and mean canopy diameter of Mulliyawalai and Theravil sites were 2.96 m and 3.85 m, respectively. Mean height was high in Theravil (19.83 m) sites than Mulliyavalai sites (17.43 m). Therefore, there was enough space found in Theravil site for further growth without reaching canopy closure and much competition than Mulliyawalai sites.

Table 1: Average, maximum and minimum value of tree height, canopy diameter and stem diameter of teak in the study sites

Study sites (Plantation spacing)	Age (years)	Sample trees (numbers)	Tree Height (m)			Canopy diameter (m)			Stem diameter-DBH (cm)		
			Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.

Mullijavalai (1.75 m × 1.75 m)	22	292	17.425±0.01	13.6	20.2	2.96±0.04	1.9	4.3	16.22±0.01	9.23	24.82
Theravil (3 m × 3 m)	22	125	19.829±0.01	14.2	27.1	3.85±0.04	3	5	20.18±0.01	15.27	25.77
Karipattammurippu (1.75 m × 1.75 m)	35	48	29.508±0.03	24.1	34.7	8.31±0.13	6.5	9.8	42.12±0.06	29.27	52.18
Mankulam (3 m × 3 m)	13	292	14.71±0.00	9.7	17.8	2.65±0.02	1.7	3.7	12.31±0.00	9.16	15.59

Note: Average value ± standard error

$$y = -0.0157x^2 + 0.8378x + 8.1806$$
$$R^2 = 0.64$$

Figure 1. Mulliyawalai, Age: 22 years

$$y = 0.8637x + 2.4014$$
$$R^2 = 0.53$$

Figure 2. Theravil, Age: 22 year

$$y = -0.1437x^2 + 4.3459x - 16.719$$
$$R^2 = 0.53$$

Figure 3. Mankulam, Age: 13 years

$$y = 15.825\ln(x) - 29.51$$
$$R^2 = 0.83$$

Figure 4. Karripatammuripu, Age: 35 years

B. **Canopy diameter and stem diameter**

Teak canopy diameter in relation to stem diameter in different sites namely Mulliyawalai (Figure 5.), Theravil (Figure 6.), Mankulam (Figure 7.) and Karripatammuripu (Figure 8.) of the forest plantation were given. Mulliyawalai site showed a clear site varition in canopy diameter over stem diameter. The site Mulliyawalai was found to be superior to others in canopy diameter over stem diameter. Liner curve was fitted to canopy diameter over stem diameter in Mankulum site, it may due to young plantation which indicates that there was enough space and time for further growth of trees without reaching canopy closure and much competition.
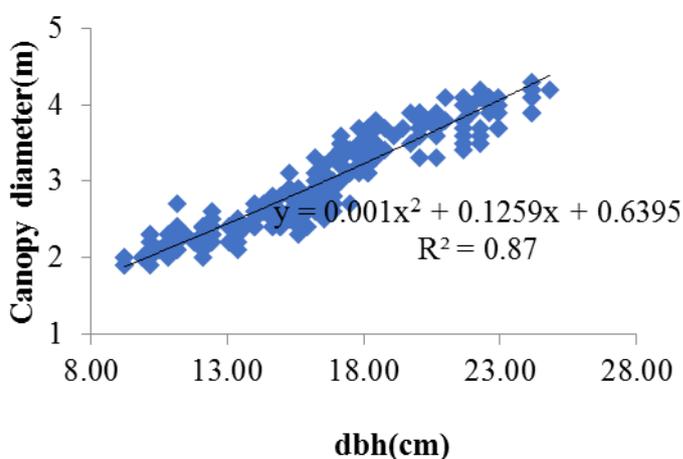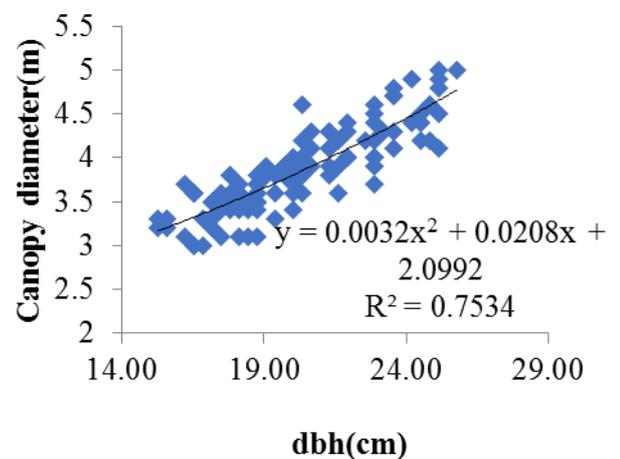

Figure 6 Mulliyawalai, Age: 22 years
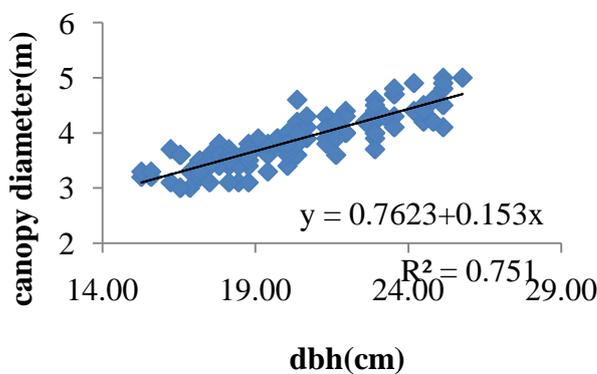

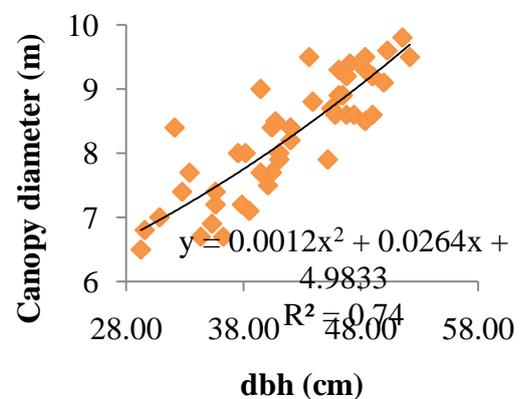Figure 7. Theravil, Age: 22 years

Figure 7. Mankulam, Age: 13 years

Figure 8. Karripatammuripu, Age: 35 years

III. CONCLUSIONS

In this study, tree height and canopy diameter over stem diameter at breast height (dbh) were evaluated to find the relationship in four forest plantation sites of the teak in dry zone of Sri Lanka. Tree height and diameter relationship was recorded with different age of plantation. Polynomial, linear and logarithmic relationship were found in tree height and canopy diameter over stem diameter. The behavior of the curves showed in different pattern and models due to variation found on age, spacing, and other factors at forest plantation sites of the district in Sri Lanka. Further, soil and climate studies are needed to find the variation of height and diameter in all sites of the plantation

IV. SUGGESTIONS

Theravil site had suitable condition for growth and development of teak plantation, leads to better regeneration of the teak and needs in care of the management practices. Replanting should be implemented in Karipattamurippu due to teak attained the harvesting age. Most of teak plantations were damaged by wild elephants. Therefore electrical fences should be established to prevent the damage to the younger plantations. Branching has been increased after the thinning and there by pruning should be practiced every year to get good quality stem. Further researches are needed to confirm this variation for the development of plantation forestry sector in terms of site class index, Allometric equation for dry zone and model development. A strategic land use planning that will facilitate and provide guidance on land use conflicts is planned to be established. In addition, private sector forest development will be encouraged through research and extension, provision of appropriate policies in the area of pricing, and by creating an increased sense of security of land and tree tenure, all of which, if implemented, would enhance opportunities for private sector investments in forestry.

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