# Comparative study on commercial log production managed under different conditions −Evaluating plantation grown teak of Sri Lanka-

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Supervisor; Professor Hirokazu Yamamoto

Key words: Forest plantations; Height – DBH curve; Taper curve;Teak products

## I. Introduction

The natural forest cover of Sri Lanka has declined drastically, and the remaining natural forest cover provides valuable environmental services. Forest plantations play a significant role as an alternative for natural forests to cater the timber demand. Government plantations are mainly comprised of *Tectona grandis*, *Eucalyptus spp, Pinus caribaea,* and *Swietenia macrophylla* (Edirisinghe et al., 2012). However, all the plantations are not managed due to the reasons such as encroachment, elephant problems, fire hazards, etc. (Subasinghe, 2016). When considering teak (*Tectona grandis* L.f) plantation distribution, it shows uneven age – class pattern. (Ruwanpathirana, 2012). With those grounds, yield prediction is an essential activity in forest management for the production of commercially valuable outputs such as poles and sawn timber. Often, it is necessary to predict the future growth scenarios even before the establishment of plantations or at very early stages. The results of such estimations will be used for the planning purposes and necessary calculations such as expenses, profits, etc. (Subasinghe, 2016).

The aim of the study is to determine the marketable products according to industrial dimensions of teak timber of Sri Lanka. The product evaluation method can be used to overcome the uncertainty and the dynamism of real systems and to generate alternative solutions. Furthermore, research results can be applied to the whole teak grown regions with different disturbances of Sri Lanka to create a rotational plan for teak clear felling at the mature age.

## II. Study sites and methodology

Two steps were taken to ensure consistency between the product type dimensions that comprised the State Timber Corporation and the teak trees in forest plantations: (1) classification teak products by considering economic value and diameter range (Teak product dimensions); and (2) field work in three teak forest plantations of Sri Lanka (teak plantation sites). Teak logs, elephant poles, fence posts and round poles are the main products of teak timber. The teak log is the raw material for furniture production. By considering the economic value of those products the end diameter of the felled tree was decided as 10cm.

Sri Lanka has conventionally been categorized into three climatic zones, namely, dry, wet, and intermediate. Most of the teak plantations are established in dry (Average annual rainfall <1,750mm) and intermediate zones (Average annual rainfall -1,750-2,500mm). This research has been carried out on three teak plantation sites (the age > 40 years) where distributed throughout the Dry and Intermediate zones to represent the main climatic zones which teak is grown as government forest plantations (Figure.1). Standing tree measurements of 168 trees and felled tree measurements of 158 trees were taken on the three plantations defined above. Diameter at breast height (DBH) and tree height were measured of the standing trees. Out of felled trees, diameter outside the bark (DOB) was measured at breast height. DOB was also measured at intervals of 2m along the length of the stem until 10cm over bark diameter reaches. The relationship between tree height and DBH is considered to be the tree height curve (H-D). The Henricksen equation was applied to stimulate the tree height curve. Relative taper curve is the mathematical expression of the change in stem diameter as a function of stem height, which is based on tree conditions (Kozak et al., 1969). The models were created using measured field data (log diameter at each 2m distance) to differentiate total timber volume and commercial timber volume (log diameter >12.7cm) Tree height and diameter of each log part were converted to generate the relative height and relative diameter. Third order equation was applied according to Sato and co- workers (2008). Rotational plan was prepared using current average annual saw log demand which is 32,000$m^3$.

Table 1. Comparison of tree properties of each plantation site

| Properties | Site | | |
|---|---|---|---|
| | Site I | Site II | Site III |
| Age of the plantation (years) | 44 | 41 | 48 |
| No of trees/ha | 152 | 199 | 204 |
| Taper factor | 0.391 | 0.440 | 0.433 |
| Avg. tree height (m) | 17.52 [b] | 15.3 [b] | 19.7 [a] |
| Avg. DBH(cm) | 32.0 [c] | 31.8 [b] | 27.7 [a] |
| Avg. tree height at 1st branching point (m) | 6.3 [b] | 6.1 [b] | 11.2 [a] |
| Avg. total timber volume/tree ($m^3$) | 0.4996 [a] | 0.4856 [a] | 0.4485 [a] |
| Avg. commercial timber volume/tree ($m^3$) | 0.2534 [b] | 0.2525 [b] | 0.3006 [a] |
| Percentage of commercial log volume/ tree | 51% | 52% | 67% |

Site I and II properties based on site III measured by significance level, [a,b,c] significant at $p$=0.05

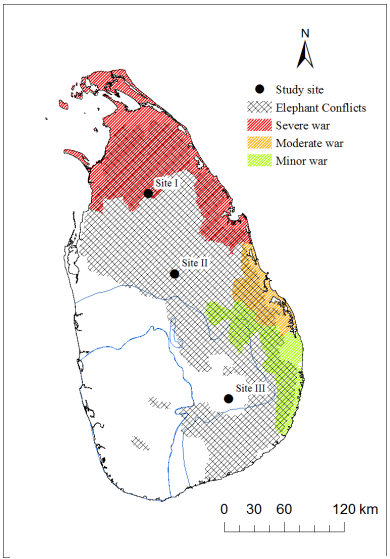


Figure 1. External disturbances and study locations

## III. Ressult and discussion

Table 1. represents the statistical results of the three sites. Commercial log production per tree of the site III shows the highest (0.3006$m^3$/tree) when compared to other sites. Commercial productivity which is 67% out of total timber volume also comes from the site III. So, it is evident that the site III has the most basic commercial parameters on other two sites. It has the highest average tree height, taper factor, and tree density. Higher productivity can cause climatic factors (e.g. rainfall and average dry period of the year) and soil type of the site III. The tree density of the site III mainly affected by favorable climatic conditions. On the other hand, management practices such as pruning and thinning can be affected by tree qualities of site III. It is evident that most of the management practices have been missed due to external disturbances (civil war and wild elephant conflict). Figure 1 represents the locations of sites and external disturbances occurrence areas.

Table 2. Remaining growing stock (log volume-$m^3$) after supplying 32,000$m^3$logs/year

| Area (ha) | Age (years) | Log volume ($m^3$) | 2018 | 2019 | 2020 | 2021 | … | 2057 | 2058 | 2059 |
|---|---|---|---|---|---|---|---|---|---|---|
| 104.5 | 65 | 5,595 | | | | | … | | | |
| 431.2 | 60 | 20,830 | | | | | … | | | |
| 2097.2 | 55 | 103,982 | 98,407 | 102,601 | 74,796 | 46,990 | … | | | |
| 7649.5 | 50 | 367,090 | 367,090 | 382,389 | 397,688 | 412,987 | … | | | |
| … | … | … | … | … | … | … | … | … | … | … |
| 454.6 | 25 | 22,112 | 22,112 | 23,021 | 23,931 | 24,840 | … | 57,571 | 58,480 | 59,389 |
| 726.5 | 20 | 36,720 | 36,720 | 38,173 | 39,626 | 41,079 | … | 93,387 | 94,840 | 96,293 |
| 1025.5 | 15 | 52,618 | 52,618 | 54,669 | 56,720 | 58,771 | … | 132,607 | 134,658 | 136,709 |
| 2016.1 | 10 | 94,548 | 94,548 | 98,580 | 102,612 | 106,644 | … | 251,804 | 255,836 | 259,868 |
| 715.6 | 5 | 32,475 | 32,475 | 33,907 | 35,338 | 36,769 | … | 88,292 | 89,723 | 91,155 |
| | Total | **1,150,310** | **1,118,310** | **1,165,511** | **1,180,712** | **1,195,912** | | **1,493,431** | **1,489,138** | **1,484,846** |

Assumptions – annual growth rate of teak plantations = 2$m^3$/ha (Pandey and Brown, 2000)

According to the developed rotational plan (Table 2), availability of mature teak planations (age ≥40 years) is likely to be sufficient to fulfill the annual demand of 32,000$m^3$. The demand assumption is based on without considering fluctuations of demand factor for teak logs along with time. The rotational plan can be sustained only with the continuation of re-planting activities after clear cutting and handling with proper management practices.

References


- Sato, J., Yamamoto, H. & Tatsumi, T. (2007): Study on Repairing Material for Wooden Cultural Buildings: A Case Study of Natural Japanese Cypress Forest in Kiso area

# 異なる条件下での木材生産に関する比較研究
## -スリランカにおけるチーク人工林の評価-

2017 年 9 月　生物圏情報学分野 47-156784 WIJENAYAKE Pavithra
指導教員　教授　山本　博一

キーワード: 人工林、樹高曲線、幹曲線、チーク林産物

### I.　はじめに

スリランカの天然林の割合は急激に減少しつつあり、残された天然林から貴重な生態系サービスが提供されている。人工林は天然林に代わり木材需要に応えるという貴重な役割を演じている。国有人工林は主にチーク、ユーカリ、マツ、マホガニーからなるが、盗伐や象による被害、火災などによりすべての人工林がきちんと管理されているわけではない。チーク造林地について考えると、これらの齢級配置は必ずしも適正ではない。これらのことから、森林管理のためには林産物の生産予測が重要である。人工林が成林する前の段階で将来の成長を予測することが必要となる。このような予測を元に計画が樹立され、費用や収益を見込むことができる。本研究ではスリランカのチーク造林地のおける林産物の生産予測を行う。予測にあたり現場の不確実性や流動性を克服して選択肢を一般化しておかなければならない。さらに、研究結果はスリランカでチークが生育するあらゆる地域に適用され、皆伐の長期計画にも応用されることが求められる。

### II.　研究対象地と研究手法

(1)チーク林産物を経済的価値と直径階によりクラス分けし、(2)家具材や防護壁の柱の材料を生産するチーク造林地において、伐採された木材の直径を 10cm の細さまで測定する。スリランカでは降水量によって、乾(年降水量 1750mm 以下),中(1750-2500mm),湿 に地域区分がなされており、多くのチーク造林地は乾と中に所在する。本研究では 40 年生以上で乾と中に生育する代表的な 3 箇所の造林地において、168 本の胸高直径と樹高を測定し、伐採木 158 本の皮付き直径を2m間隔で測定することによって、それぞれの造林地における樹高曲線と相対幹曲線を得た。相対幹曲線式は数学的に幹の形状を表現し、総材積や利用材積(末口径 12.7cm 以上)を決定するものである。各部位の上部直径は相対高と相対径を介することにより、三次式より計算される。持続可能な林産物供給のために年間 32,000 $m^3$の木材需要に対応するための伐採計画についても検討を行う。

### Ⅲ.　結果および考察

表－1は 3 つの試験地における林産物生産を比較したものである。SiteⅢは利用材積率が 67%あり、他の2つのサイトと比べて生産性が高い。これは平均樹高が高く、幹形が優れ、樹木密度が高いことによる。立木密度が高いのは気候条件と土壌条件にも起因する。他方、枝打ちや間伐などの管理が材質にも影響を与えている。図-1は内線や象による攪乱などの外部要因が森林管理に影響していることを物語っている。

表－1　各造林地における樹木特性の比較

| 特性 | Site | | |
|---|---|---|---|
| | Site I | Site II | Site III |
| 林齢(年) | 44 | 41 | 48 |
| Ha　あたり立木本数 | 152 | 199 | 204 |
| 正係数（相対幹材積） | 0.391 | 0.440 | 0.433 |
| 林分平均樹高(m) | 17.52 [b] | 15.3 [b] | 19.7 [a] |
| 林分平均胸高直径(cm) | 32.0 [c] | 31.8 [b] | 27.7 [a] |
| 林分平均力枝高 (m) | 6.3 [b] | 6.1 [b] | 11.2 [a] |
| 林分平均幹材積 ($m^3$) | 0.4996 [a] | 0.4856 [a] | 0.4485 [a] |
| 林分平均利用材積($m^3$) | 0.2534 [b] | 0.2525 [b] | 0.3006 [a] |
| 利　用　材　積　率 | 51% | 52% | 67% |

[a,b,c] significant at $p$=0.05

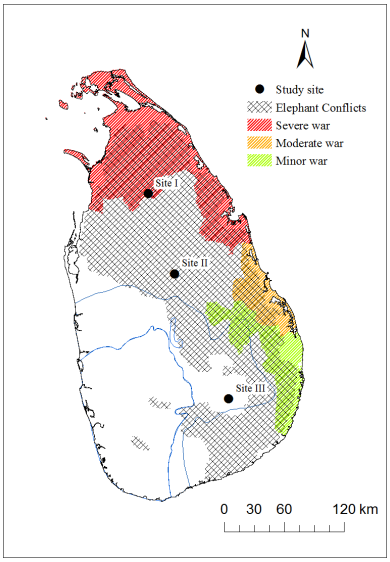


図-1　外部攪乱要因と試験地位置図

表－2　年間 32,000$m^3$を供給した後のチーク材蓄積量 (log volume-$m^3$)

| 面積(ha) | 林齢(年) | 蓄積量 ($m^3$) | 2018 | 2019 | 2020 | 2021 | … | 2057 | 2058 | 2059 |
|---|---|---|---|---|---|---|---|---|---|---|
| 104.5 | 65 | 5,595 | | | | | … | | | |
| 431.2 | 60 | 20,830 | | | | | … | | | |
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Assumptions – annual growth rate of teak plantations = 2$m^3$/ha (Pandey and Brown, 2000)

チーク造林地の伐採計画を検討したところ(表－2)、40 年生以上の成熟した人工林から年間 32,000$m^3$ の需要に対応できることが明らかとなった。この推定は現在の需要が継続して、皆伐後の再造林と適切な管理が継続する前提にしたものである。

引用文献

Sato, J., Yamamoto, H. & Tatsumi, T. (2007): Study on Repairing Material for Wooden Cultural Buildings: A Case Study of Natural Japanese Cypress Forest in Kiso area