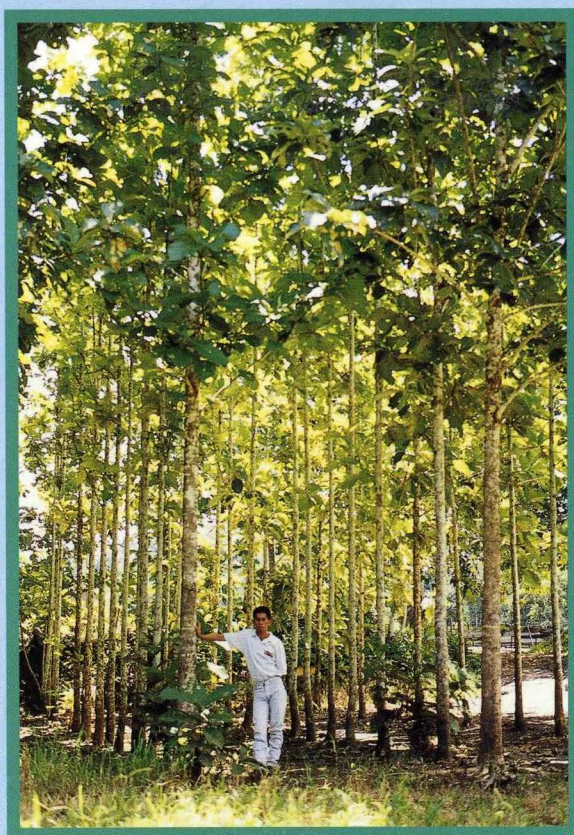


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## GROWTH PERFORMANCE OF TEAK

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### ABSTRACT

Teak is one of the most important commercial tree species of the Tropics. The growth performance of teak in several regions of the world was studied and compared to the growth rates obtained in several trial plots in Sabah. Formulae describing the relationships among age, height, volume,

total timber yield and yield of stem wood in other world regions were used to estimate the yield of the Sabah's plots. According to this study, teak appears to have a remarkable interest for the planting programmes of the region.

### INTRODUCTION

Teak (*Tectona grandis* L.f., Verbanaceae family) is one of the most economically important timber species of the Tropics. Its reputation comes from the matchless combination of qualities of its wood, such as termite, fungus and weather resistance, lightness, strength, attractiveness and workability (Kadambi, 1972). Teak grows naturally in the deciduous forests of India, Myanmar, Laos, Thailand and Indonesia (Java and Muna; Pratiwi & Lust, 1994). For its value, it has been introduced and planted worldwide since the beginning of the 19<sup>th</sup> century, especially in Asia, Africa and Central America. The largest plantation activities of Asia are concentrated in Indonesia (1,500,000 ha), India (1,000,000 ha), Myanmar (230,000 ha), Thailand (160,000 ha), Bangladesh (80,000 ha), Philippines (15,000 ha) and Sri Lanka (70,000 ha). In Africa and Central America there are about 160,000 and 75,000 ha planted with teak respectively (source: Perum Perhutani, 1995; Behagel, pers. comm.; CIRAD,

1997). In 1993, the countries with the largest teak wood production were Myanmar with around 1,000,000 m<sup>3</sup>/year, Indonesia with 750,000 m<sup>3</sup>/year and India with 510,000 m<sup>3</sup>/year (Dupuy & Verhaegen, 1993).

In Malaysia, teak has been less developed compared to neighbouring countries. In Peninsular Malaysia, only several hundred hectares have been planted so far, especially in the North (State of Perlis; Tang & Kadir Jaafar, 1979). In Sabah, the earliest planting dates back to 1926, when a Dutch company planted few hectares in the district of Kudat; several other trial plots have been planted in the period 1962-1977 by the Forestry Research Centre (FRC) of the Forest Department of Sabah (Anuar Mohamad & Jupuri Titin, date unknown). Recently, several Sabah's plantations have placed their interest on teak; however, their planting is young and data are not available.

Due to the high value of teak for the economy of tropical timber plantations, it is interesting to

describe the growth and productivity of teak in industrial plantations. In this paper, we first develop a list of ecological requirements of the species; secondly, the growth of teak in planta-

tions is analysed on the basis of the data available for some countries, and compared with the data available for the trial plots established by FRC in Sabah.

## GENERALITIES-ECOLOGICAL REQUIREMENTS

Teak can grow on a large variety of soils. However it develops best on well-drained and fertile soils, especially on volcanic substrata such as igneous and metamorphic soils or on alluvial soils of various origins. The optimum soil pH is between 6.5 and 7.5, and the availability of calcium in the soil is an important factor the deficiency of which makes the teak growth stunted (Kaosa-ard, 1981).

Optimum rainfall for teak ranges between 1250 and 3750 mm / year; however, for the production of good quality timber, the species requires a dry season of at least four months with less than 60 mm precipitation (Kaosa-ard, 1981). Teak can stand to daily temperature ranging between 2 and 46°C, but grows best when the minimum monthly temperature is above 13°C and the maximum monthly temperature below 40°C. The optimum mean annual temperature ranges between 22 and 27°C.

In natural conditions and over most of its range, teak grows mixed to other tree species; however on dry and rocky sites it tends to develop pure stands. When the site and climatic conditions are not too far from the teak natural requirements, teak can regenerate easily under its own canopy. Natural regeneration is found for

example in Sabah in the Bandau trial plot near Kota Marudu.

Teak is a pronounced light-demander, with a low tolerance of shade and requiring abundant overhead light; however, in the hottest sites and during natural regeneration seedlings and saplings benefit from some protection from the sun. It is very sensitive to root competition, and it is essential to separate neighbouring stands of teak of different ages by isolating ditches. Teak seedlings are also very sensitive to suppression by weeds.

Rotation of teak plantations is based on financial considerations. The present rotation ages in India and Indonesia varies between 40 and 80 years; however, due to the economic pressure, there is a tendency to shorten teak rotation below 40 years (Pratiwi & Lust, 1994).

A thinning regime must be defined for each plantation in order to obtain a regular growth and production of timber of suitable size. In general, for a rotation ranging from 30 to 60 years, 3 to 6 thinnings are needed according to the site quality and to the objectives of the plantation in relation to dimension, rotation length and productivity criteria (Dupuy & Verhaegen, 1993).

## GROWTH-MATERIAL AND METHODS

Teak growth has been studied scientifically in only a few countries. Reliable data referring to plantations are scarce or unavailable for three among the largest planting countries, Myanmar, Thailand and Indonesia. By contrast, data are available for India (Kadambi, 1972), for some African countries as Ivory Coast (Maitre, 1983)

and Nigeria (Akindele, 1989), and for Central America (Keogh, 1982 & 1990).

In the African region, the estimations for Nigeria and Ivory Coast were very similar; in our study we included the data from Ivory Coast alone, for which the data were more complete. Maitre (1983) built yield tables for Ivory Coast

on the basis of 33 trial plots established in plantations and with ages comprised between 8 and 51 years. The plots have been regularly thinned 3 to 7 times along the years according to their basal area. The volume measurements included both stem wood and small size wood thinnings with bark, provided the log was superior to a minimum diameter of 22 cm. The measured height referred to the best 100 trees per hectare.

Kadambi (1972) found the yield table for the India-Burma region (Laurie & Sant Ram, 1940, citation) inconsistent because of poor maintenance of most of the trial plots. He recovered the data for the properly maintained trials and completed the sample with additional new 20 plots in Madhya Pradesh and Bombay region. His sampling was based on 617 measurements on 300 plots in India. His definition of volume is less clear than the one in Maitre (1983), as he did not specify the size limits of his different classes: stem wood, timberland, stem small size wood. We used for our calculations the stem wood only, hoping in this way to exclude the volume of the small branches that are collected and used in India as firewood. For information, in the Kadambi (1972) tables, the small size wood made up between 15% and 25% of the total yield of the mature plots.

Keogh (1982 and 1990) presented a summary of the performance of teak in the Caribbean/Central America region including Colombia and Venezuela. He analysed the classification of the plantation sites in terms of growth, and produced several formulae connecting age, height and volume in the different site quality classes. His definition of volume was again different, referring to the portion of the stem without bark and above 10 cm of diameter; the mean height was defined there again as the height of the 100 best trees per hectare. By studying ten teak stands of the Central America region, Keogh (1982) established the following formulae:

$$\log h = \log IS + b \left( \frac{1}{x} - \frac{1}{xk} \right) \quad (1)$$

and

$$V = 3.394 + 0.344h^2 - 62.78 \quad (2)$$

where  $h$  = dominant height (m);  $IS$  = site index;  $x$  = age (years);  $xk$  = age of reference (years);  $b$  = regression coefficient of the equation  $\log h = a + b(x)$ , valid for the Central America region;  $V$  = volume ( $m^3$ ).

Other interesting tariff formula were established by Maitre (1983) for the Ivory Coast teak; the first describes the relationships between total volume, circumference and height:

$$V = 0.03077C^2h + 0.01827C\sqrt{h} - 0.0186 \quad (3)$$

Where  $C$  = circumference at 1.30 m, and  $h$  = height of the 100 best trees per hectare. A second set of formulae allows calculating the portion of stem wood from the total volume of the tree and its height, as follows:

$$HF = 0.309H + 1.5 \quad (4)$$

and

$$VF = 1.645V * \frac{HF}{H} + 0.067 \quad (5)$$

where  $HF$  is the height of the exploitable stem,  $VF$  is the exploitable stem wood,  $H$  is the total height and  $V$  is the total volume. We used these formulae for estimating the growth and the site quality of the Sabah trials and to make a comparison with the teak growth in India, Central America and Ivory Coast.

**Table1. Characteristics of the teak trial plots established by the Forestry Research Centre in Sabah and used for the present study.**

Name	Location	Year of planting	Spacing (m)	Area in hectares	Number of plants/ha
Sibuga	Sandakan	1963	3.05x3.05	0.14	200
Gum Gum	Sandakan	1977	3.00x3.00	0.60	505
Bandau	K. Marudu	1926 – 1945	3.00x3.00	1.5	442
Rancangan	Tawau	1962	3.05x3.05	0.09	478
Jalan Apas	Tawau	1967	1.83x1.83	0.05	2240

Characteristics of the teak stands in Sabah are reported in Table 1. In these plots, the height was measured from the base of the tree up to the top tip, and the average height calculated on all the trees. The plots are irregular in form and the actual present number of trees per hectare is known with only low precision, mainly due to unrecorded mortality. The Bandau's plot was

established in 1926 but the biggest trees were probably harvested during the World War II (1940-1945). Following this putative harvesting, the natural regeneration has taken place, so that today it is difficult to tell the exact age of the trees. In order to be conservative, we considered the stand as even-aged and established in 1926.

## GROWTH-RESULTS

The teak plots established in the Indian region could be subdivided in four classes of height growth, ranked according to the site quality (Fig. 1). At an age of 50 years, the height of Indian teak trees ranged between 12 and 37 m, translating the high environmental variability of that country. Due to the recent introduction of teak in Central America, data for that region were sufficient only for statistics up to 30 years. The height of the teak in the American region was included between 12 and 33 m. The range of variation was close to the range observed in India, however the average growth was better, the highest tree at age 30 in India being only 30 m of height (Figure 1).

In Ivory Coast, the height at an age of 50 years was comprised between 26 and 40 m, a better performance compared to the two regions of

above (Fig. 1). Teak seems to grow faster in Ivory Coast, despite of the fact that three very diverse ecological regions were included in the study: wet dense forest, dry lowland forest and savannah. The difference was probably due to the fact that all the Ivory Coast's teaks were planted in this century and regularly thinned and maintained, in contrast to the Indian study which refers, among others, to some old plantations of the 19<sup>th</sup> century that went through a number of disturbances.

The Sabah's populations (Fig. 2) ranked in between site quality classes I and III according to the world's region. The Rancangan's plot performed very well in the first ten years, but later the growth slowed down. The same tendency was

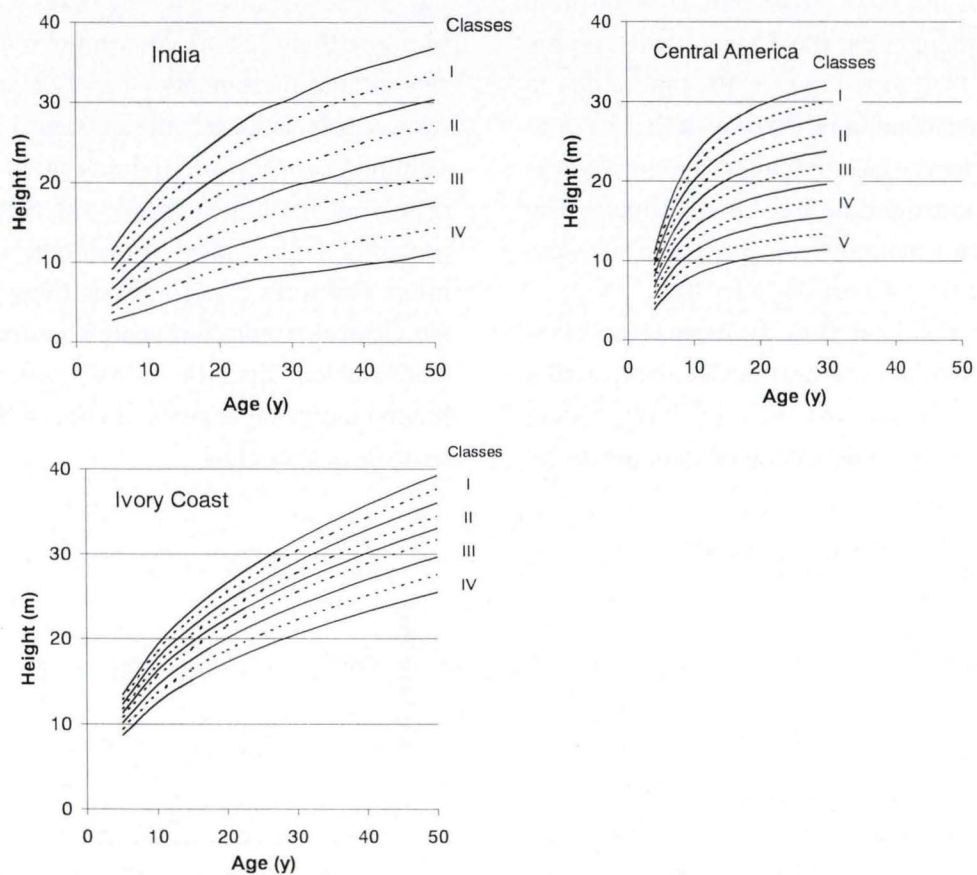


Fig1. Height / age relationships in several world regions, according to the site quality.  
Note: Classes I to IV or V refer to different site qualities, classe I covering the most fertile soils and classe IV or V the sites with the lowest fertility.

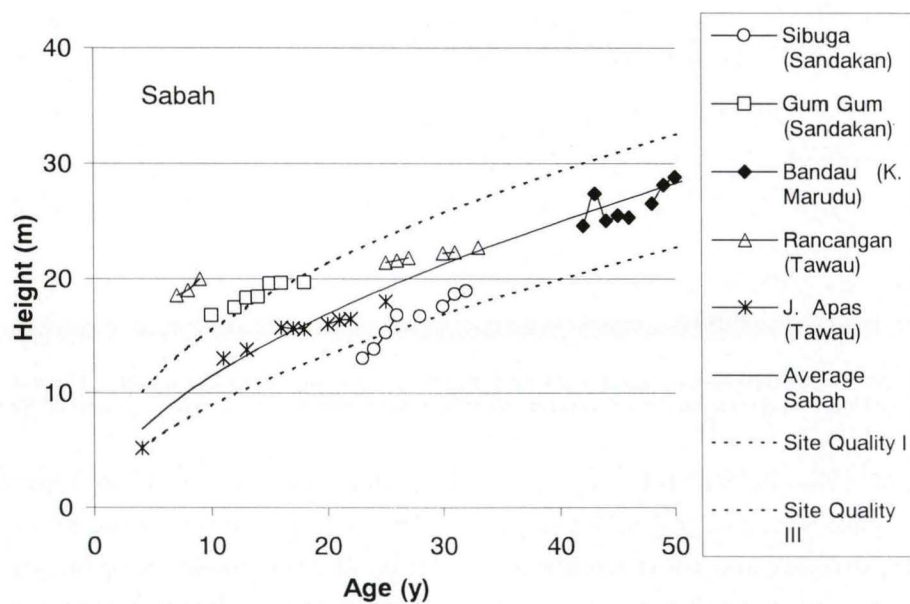


Fig2. Height / age relationships in Sabah. Formula (1) in the text has been used to adjust the growth curves to the raw data.

observed for the Jalan Apas' plot. Both of these plots are situated near the Tawau town, and the question if their slowing growth is more due to environmental conditions intrinsic of the site or to external factors as lack of maintenance or competition with surrounding trees is legitimate. The older Bandau's plot ranked in the Indian site class II and in the Ivory Coast site class III.

In terms of volume (Fig. 3), Ivory Coast plantations were again the best performers, with a production at 50 years of around 600 m<sup>3</sup> of stem timber (note that the definition of stem timber by

this author included only the stems with a diameter more than 22 cm). Maximum mean and current annual increments were 17.6 and 18.7 m<sup>3</sup>, respectively, at ages between 6 and 10 years. The volume growth of the Indian region was lower, reflecting again the variable site conditions and probably the low level of maintenance and thinning that were carried out on these plots. Data for Central America revealed a volume growth comparable to the Ivory Coast's one, with a maximum volume at 30 years of about 400 m<sup>3</sup> for the best site quality class.

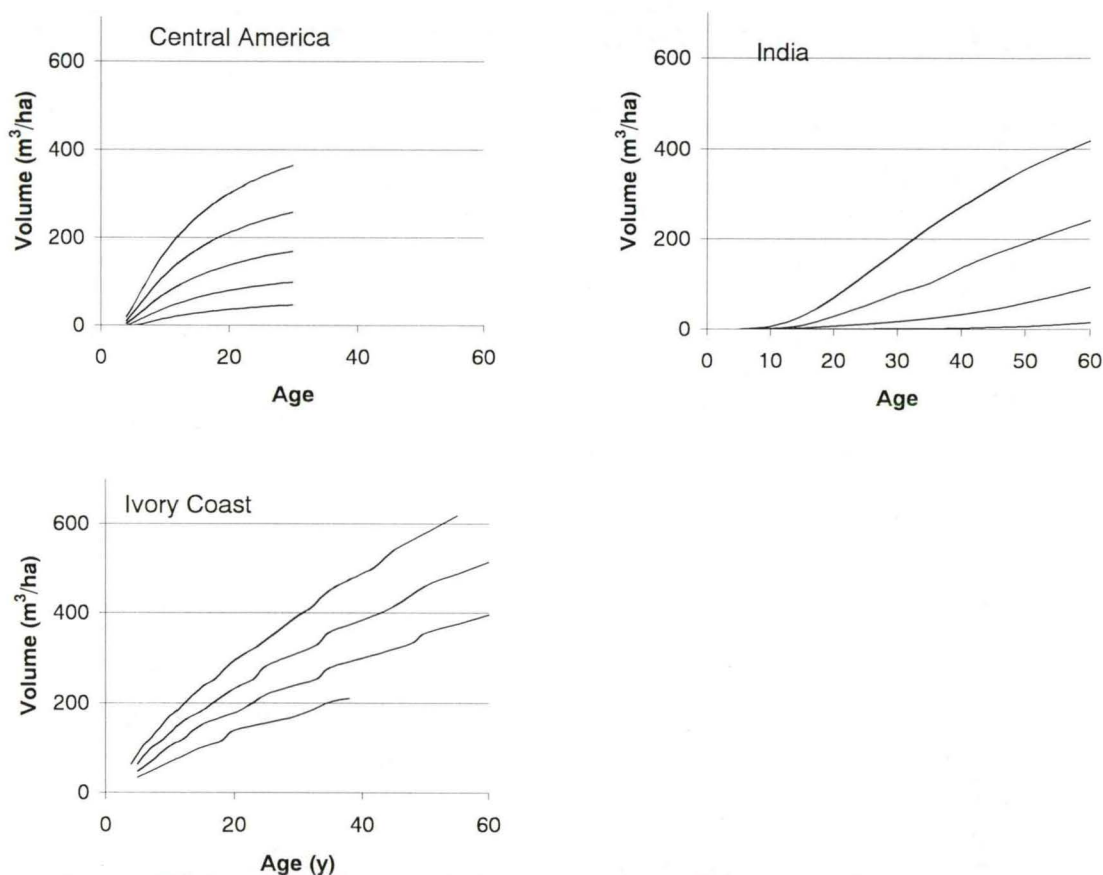
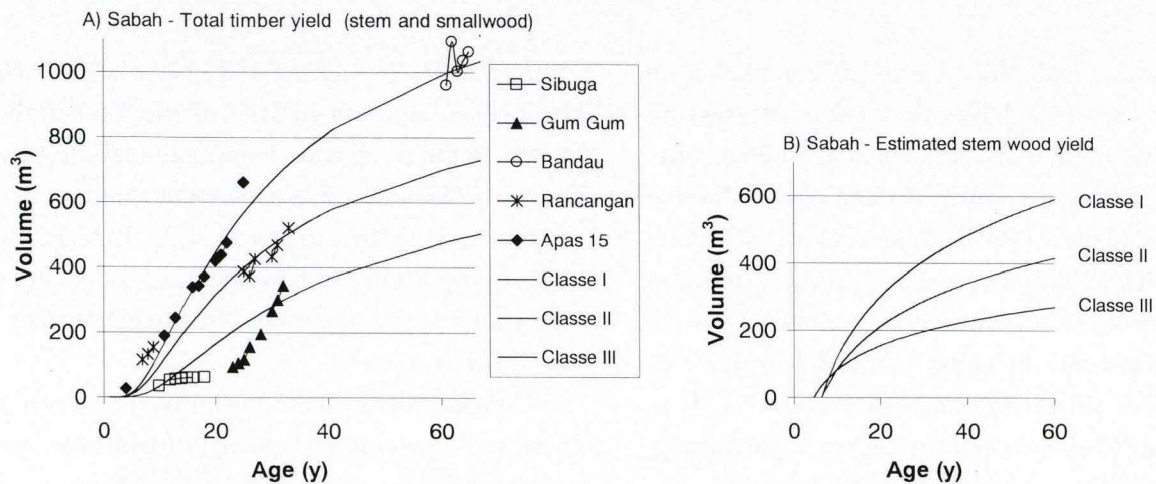


Fig3. Volume / age relationships in several world regions, according to the site quality. The data for India, Ivory Coast and Central America referred only to stem wood of a certain commercial diameter.

The total yield of the Sabah plots belonging to the first quality class exceed 1,000 m<sup>3</sup>/ha (Fig. 4A). However, this estimation (formula 3) included both stem wood, small size wood and branches. In order to compare the Sabah's teak performance with the yield obtained for the other countries studied, we estimated the stem wood

production on the basis of the formulae (4) and (5). The figure of the stem wood production in Sabah (Fig. 4B) is comparable to the yield obtained in Ivory Coast, with a maximum stem wood mean and current annual increment of 14.8 and 17.2 m<sup>3</sup>, respectively (Table 2).



**Fig4.** Volume / age relationships in several world regions, according to the site quality. The data for Sabah in the graph above (A) refer to the total volume of the trees. In order to homogenise the data with the the data from India, Ivory Coast and Central America (which referred only to stem wood of a certain commercial diameter), we estimated the stem wood yield for the Sabah's plot, by using a conversion formula published by Maitre (1983). The estimated stem wood yield is represented in the graph on the left (B).

**Table2.** Estimated stem wood yield ( $\text{m}^3$ ), mean ( $\text{m}^3/\text{ha}/\text{y}$ ) and current annual increments ( $\text{m}^3/\text{ha}$ ) for three site qualities in Sabah.

Site quality I				Site quality II			Site quality III		
Age	Volume	MAI	CAI	Volume	MAI	CAI	Volume	MAI	CAI
11	116	10.6	17.2	82	7.5	12.1	31	2.8	5.1
16	214	13.4	16.8	150	9.4	11.8	71	4.5	6.9
21	311	14.8	14.1	219	10.4	10.0	116	5.6	6.8
26	378	14.6	10.3	267	10.3	7.3	152	5.9	5.6
31	432	13.9	10.2	304	9.8	7.2	183	5.9	5.6
65	620	9.5	2.4	436	6.7	1.7	300	4.6	1.6
71	626	8.8	0.8	441	6.2	0.6	307	4.3	0.8

In interpreting our estimations, one should take in account the following facts: 1) the Sabah's plots were not regularly maintained nor thinned, and their total growth has certainly been reduced by overcrowding and mortality; 2) the estimation of Maitre (1983) used for the volume calculation the best 100 trees per hectare, whereas, lacking this measurements, we used the average height of all trees. This figure is obviously lower, resulting in an underestimation of the total yield; 3)

low precision in the height and stand density (survival) measurements along the years brought some approximation to the data, as well as the small sample size and the small number of plots. Due to point 3, we would like to suggest to consider the Sabah's yield data with some scepticism. In general however, points 1 and 2 above are supposed to make our estimations rather conservative.

## CONCLUSION

The few teak plots that have been planted in Sabah on a trial basis showed an interesting growth pattern, both for height and volume, ranking together with some of the most productive regions of the world. In other regions as Nigeria (Akindele, 1989), even higher productivity rates of 25 m<sup>3</sup>/ha/year were reported for intensive silviculture systems including regular weeding, maintenance, thinnings and fertilisations. It is tempting to assume that the growth of the Sabah's plots could have been better, should suitable silviculture treatments been applied. However it must be kept in mind that the volume of merchantable timber and its price depends much on a number of factors that are poorly controlled at the moment in Sabah, such as silviculture, pests and diseases, quality and form of the trees, etc. According to some authors, the wastage due to

fluting, early branching and insect holes in the timber can amount to 50% of the total timber yield. In the same way, in our calculation it was not possible to take into account the proportion of sapwood compared to heartwood. In teak, sapwood proportion can be important, especially at the young age, accounting often to as much as 4 to 10 cm in diameter.

Considerations on the economy of teak plantation, and relationships between investments, benefits and risks are beyond the scope of this paper. We can however affirm that teak is without doubt a potential species for high value plantation establishment in Sabah. In order to support the species with appropriate techniques, and management and marketing practices, we would like to suggest that more research should be planned in the future for this species.

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