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# Teaknet Bulletin

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TEAKNET is celebrating its 25<sup>th</sup> Anniversary this year

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We wish a very  
Happy & Prosperous New Year  
to all our Readers !

## Editorial

Greetings for the Year 2020!!

This year marks a significant milestone for TEAKNET, entering the 25<sup>th</sup> year in 2020 with new hopes and aspirations. Looking back at the years, we have been successful in establishing a global network of teak cultivators, traders, private enterprises, plantation managers, researchers, students and others. Through these years, TEAKNET has been successful in disseminating relevant information on teak and providing custom made solutions to different stakeholders. The success of this network is the result of your valuable contributions and we seek your continued support in all our future endeavours.

In this issue, we bring you an article on 'Yield table of teak plantations in Benin' and updates of the forthcoming 4<sup>th</sup> World Teak Conference in Ghana. The World Teak Conference with the theme 'Global Teak Market: Challenges and Opportunities for Emerging Markets and Developing Economies' scheduled during 24 – 27 August 2020 will address the most crucial issues of the global teak sector. The details of the forthcoming National Teak Forum on sustainable value chains for sustainable local development in LAO PDR during 18-20 February 2020 is also included in this issue, In addition, market price of plantation teak imported to India and our regular column on teak prices are provided for the benefit of our readers.

We invite your feedback on issues related to teak and enrich us with articles/news items of interest/research papers etc. of non-technical nature for inclusion in the Bulletin.

S.Sandeep  
TEAKNET Coordinator



# Yield Table of Teak (*Tectona grandis* L. f.) Plantations in Benin (West-Africa)

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## Abstract

Benin has a long tradition of cultivating and managing teak plantations. Silvicultural treatments in thinning and harvesting the plantations were however based on the yield tables elaborated for teak plantations in Côte-d'Ivoire and elsewhere. In order to fill the information gap on the silviculture of teak plantations, we undertook to elaborate this yield table. With that framework, data were collected for over 10 years from permanent plots. They were complemented with data from stem analysis and from temporary plots. An overall 1,026 combinations of top heights and corresponding ages were used to fit the basic yield table model. From the main results, the yield table elaborated is composed of 5 fertility classes. Their productivity indices were respectively 34, 28, 22, 16 and 10 meters as top heights at the reference age of 25 years. The first three classes are suitable for growing teak timber of good quality during a rotation period of 40 years; the fourth class is more convenient for small logs production whereas the last class is more suitable for growing alternative native species. This yield table could be a useful tool to guide the silviculture of teak plantations throughout the tropics. The comparison of the yield table with that of the sub region showed that teak plantations in Benin are more productive at early stages than those of Côte-d'Ivoire although the latter have more productivity with age. Teak plantations of Benin are found to be more productive than those reported in the provisional yield tables developed for teak plantations in Ghana.

**Keywords:** *Tectona grandis*, teak plantations, yield table, fertility classes, productivity indices, Benin

## Introduction

Teak (*Tectona grandis* L. f.) is one of the most planted forest species in the world. It is native to South-East Asia (Pandey and Brown, 2000; Midgley *et al.*, 2015). Its area in natural forests was estimated at about 29 million ha (Kollert and Cherubini, 2012) whereas in plantations, the area covered worldwide by the species was estimated at 4.35 to 6.89 million ha (Bhat and Ma, 2004; FAO, 2009; Midgley *et al.*, 2015). The wood quality of the species and its resistance to wildfires favoured its introduction and expansion in several tropical countries (Bhat and Ma, 2004). Teak was introduced in Benin around 1916 by the Catholic mission (Behaghel, 1999). Since 1949, it has been intensively planted and its area is now about 40,000 ha of which 50% are private plantations.

In order to plan silvicultural interventions, forest managers in Benin often refer to the yield table of teak plantations of Côte-d'Ivoire (Dupuy *et al.*, 1999). Yield table is a table or figure describing, in time and forest space, the probable evolution of even-aged forest stands; this evolution is ordered with respect to species and the levels of fertility of forest sites (Décourt, 1964; Pardé and Bouchon, 1988). As such, the yield table is an important tool and silvicultural guidance (Décourt, 1964) for the sustainable management of forests.

A thorough inspection of the yield table of teak plantations in Côte-d'Ivoire (Dupuy *et al.*, 1999) however showed significant deviation in dynamics with respect to Benin's teak plantations (Ganglo *et al.*, 1999).

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The deviation is especially noted at the early and advanced ages of the plantations. The dynamics of Benin's teak plantations also differ from those of India (Seth, 1959) and Ghana (Nunifu and Murchison, 1999). A more suitable yield table, developed based on data collected in the teak plantations of Benin is therefore essential and the objective of this paper is to present the results of our study.

## Methods

### Study area

The main teak plantations managed by the "Office National du Bois" (ONAB) (Figure.1) and located between 6° 51'- 7° 04' of north latitude and 02°03' - 2°22' of east longitude and covers about 15,000 ha was selected for the study. The study area experiences a subequatorial climate. The average annual rainfall varies between 1,000 to 1,300 mm and the average daily temperature is 27.5° C.

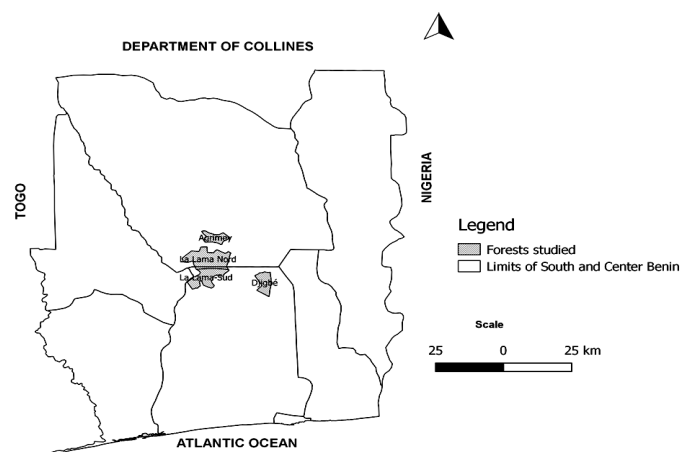


Figure 1: Position of the study area in Benin (a); Forests studied in Southern and Center Benin (b)

### Teak plantation assessments and data collection

From 2005 to 2014, ninety permanent plots of 1000 m<sup>2</sup> (25m x 40m) were set in place in the different forest sites of the plantations. Depending on the financial resources available, periodic inventories were undertaken in the permanent forest plots to collect data, either on yearly basis or at 2 to 3 year intervals. The data collected included diameter at breast height (1.30 m above ground level) and height of trees. In order to ensure statistical significance, more representative sampling of forests sites and ages of plantations were included and complemented the data from permanent plots as well as data from temporary plots and stem analysis (Somaru *et al.*, 2008; Ugulino *et al.*, 2014). A total of 62 teak trees were therefore targeted in the age gaps identified and felled for stem analysis.

## Statistical analysis

### Basic yield table model fitting

In the process of developing yield table, the model explaining the top heights (Hd) of plantations with respect to their ages [Hd = f(Age)] is identified as one of the most important and fundamental question to be addressed (Décourt, 1964; Dupuy *et al.*, 1999, Bermejo *et al.*, 2004; Vanclay, 2010). Indeed, the choice of soil fertility classes is based on that model and many stand parameters also depended on it. The following candidate functions explaining the relationships between top heights (Hd) and ages of plantations (Age) were fitted and evaluated:

$$Hd = k * Age^a * e^{b*Age} \quad (\text{Model 1, Dupuy } et al., 1999) \quad (1)$$

$$Hd = k * e^{a/Age} \quad (\text{Model 2, Schmacher (1939) cited by Vanclay, 2010}) \quad (2)$$

$$Hd = k * e^{a/(Age+1)} \quad (\text{Model 3, Laumans, 1992}) \quad (3)$$

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In these functions, the values of the coefficients a, b, and k were obtained from model fitting (Table 1). 1026 combination (Hd, Age) of data were used to fit the models. They were composed of 259 (25.24%) combines of data from permanent plots; 457 (44.55%) combines of data from stem analysis, and the rest 310 (30.21%) were obtained from temporary plots.

Table 1. Summary of the models fitted on top heights of teak plantations

Number of observations	Model functions	Value of coefficient (k)	Value of coefficient (a)	Value of coefficient (b)	Model expression	Residual standard error	Sum of Squares of residuals	Fitting Efficiency	R <sup>2</sup>	Akaike Information Criterion (AIC)
1026	$Hd = k * Age^a * e^{b*Age}$ (Model 1)	1.650	0.998	-0.01995	$Hd = 1.650 * Age^{0.998} * e^{-0.01995*Age}$	3.594	13213.78	0.7594	0.8215	5546.093
1026	$Hd = k * e^{a/Age}$ (Model 2)	32.116	-7.943	-	$Hd = 32.116 * e^{-7.943/Age}$	3.990	16302.4	0.7412	0.9424	5759.816
1026	$Hd = k * e^{a/(Age+1)b}$ (Model 3)	61.717	-5.422	0.535	$Hd = 61.717 * e^{-5.422/(Age+1).535}$	3.670	13778.13	0.7448	0.8077	5587.044

### Other functions fitting and calculation of parameters of the yield table

The other models fitted are summarized in Table 2.

The ratios  $\frac{Ge}{G}$  and  $\frac{Ve}{V}$  were calculated respectively as expression of the weight of basal area (Ge) and volume (Ve) removed during thinning, compared to the basal area (G) and volume (V) of the forest stand before thinning. Those ratios were calculated from inventory data on thinned plots and the tree volume (V) was calculated according to Ganglo *et al.* (2017). Data analyses was done using the statistical software R (R core Team, 2017). The non-linear models were fitted with the *n/s* function. The linear fitting was done with the *lm* function on the logarithmic transformed variables in the models (Fayolle *et al.*, 2013).

Table 2. Other models fitted in the framework of the yield table

Number of observations	Model functions	Value of coefficient (a)	Value of coefficient (b)	Value of coefficient (c)	Model expressions	Residual standard error	Fitting Efficiency	R <sup>2</sup>	Akaike Information Criterion (AIC)
1007	$Cg = a * Hd^b * N^c$	83.100	0.632	-0.342	$Cg = 83.100 * Hd^{0.632} * N^{-0.342}$	10.02	0.904	0.882	7594.766
1007	$Hg = a * Hd^b * N^c$	2.250	0.888	-0.093	$Hg = 2.250 * Hd^{0.888} * N^{-0.093}$	1.828	0.922	0.908	4119.596

**Note :** *Cg* (cm) is the circumference of the mean basal area tree;  
*N* is the density (stock) of forest plantations per ha  
*Hg* (m) is the height of the mean basal area tree.

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## Model evaluation

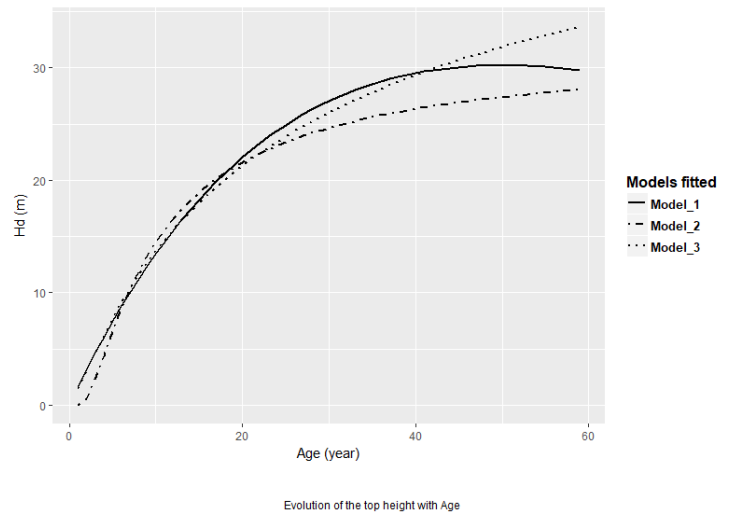
A total of 311 data were retained for model validation (benchmark test) (Vanclay, 2010). A paired samples t- test on the data was done to find out the differences between the predicted values of top heights and the corresponding observed values. The quality of the fitted models was also examined by taking into account the values of the coefficient of determination ( $R^2$ ) (Cailliez, 1980; Rondeux, 1999), the residual standard error (Fayolle *et al.*, 2013), the distribution of the residuals with respect to the predicted values and the variables explained (Vanclay and Skovsgaard, 1997). The Modelling Efficiency (ME) (Vanclay, 2010; Fayolle *et al.*, 2013) and, the Akaike Information Criterion (AIC) (Akaike, 1974; Symonds and Moussalli, 2011) were also taken into account (Cailliez, 1980; Rondeux, 1999; Vanclay and Skovsgaard, 1997; Fayolle *et al.*, 2013).

## Results

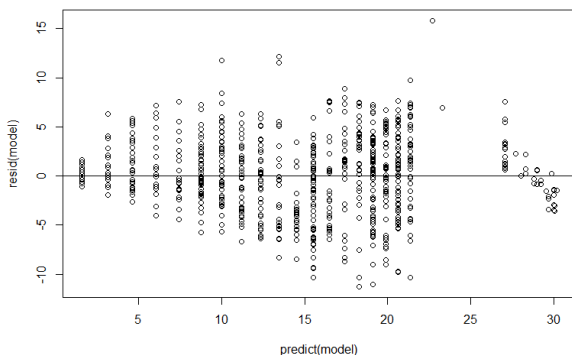
### Models explaining the top heights of plantations with respect to their ages

The models fitted are plotted in Figure 2 and summarized in Table 1. Figure 2 - shows that among the different models, model 2 is the best fitted plantations of lower productivity classes. This was observed especially in the oldest ( $\geq 40$  years) plantations. On the other hand, model 3 was found to be best fitted for plantations of higher productivity classes but overestimated the top heights of the oldest plantations ( $\geq 40$  years). It is noteworthy that the data used in the oldest plantations ( $\geq 40$  years) were collected in less productive plantations since the most productive ones (Lama forest) were less than 40 year-old at the time of data collections. Model 1 was found to have slightly an intermediate position between the two other models, especially in the oldest plantations.

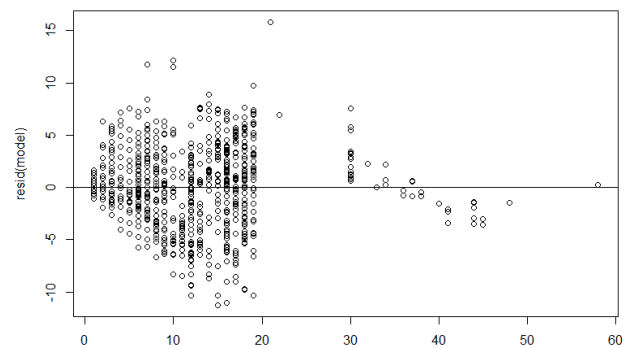
The residuals of the models fitted were plotted against plantation ages (Figure 1) and predicted top heights (Figure 2). From these figures, we deduced that - in comparison to the other two models, the residuals of **Model 1** (Fig. 1a and 2a ) were more balanced around the line ( $Y = 0$ ) in either cases.



**Figure 2 :** Models explaining the evolution of the top heights of plantations according to their ages



**Figure 2a:** Model 1 : Distribution of residuals against the predicted top heights



**Figure 1 a:** Model 1 : Distribution of residuals against plantations ages

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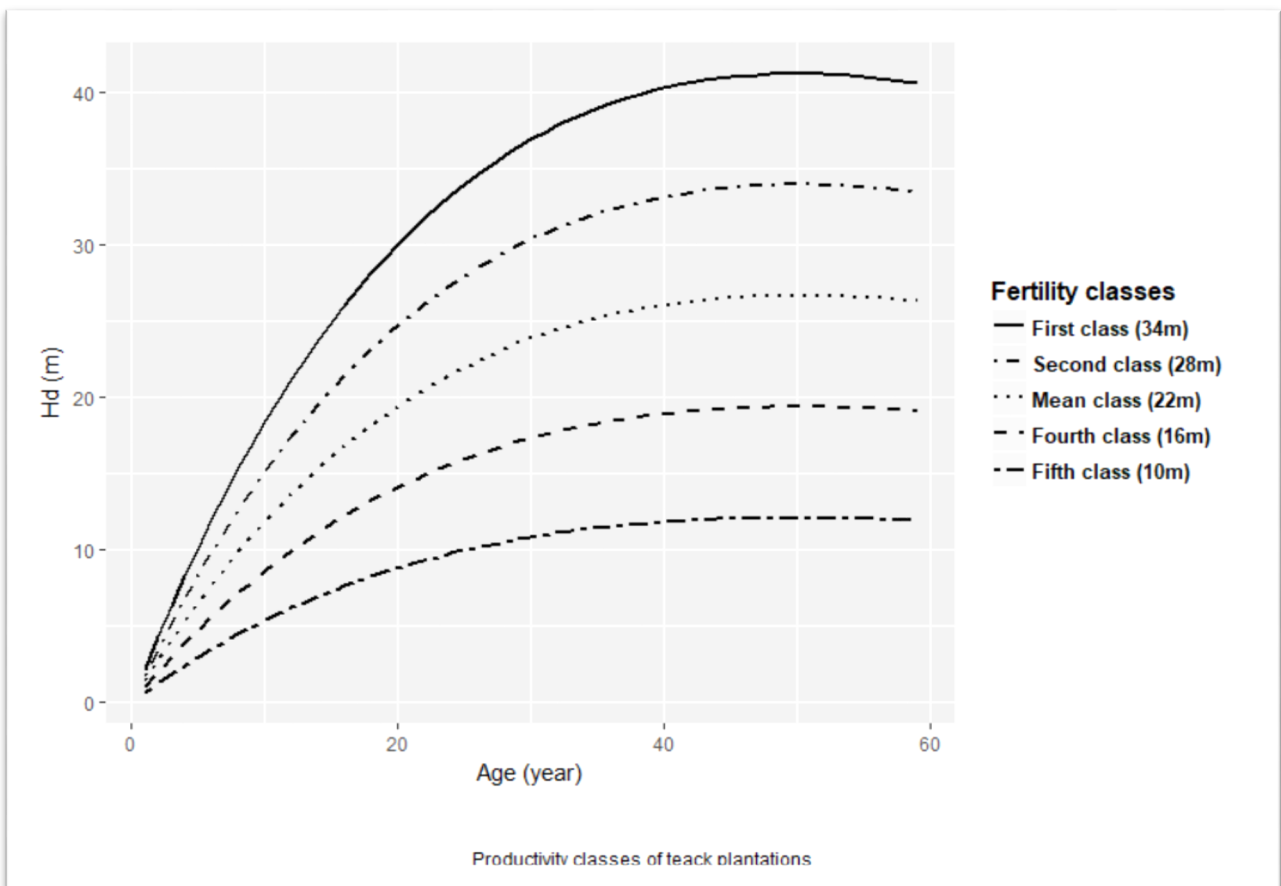
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From the results of the paired *t* - test run on the 311 data retained for model validation, there was no significant difference between the mean value of **Model 1**'s prediction and the mean value of the top height (Hd) observed (p-value = 0.6915) whereas the differences between the other models' predictions and the mean values of Hd observed were significantly different (p-value < 2.2e-16 for **Model 2** and p-value = 1.875e-11 for **Model 3**). We deduced from Table 1 that even if **Model 2** has the highest coefficient of determination (R<sup>2</sup>), **Model 1** is the best function with respects to the remaining quality appreciation parameters.

In conclusion, **Model 1** was found to be the most suited to predict the top heights of plantations with respect to their ages. Its expression is:

$$Hd = 1.650 * Age^{0.998} * e^{-0.01995 * Age} \quad (4)$$

In order to cover maximum extent of the scatter plot, we selected five productivity classes for teak plantations in Benin (Figure 3).



**Figure 3:** Fertility curves retained for teak plantations in Benin

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### Choice of the reference age of plantations

The reference age ( $A_r$ ) of plantations is the age at which productivity is assessed in forest sites in order to define and compare plantation productivity classes and soil fertility indices (Pauwels *et al.*, 1999). The calculation of the mean annual increment and current annual increment of plantations (Tables in Appendix 2) revealed that globally, the maximum increments of plantations are achieved early at about 10 years on the most fertile soils and at about 20 years on less fertile ones. These led us choose 25 year-old as the reference age of the plantations studied.

### Presentation of the table

The yield table is summarized in the Tables of Appendix 2 and is presented for each productivity index. The first four productivity indices correspond to forest sites where teak timber can be produced in Benin. However, on the forest sites corresponding to the fourth productivity index ( $H_r = 16$  m) we recommend the production of small size logs because productivity is low in these sites. The fifth productivity index corresponds to the less fertile sites of the teak plantations which would be more suited for the production of poor quality wood, especially perch if teak is grown. One can also consider fertility enhancement of such sites with native species such as *Parkia biglobosa*, *Vitellaria paradoxa* and *Pterocarpus erinaceus*, that are found at the northern part of Massi forest.

### Discussion

The yield table developed in this study is compared with the one by Laumans (1992) for teak plantations of Southern Benin. Laumans (1992) used only data from temporary plots to develop the model. This showed higher increments in young plantations but lower increments and early flattened pattern in older plantations. In 1992, the Lama teak plantations which are among the most productive of Benin, were only 5 year-old and their data reflected only the early vigour that would have influenced Laumans' model. Apart from the data from the young, most productive plantations of Lama, the rest of the data used by Laumans (1992) were collected in older, less productive plantations and this contributed to flattening up of the model in late ages.

Data from stem analyses and 200 permanent plots measured from 1975 to 1990 were used to develop the models for teak plantation of Côte-d'Ivoire (Dupuy *et al.*, 1999). In the model, it was noted that the early growth in the first ten years of plantation is stronger in Côte d'Ivoire than in Benin and at older ages (50 years and more). While the productivity curves of teak plantations in Benin flattened up, those of Côte-d'Ivoire still showed continuous growth.

Nunifu and Murchison (1999) developed the fertility model for teak plantations in Ghana based on data collected from 100 temporary plots. Area perusal of the data from those studies show that (1) the dynamics of teak plantations are different between the two countries and (2) the teak plantations in Benin are more productive than those reported by other authors.

### Conclusion

The yield table developed in this study helped to fill an important gap in the silviculture of teak plantations in Benin and the tropics where teak is widely planted. The table comprises of five fertility classes of which the first three are suitable for good quality teak wood production with a rotation age of 40 years.

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The dynamics of teak plantations in Benin are quite different from those observed in the sub region of West Africa, especially in Côte-d'Ivoire and Ghana. This yield table offers sufficient reliability to support the silviculture regime of teak plantations in Benin and in the tropics up to 40-year-old. Further data collections especially in the most productive plantations of Lama forest are needed to complement the data used in this study and to update the yield table.

### Acknowledgements

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### Supplementary materials (Tables in appendix 2)

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## 4<sup>th</sup> World Teak Conference Updates

24-27 August 2020

Accra, Ghana



The banner features a background image of a lush green forest. At the top left is a circular logo for the 4th World Teak Conference, Ghana 2020, with the dates 24-27 August 2020. To the right of the logo, the text reads "4<sup>th</sup> World Teak Conference 24-27 August 2020 Accra, Ghana". Below this, the main title is "Global Teak Market: Challenges and Opportunities for Emerging Markets and Developing Economies" with the website [www.worldteakconference2020.com](http://www.worldteakconference2020.com) underneath. At the bottom, there are logos for the organizers: IFC (International Forestry Commission), TEAKNET (International Teak Information Network), IITRO (International Tropical Timber Organization), and IUFRO (International Union of Forest Research Organizations).



The deadline to submit Abstract is  
**15 January 2020**

Visit the Conference Website  
[www.worldteakconference2020.com](http://www.worldteakconference2020.com)

# National Teak Forum in LAO PDR: Sustainable Value Chains for Sustainable Local Development

19-20 February 2020, Vientiane and Luang Prabang, Lao PDR



The ITTO Teak Project Phase I, “Enhancing Conservation and Sustainable Management of Teak Forests and Legal and Sustainable Wood Supply Chains in the Greater Mekong Sub-region (PP-A/54-331)”, aims to assist governments, local communities and smallholders to enhance natural teak forest management, production and marketing through the establishment of legal and sustainable wood supply chains, improving local economy and local communities’ livelihood in the Mekong Sub-region.

The teak project has officially started 1 March 2019 and will end on 28 February 2022. The Launching Workshop and the First PSC meeting were conducted on 23-25 April 2019 in Bangkok, Thailand.

The project is being executed by ITTO in collaboration with five agencies of the implementing countries, namely Cambodia’s Forestry Administration (FA), Lao PDR’s National Agriculture and Forestry Research Institute (NAFRI), Myanmar’s Forestry Department (FD), Thailand’s Royal Forest Department (RFD) and Vietnamese Academy of Forest Sciences (VAFS). In addition, Kasetsart University of Thailand through the Regional Project Leader is coordinating all activities being implemented in the five participating countries.

The organization of the 2<sup>nd</sup> Project Steering Committee (PSC) and the 3<sup>rd</sup> Project Technical Meeting (PTC) on 18 February 2019, as well as the ‘*National Teak Forum in Lao PDR: Sustainable Value Chains for Sustainable Local Development*’ is scheduled on 19-20 February 2019, Vientiane and Luang Prabang, Lao PDR.

The PSC meeting is aimed at reviewing the overall progress of the project implementation, including reviewing the responses of the project team to the recommendations of the 1<sup>st</sup> PSC meeting and providing directions and recommendations to the Executing Agency and Project Team in achieving the project targets. The project technical meeting will further discuss results and recommendations of the 2<sup>nd</sup> PSC meeting and formulate operational action plans on the ground and solving any technical problems encountered.

For more details [click here](#)

## Prices of Plantation Teak Imported to India

Country of Origin Logs	US\$ per cu.m C&F
Angola	389-574
Belize	350-400
Benin	290-714
Brazil	344-540
Cameroon	405-616
Colombia	478-743
Congo D. R.	450-761
Costa Rica	357-780
Côte d'Ivoire	289-756
El-Salvador	320-732
Ghana	294-452
Guatemala	324-646
Guyana	300-450
Kenya	515-876
Laos	300-605
Liberia	265-460
Malaysia	225-516

Mexican	295-808
Nicaragua	402-505
Panama	335-475
PNG	443-575
Sudan	358-556
Thailand	511-700
Togo	334-590
Trinidad and Tobago	603-753
Uganda	411-623
Sawn wood / Squares	
Benin sawn	530-872
Tanzania sawn	307-613
Uganda Teak sawn	680-900
Brazil squares	333-556
Ecuador squares	333-454
Nigeria squares	434-517

Variations are based on quality, lengths of logs and the average girth.

*Courtesy: ITTO TTM Report 23(23): 1-15 December 2019*

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Dr. P.K. Thulasidas

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