Leaflet No. 3

Investigation on the Optimum Thinning Regime for *Tectona grandis* (teak) Plantation in the Oaktwin Township

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အုတ်တွင်းမြို့နယ်အတွင်းရှိ ကျွန်းသစ်မျိုးများအတွက် သင့်ဝ်တော်သည့်ဝ် ပင်ကျပ်နှုတ်ခြင်း အစီအစဉ်များ လေ့လာစုံစမ်းဖော်ထုတ်ခြင်း

ဒေါက်တာချောချောစိန်
ဦးစီးအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

ရွက်အုပ်များ တစ်ခုနှင့်တစ်ခု ထိစပြုလာသည်နှင့် ပင်ကျပ်နှုတ်ခြင်း လုပ်ငန်းကို ဆောင်ရွက်ကြရမည် ဖြစ်ပါသည်။ ဤစာတမ်းတွင် တောင်ငူခရိုင် အုတ်တွင်းမြို့နယ် အတွင်းရှိ ကျွန်းစိုက်ခင်းများတွင် အကြောင်းအမျိုးမျိုးကြောင့် ပင်ကျပ်နှုတ်ခြင်း လုပ်ငန်း မဆောင်ရွက်ရသေးသည့် သက်တမ်းမတူသော စိုက်ခင်း(၅)ခုတွင် နမူနာကွက်များ ဖော်ထုတ်၍ အပင်များ၏ အမြင့်နှင့်လုံးပတ်များ တိုင်းတာခဲ့ပါသည်။ ၎င်းနောက် စိုက်ခင်း အသက်အလိုက် ပင်ထောင်များ၏ ရင်စို့ဖြတ်ပုံဧရိယာ၊ အသက်နှင့် ပျမ်းမျှလုံးပတ်အရ တစ်ဧကတွင် ရှိသင့်သော အပင်အရေအတွက်တို့ကို လေ့လာစုံစမ်း ဖော်ထုတ်ထားပါသည်။

Investigation on the Optimum Thinning Regime for Tectona *grandis* (teak) Plantation in the Oaktwin Township

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Abstract

Thinning used to be conducted when the crown of the trees are touched. This study was focused on the investigation of the optimum thinning regime for *Tectona grandis* (teak) of five different age un-thinned plantations in Oaktwin Township. Three sample plots were established in each plantation and all are square with 60 m x 60 m in size and further divided into subplots of 20 m x 20 m. The diameters at breast height (dbh) - 1.3 m above ground and heights of all the standing trees were measured using diameter tape and clinometer respectively. This study reports the basal area and the maximum number of trees per ha related to mean diameter and age according to Reineke Model.

Key Words: Basal Area, Mean Diameter, Maximum number of Stands, Un-thinned plantation, Age

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1. Introduction

Teak belongs to the family Verbenaceae. It can be found within mean rainfall of 900-3500 mm and mean annual temperature of 25-32° C with an elevation lower than 1000 m (Troup, 1921; Hundely and Ko, 1987, Lamprecht, 1980; Gyi and Tint, 1998). In Myanmar, teak occurs naturally in all parts of the country except in the dry zone, the tidal regions of the delta area and in areas where the elevation exceeds 914 m (Gyi and Tint, 1995). Teak forests in Myanmar cover 16.5 million ha out of 28 million ha of teak bearing forests all over the world (Anon., 1993).

Since teak occurs on a great variety of soils and over a wide range of locally different environments, it can display geographic differences in one or more important characteristics. Teak of the best timber quality, producing cylindrical and sound logs occurs in the Bago Yoma where the rainfall varies from about 50 to 60 inches, and the soil and climatic conditions are favorable for the best growth of teak (Kermode, 1964).

Due to the population pressure and ever increasing demand of timber for domestic uses and export, extensive teak plantations in large blocks were formed in Myanmar starting from year 1976 (FD, 2001). Within a period of 50 years from 1948 to 1998, 567,650 acres of teak plantations were established (FD, 2001). In promoting plantation programs, it is important that all the plantations should produce maximum volume of good-quality timber in short rotations. Although growth and yield of the plantations are largely influenced by site quality and genetic characteristics, plantations need to be conscientiously managed to enhance stand quality and promote wood production. Tending operations such as thinning are typically used to increase production of usable-sized trees (Zeide, 2001). Thinning can also provide an intermediate financial return from the removed trees (Evans and Turnbull, 2004). Therefore, it is inevitable for plantation managers to have the knowledge and understanding of management strategies for successful establishment of teak plantations.

The objectives of the study are as follows

(a) To estimate the basal area of teak plantations in relation to their mean diameter per ha.
(b) To estimate the maximum stems per ha in relation to their mean diameter.
(c) To investigate optimum thinning regime for teak plantation in Oaktwin Township.

1.1 Literature Review

1.1.1 Development of teak plantations

The durability and workability of teak were recognized many centuries ago, leading to its relatively widespread cultivation throughout the tropics. Today, teak ranks among the top five tropical hardwood species in terms of plantation area established worldwide(B.Krishnapillary, 2000).The area of teak plantation in Myanmar, which is estimated to be 139,000 ha was first established in about the year 1700. The yield from these plantations makes an important supplement to that from the natural forests. Development of teak plantations . in India commenced in 1842. From that year until 1862, more than 1

million teak plants were raised for plantation development. The area planted is now about 980 000 ha. (B.Krishnapillary, 2000).

In Thailand, pioneer plantations of teak were first established in 1906, a very heavy dependence on plantation-grown teak for its rapidly growing export-oriented furniture manufacturing industry. This industry employs approximately 400 000 people and is responsible for export earnings of approximately US$400 million. In conjunction with the Scandinavian designs and manufacturing techniques, they have done much to popularize teak furniture on a global basis since 1945.

Teak plantations in Indonesia are largely located in Java and currently exceed 700 000 ha (B.Krishnapillary, 2000). Teak was probably introduced into Java in the fourteenth century, although some reports suggest that its introduction may have been as early as the seventh century (B.Krishnapillary, 2000). Harvests from Javanese teak plantations today support a rapidly expanding furniture manufacturing industry, the products of which are increasingly directed towards export markets. Production of teak occurs in two sectors: one is a free market and the other is controlled by a State enterprise company, Perum Perhutani. Perhutani's teak production and processing activities are well organized and extensive, involving the provision of quality planting stock, consumable inputs such as fertilizers, and specific advice to assist landholders with the establishment and management of their teak plantations. In return for these inputs, Perhutani is granted the rights to the logs harvested from the areas concerned.

Cultivation of teak in Malaysia is a relatively new undertaking. The total areas planted in peninsular Malaysia and Sabah are estimated to be approximately 2 000 ha each (Asian Timber, 1996; Tee, 1995). Until recently, it was widely believed that teak grows best in the drier states in the north of peninsular Malaysia and it was not promoted in other parts of the country which are hotter and wetter. However, results from those areas now indicate that they are equally suited to the production of teak, and this has generated considerable interest in the establishment of teak plantations on a large scale.

The establishment of teak plantations in Malaysia is being actively promoted by the Department of Forestry, the Forest Research Institute Malaysia (FRIM), the Federal Land Development Authorities, other government agencies and the private sector. These commercial planting programmes aim to achieve mean annual increments of 8 m^3 or more per hectare per year. Developments are occurring on an industrial plantation scale (>100 ha) as well as on smallholdings. Smallholder planting is being vigorously promoted as an enterprise requiring low labour inputs and offering potentially high returns. Elsewhere in Asia, teak has been established in Bangladesh (~73 000 ha), Sri Lanka (~38 000 ha), China (~9 000 ha), the Philippines (~8 000 ha), the Lao People's Democratic Republic (~3 000 ha), Nepal (~2 000 ha) and Viet Nam (~1 500 ha). In Africa, teak has been established in plantations in Nigeria (~70 000 ha), Côte d'Ivoire (~52 000 ha), Sierra Leone, the United Republic of Tanzania (~3 000 ha) and Togo (~4 500 ha) (B.Krishnapillary, 2000). Plantations of teak are also widespread in the tropical Americas, where it was introduced early in the twentieth century. Teak plantations now cover an estimated 33 000 ha, spreading mainly across Costa Rica, Trinidad and Tobago, Panama, El Salvador, Colombia, Guatemala, Venezuela and Ecuador (B.Krishnapillary, 2000). In the Pacific region, teak was introduced by the Germans to Papua New Guinea in the early 1900s and some 3 500 ha of plantations were subsequently established (B. Krishnapillary, 2000). It was introduced to plantations in Fiji and the Solomon Islands. Teak has also been planted in northern Australia at trial levels.

Although it is widely planted, plantation- grown teak has not, until recently, had a significant impact on supplies of industrial roundwood in the global timber trade except for some short-term log exports from Papua New Guinea and Ecuador.

1.1.2 Management strategies

Teak is a light-demanding species. Inferior trees are readily suppressed if stand density is too high. Accordingly, plantations must be thinned regularly and heavily, particularly in the first half of the rotation. Initial planting density is generally between 1 200 and 1 600 plants per hectare. The spacing of trees and the number, timing and intensity of thinning strongly affect the pattern of growth and the yield of the plantation. If thinning is carried out late, growth rates decline or cease, whereas if the stand is thinned too early or too heavily, the trees have a tendency to wind throw, produce side branches and epicormic shoots. This also reduces the potential yield of the plantation since growth is diverted from the main stem, which should be free from defects such as those caused by side branches and epicormic shoots. The timing of the first thinning is often determined by the crown of the trees and is commonly carried out when the trees reach 9.0 to 9.5 m. The second thinning may be carried out when the trees reach 17 to 18 m (B.Krishnapillary, 2000).

1.1.3 Ecological requirements

Soil requirements

Teak can grow on a variety of soils. The quality of its growth, however, depends on the depth, structure, porosity, drainage and moisture-holding capacity of the soil. It develops best on deep, well drained and fertile soils, especially on volcanic substrata such as igneous and metamorphic soils or on alluvial soils of various origins. The optimal soil pH is between 6.5 and 7.5. The calcium content of the soil is also an important factor; calcium deficiency in the soil results in stunted growth of teak (Kaosa-ard, 1981).

1.1.4 Temperature and rainfall

Teak grows best when the minimum monthly temperature is above 13˚C and the maximum monthly temperature is below 40 ˚C. Optimal rainfall for teak ranges between species requires a dry season of at least four months with less than 60 mm precipitation (Kaosa-ard, 1981).

2. Materials and Methods

2.1 Study area description

The Oaktwin Township is situated between 18° 15' N and 96° 18' E. The study site in the Oktwin Township lies within the area which is influenced by tropical savannah climate with a pronounced dry period between the monsoons. According to the climatic data of 2010-2012, the number of yearly rainy days is found to be around 75.

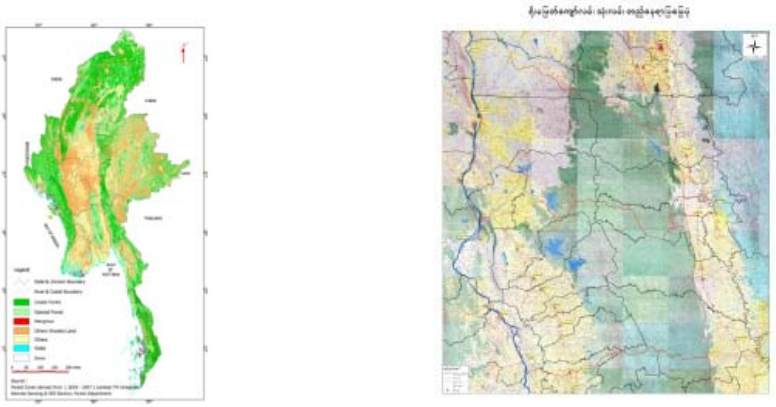


Figure (1) Oaktwin Township

2.2 Data collection and analysis

Survey and inventory in forestry is one of the basic steps to other forestry branches in formulating the silvicultural and management plan. For large areas, sampling could provide all necessary information at much lower costs with reliable result than total enumeration (ADAM, 1989). A field survey was carried out in five different aged of plantations (6, 8, 9, 10 and 11 years old) with subjective sampling. The three temporary sample plots were selected only in places where stocking was full for each plantation. The sample plots are all square with 60 m x 60 m in size and further divided into subplots of 20 m x 20 m. The diameters at breast height (dbh) - 1.3 m above ground and heights of all the standing trees were measured using diameter tape and clinometer respectively. The data was analyzed by using Statistical Software.

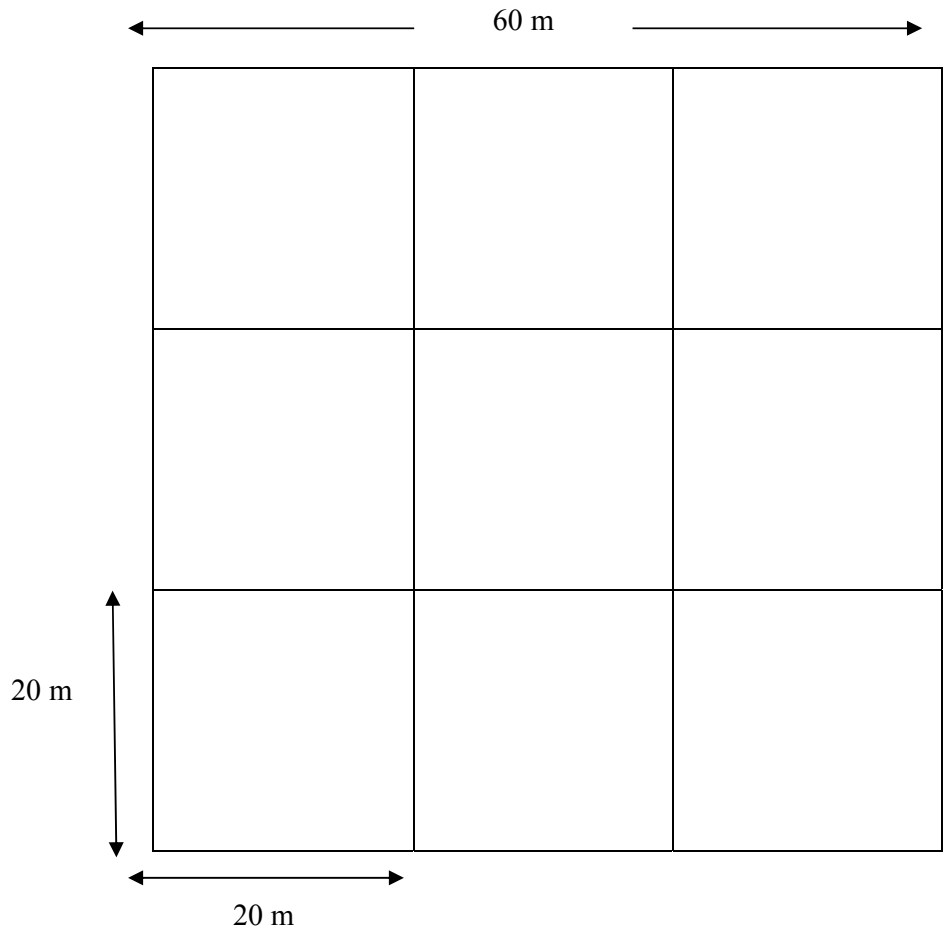


Figure (2) Lay out of sample plot

Table (1) Location of teak plantations in the Oaktwin Township

Year of plantation establishment	Location of teak plantation
1/2003	Kabaung Reserved Forest , Compartment No(207/209)
1/2004	Kabaung Reserved Forest , Compartment No(212/213)
1/2005	Bone Taung Reserved Forest , Compartment No(17)
1/2006	Bone Taung Reserved Forest
1/2008	Kabaung Unclassed Forest, Compartment (17)

3. Results and Discussion

3.1 Stand density

3.1.1 Estimated basal area of stand

In even-aged stands, there are many definitions for stand density and is a main parameter to plan the thinning regions. Stand density is a measure of how many trees are growing per unit area, either absolutely in terms of number of trees, basal area or volume per unit area or relative to some stand condition. It can describe how much a site is being used and the intensity of competition between trees for the site's resources (i.e., water, light, nutrients and space). The growth rates of individual trees slow down at greater stand density because there are more trees competing for the site's limited resources. Stand density measures are the quantitative descriptions of stocking (Helm, 1998). In this study, two parameters of stand basal area and stand density index were used to determine stand density.

(a) (b) (c)

Figure (3) : (a) 8 years, (b) 9 years and (c) 10 years old teak **plantation**

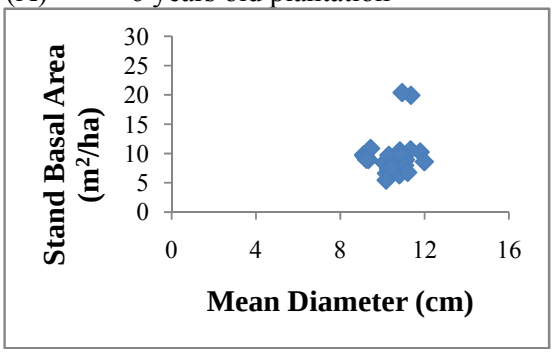
Stand basal area (SBA) is simply the cross-sectional area of all trees at breast height per hectare of forest or plantation (m^2/ha). Stand basal area can be used to estimate stand volume and is a useful measure for stand density, as it is easy to measure. Stand basal area values depends both on the number of trees and the size of trees. The relationship between stand density and average tree size is important to compare different thinning regimes for plantation. Von Gadow and Bredenkamp (1992) concluded that sawn timber necessitates larger diameter trees, whereas a large stand basal area is needed for pulpwood.

According to Weidelt (1998), it was observed that the approximate average stand basal area in a moist evergreen forest is about 30 m^2 per hectare. The un-thinned 67-year-old stand of *Flindersia brayleyana* on basaltic soil carried a stem basal area of 78 m^2 /ha (Brown *et al*., 2004). This is similar to the basal area recorded in the Monteverde forests of Costa Rica (Nadkarni *et al.,* 2000), of which 70% was contributed by *Flindersia brayleyana*. In the Eucalypts plantation at a productive site, stand basal area may be up to 80-85 m^2/ha. The stand basal area is a suitable parameter to compare un-thinned even-aged stands of a given age and site. In this study, the maximum and minimum basal areas for 6 year, 8 years, 9 years , 10 years and 11 years old plantation were 20.39 m^2/ha (1008 stems/ ha) and minimum was 5.44 m^2/ha (766 stems/ha), 23.28 m^2/ha (1004 stems/ ha) and minimum was 4.50 m^2/ha (744 stems/ha), 26.21 m^2/ha (1009 stems/ ha) and minimum was 10.25 m^2/ha (785 stems/ha), 15.29 m^2/ha (1102 stems/ ha) and minimum was 9.66 m^2/ha (786 stems/ha), 33.96 m^2/ha (1109 stems/ ha) and minimum was 9.01 m^2/ha (715 stems/ha) respectively. Differences in basal areas were due to the different number of trees and size of the trees.

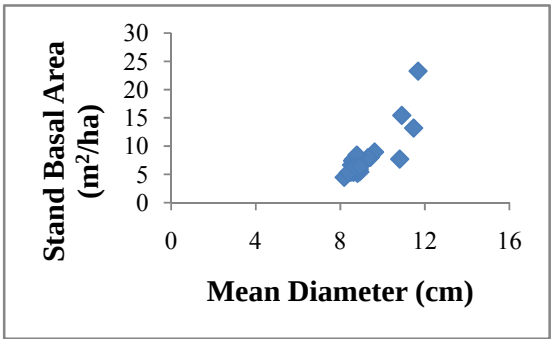
Table (2) Maximum and minimum basal area and stems per hectares of five different ages of plantation.

Age	Maximum stems/ha	Minimum stems/ha	Maximum BA/ha	Minimum BA/ha
6 years	1008	766	20.39	5.44
8 years	1004	744	23.28	4.50
9 years	1009	785	26.21	10.25
10 years	1102	786	15.29	9.66
11 years	1109	715	33.96	9.01

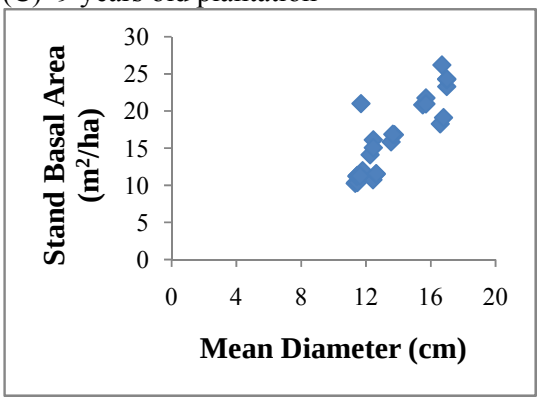
(A) 6 years old plantation



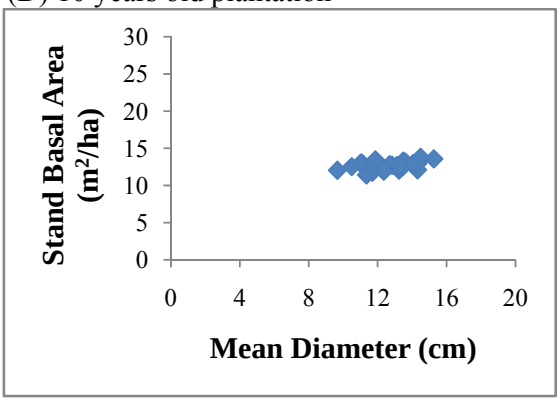
(B) 8 years old plantation

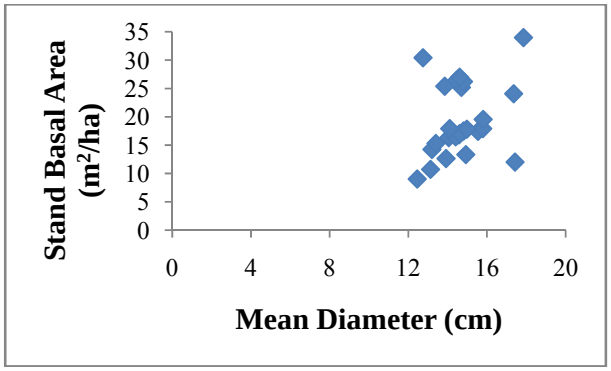


(C) 9 years old plantation



(D) 10 years old plantation





(E)

Figure (4) Mean diameter and stand basal area of teak plantations in the Oaktwin Township

Figure (4) shows the basal area calculated for different age of plantation relative to their mean diameter ("mean basal area tree", definition see below) in Oaktwin Township. In most stand volume estimation models, the stand basal area plays the key role. Consequently, it is important for the projection of potential volume to identify how one can estimate the future basal area. Hui and von Gadow (1993) developed a model that includes the stem number and top height to calculate the basal area in *Cunninghamai lanceolata* stands. To determine basal area in this study, a modified version of this model was applied. This model consists of the varying age and is given as follows:

$$G = a * N^{\alpha} * H_d^{\beta} * t^{\delta}$$ **Equation (1)**

Where G = Stand basal area (m^2)
N = Number of stems (per ha)
H_d = Top height (m)
t = Age (years)
a, α, β and δ = Model parameters

The same model was used for different aged of plantations, irrespective of site differences. The parameter values of equation (1) for teak is given in table (3).

Table (3) Parameters for the prediction of the basal area of teak according to equation (1), in Oaktwin Township

Species	Age	Model parameter				r^2
		A	A	β	Δ	
Tectona grandis	6 years	0.0331	1.0947	1.2415	-1.3960	0.68
	8years	0.0296	0.844	1.3893	0.0272	0.61
	9 years	0.0486	0.2444	1.1235	0.48104	0.90
	10 years	0.0320	0.8711	0.2546	-0.2772	0.61
	11 years	0.0471	1.6370	0.7527	-1.1291	0.57

Depending on the specific site or species, this model provides an estimation of the basal area of the stand. In Oaktwin Township, the 9 years old plantation had a high r^2 of 0.90, followed by 6 years old plantation with an r^2 of 0.68, 8 years and 10 years old plantations with an r^2 of 0.61, and the lowest was occurred in 11 years old plantation with r^2 of 0.57. R^2 value was higher in 9 years old plantation as they were older aged plantations. By substituting the parameter values of table (3) in the above equation, the plantation manager can easily estimate the basal area of the stands of teak if they know top height, number of stems and age of the stand.

3.1.2 Stand density index (SDI)

For determining relative stand density (Vissage and Miles, 2003, USDA Forest Service, 2005), stand density index (SDI) has been used in past strategic-scale fire hazard assessments. In the fully stocked pure or nearly pure stands, SDI was first projected by Reineke (1933) as a stand density assessment means based on size density relationships. It is a measure of the stocking of a stand of trees based on the number of trees per unit area and diameter at breast height of the tree of average basal area. SDI may also be defined as the degree of crowding within stocked areas by using various growing space ratios based on crown length or diameter, tree height or diameter and spacing. The number of trees per unit area is directly proportional to the mean diameter of the trees. High-density stands will undertake density-dependent mortality or self-thinning. According to von Gadow and Hui (1998), this relation can be defined by a limiting line. The following model was developed by Reineke (1933):

$$N = \alpha * D_g^{\beta} \qquad \textbf{Equation (2)}$$

Where, N = Number of stems per unit area
D_g = Mean diameter (mean basal area tree in cm)
α, β = Parameters

In the un-thinned stands of different ages, it is necessary to encompass data to determine the relationship between number of trees and mean diameter. In this study, the data were collected from un-thinned stands. Parameter values for the Reineke model applied to stands in Oaktwin Township are given in table (4). In this study, the parameter β values ranged from -0.0125 to -0.1463 for different ages of teak in Oaktwin Township. Reineke (1933) found that the parameter β value of the limiting line in several even-aged stands of different species, including Pinus and Eucalyptus, was -1.605. According to von Gadow's finding (1986), *Eucalyptus grandis* and some other pines had a limiting line value of -1.98.

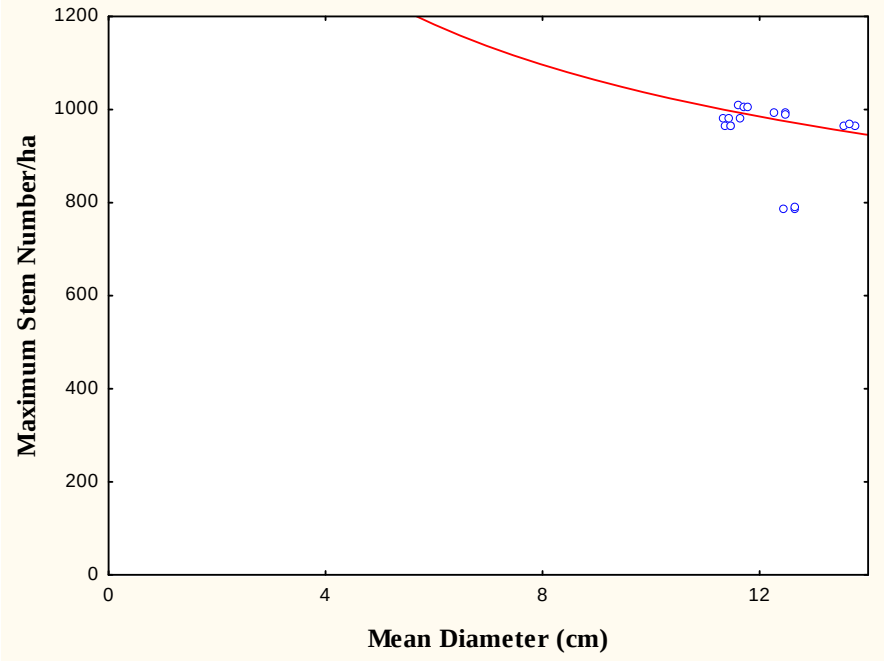
Table (4) Parameters values of Reneike model (1933) for teak according to equation (2), in Oaktwin Township

Species	Age	Parameter values for REINEKE model		N	r^2
		α	B		
Tectona grandis	6 years	1374	-0.1463	27	0.06
	8years	1074	-0.0651	27	0.06
	9 years	987	-0.0357	27	0.05
	10 years	925	-0.0319	27	0.02
	11 years	898	-0.0125	27	0.02

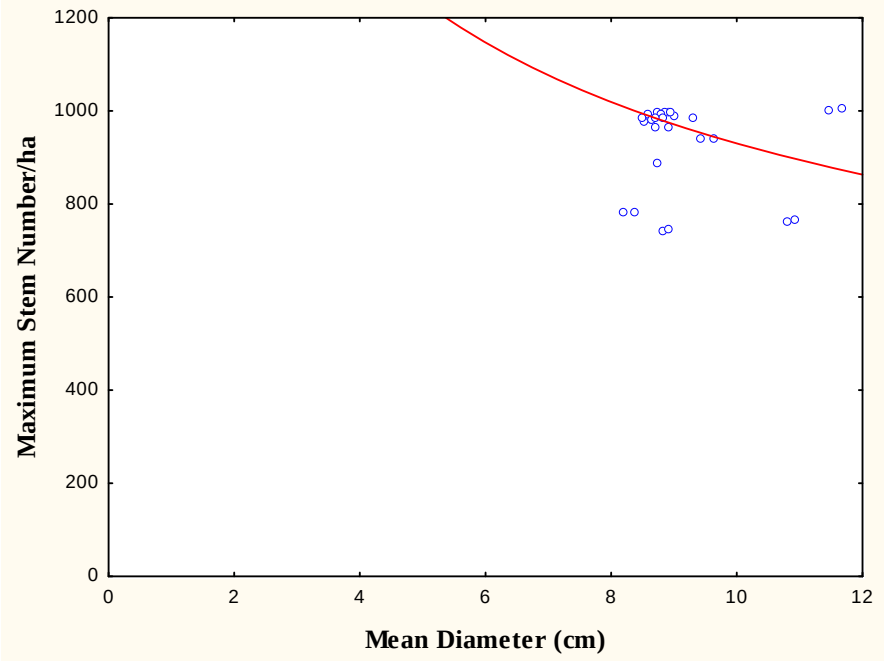
Figures (3) shows the fitted curves to the Reineke model for different age of teak plantations in Oaktwin Township. The curve was extended over the maximum calculated mean diameter. The highest number of trees present is 1008 trees/ha, 1004 trees/ha, 1009 trees/ha, 1102trees/ha, 1109 trees/ha given for the original spacing as 2.74 m x 2.74 m of 6years, 8 years, 9 years, 10 years and 11 years old plantation in Oaktwin Township. Less stem number was observed due to their being easily assessable and consequently illegal cutting may probably occurred.

According to the growth behavior of the Reneikel model, it was observed that all the stands were not thinned. The thinning regimes for the different ages of teak is described by the curves as shown in figure (5) and indicating a slight difference among the different ages of plantation. Height variation of mean diameter is due to site differences. As a result, the limiting line could be applied to determine such site differences (von Gadow and Bredenkamp, 1992). The second reason is pests and diseases, which have affected in young stands. The fitted curve represents impressive forms of 'limiting lines', which is acceptable for growing in Oaktwin Township. For example, if the mean diameter is 9 cm, the number of stems per hectare should be 930 trees per hectare for 8 years old plantation (see table (5)).

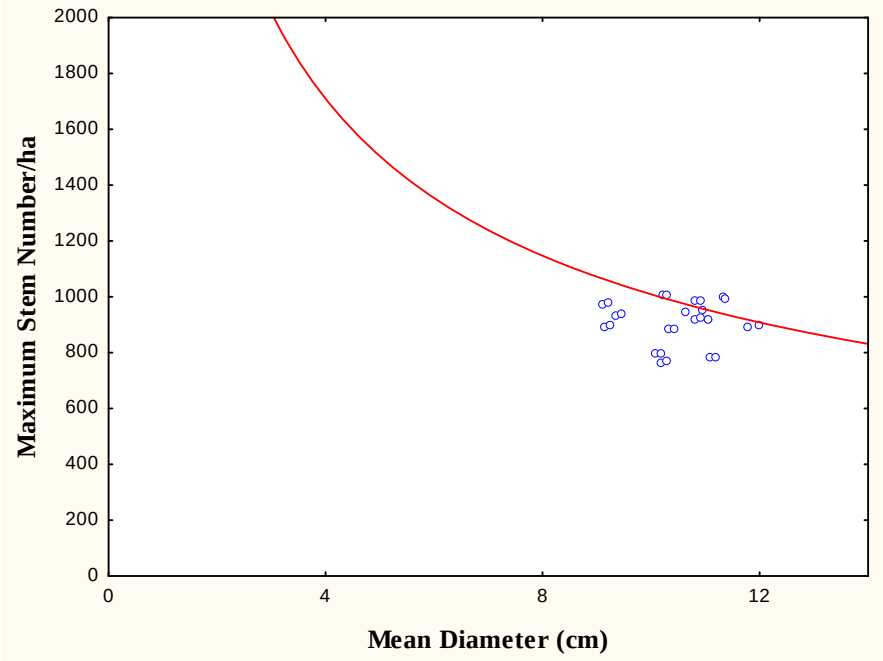
(A) 6 yr old plantation



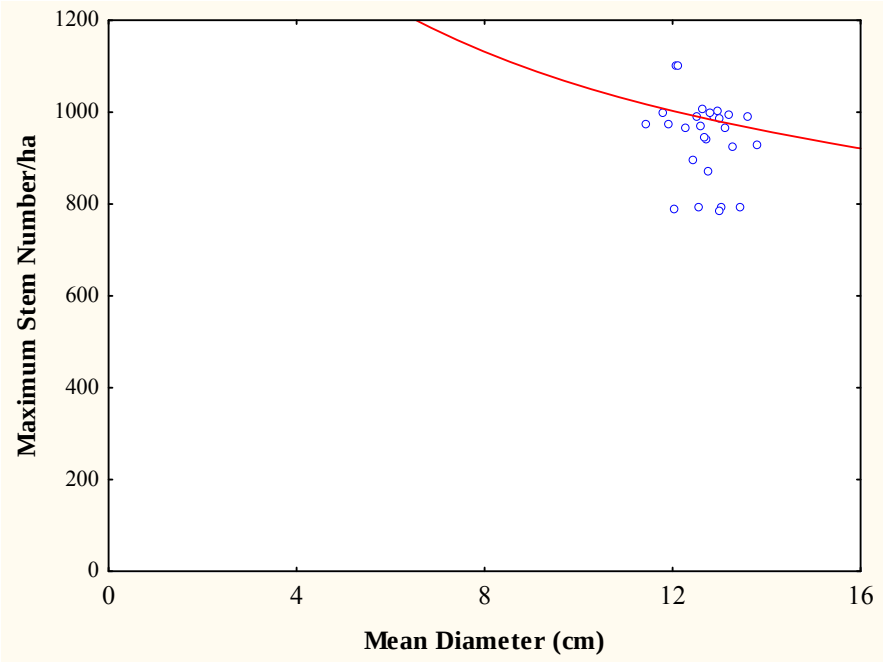
(B) 8 yrs old plantation



(C) 9 years old plantation



(D) 10 years old plantation



(E) 11 years old plantation

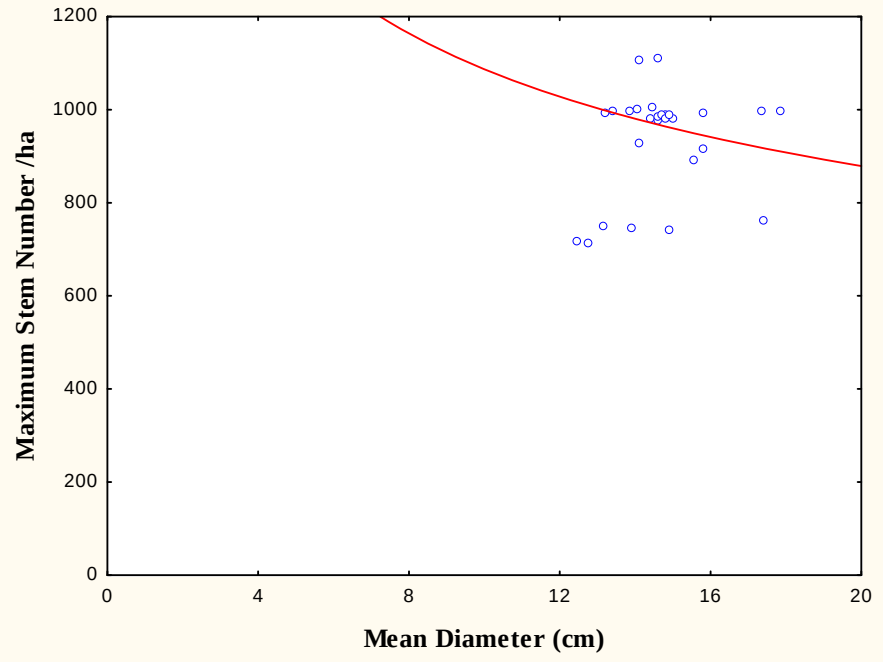


Figure (5) Fitted curves by the Reneike model for different ages of teak stands in Oaktwin Township.

Bredenkamp (1984) observed an 80 cm mean diameter value in 22-year old *Eucalyptus grandis*, which is very good for a fast growing species plantation in the South Africa. The limiting lines for teak can also be applied to other plantations in order to plan thinning operations in Oaktwin Township. However, the limiting line could be moved to the origin depending on the quality of site. The general degree of crowding for a stand could be mentioned numerically as the projected number of trees per hectare at an explicit mean diameter. The Reineke equation could be written as equation (3), if the mean diameter is 9 cm, which shows the maximum number of stems per hectare for the respective mean diameter.

$$SDI = \alpha.(9)^{\beta} \qquad \textbf{Equation (3)}$$

For the given N and Dg of 9cm, the SDI for any stand is defined by the following formula:

$$SDI = N\left(\frac{9}{D_g}\right)^{\beta} \qquad \textbf{Equation (4)}$$

In accordance with the above consideration, if α and β (equation 4) for 8 years old teak is known, Reineke's N will be 930 stems/ha when Dg is 9 cm. This means that the stand is under-stocked when the SDI value is less than 930. For the estimation of this value with other stands, N and Dg can be substituted in equation 4.

Table (5) Example for calculations of the estimation of mean diameter and number of stems per hectare

Species	Age	D_g (cm)	No. stems/ha according to eq(2)
Tectona grandis	6 years	11	962
	8 years	9	930
	9 years	11	905
	10 years	12	853
	11 years	14	848

4. Conclusions

Thinning is a silvicultural operation where the main objective is to reduce the density of trees in a stand, improve the quality and growth of the remaining trees and produce a saleable product. Thinning can increase stand yield by utilizing merchantable trees and by maintaining rapid growth of individual trees by minimizing competition. Thinning should be timed correctly if benefits are to be maximized. The stand yield is reduced when stands are thinned too early. On the other hand, the trees respond slowly, when stands are thinned too late. Thinning schedule can also be different where site quality and management objectives differ. Teak is a species planted for good quality timber, so proper site conditions, a good provenance selection and appropriate management must be done to achieve the best stem form, growth and wood quality. This study indicates that the optimum thinning regime of teak plantation, number of stems per hectare of teak plantation in Oaktwin Towinship can be estimated using the available dbh and the Reineke equation. Teak forest products are very important for the development of Myanmar. Some attention must be paid to the management of teak forest plantations, especially with respect to the principle of sustainable management. Research is still needed to improve the existing methods, in order to fulfill continuously the wide range of always changing human forest needs.

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References

Adam, H.A. (2000) M.Sc. thesis, Developing sample method for assessment of growing stock, composition and distribution of trees in Abu Haraz natural reserve forests in N.Kordofan State, Sudan.

Anon, 1993. Development of teak in China. In " Teak in Asia" Technical Document GCP/ RAS/ I34/ ASB, FORSPA Publication 4, FAO-RAPA, 11- 26 pp.

Asian Timber. 1996. First teak plantation for Sarawak. (July): 12.

Brown et al., 2004: Stem and crown dimensions as predictors of thining responses in a crowded tropical rainforest plantation of *Flindersia brayleyana* F. Muell. For. Ecol. Manage. 196 (2-3): p. 379-392.doi:10.1016/j.foreco.2004.03.029.

Evans, J. and Turnbull, J. W., 2004: Plantation forestry in the tropics. Third edition. Oxford University Press, Oxford, UK.

Gadow, K. v. and Hui, G., 1998: Modelling Forest Development and Thinnings. IUFROSPDC textbook Project No.2. Cuvillier Verlag, Göttingen, Germany.

Gadow, K. v. and Bredenkamp, B., 1992: Forest Management. Academica, Pretoria.

Gyi, K.K. and Tint, K. 1995. Status of management of natural teak forests in Myanmar. In "The Regional Seminar on Teak", Yangon, Myanmar.

Hui, G. Y. and Gadow, K. v.,1993: Zur Modellierung der Bestandesgrundflächenenwicklung dargestellt am Beispiel der Baumart Cunninghamia lanceolata. Allg. Forst-u. J.-Ztg. 164(8):p.144-145.

Kaosa-ard, A. 1981. Teak (*Tectona grandis* L.f.) – its natural distribution and related factors. Natural History Bulletin of the Siam Society, 19: 55-74.

Kermode, C.W.D. 1964. Some aspects of Silviculture in Burma. Central press, Rangoon.

Reineke, L. H., 1933: Perfecting a Stand Density Index for Even-Aged Forests. Journal of Agricultural Research, Vol 46, No.7, p. 627-638.

Tee, B. 1995. Teak in Sabah. A sustainable agroforestry – the Haris Salleh experience. Kota Kinabalu, Malaysia, Sejati Sd.

Vissage, J. S., Miles, P. D., 2003: Fuel-reduction treatment: a westwide assessment of opportunities. J. For. 101 (2), p. 5–6.

Zeide, B. and W. T. Zakrzewski., 1993**:** Selection of site trees: the combined method and its application. Can. J. For. Res. 23: p. 1019–1025.