Data assessment on experimental plots in Teak stands

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Summary

During a DSE training course in Chiang Mai, Thailand, 1997, the objective was to develop a growth model for Teak stands. To get real data 3 experimental plots were established within the concept of a growth series in 11, 28 and 100 year old Teak stands in Mae Moh plantation. In these plots the tree numbers decrease from 917 trees per ha on the youngest plot over 467 to 122 trees per ha on the oldest plot. Top height increases from 13.2 m over 19.3 up to 36.2 m. The corresponding stand volume amounts to only 51 m^3 on the youngest plot, the 28 years old stand reaches 106 m^3 and the old stand 486 m^3. Under some economic assumptions the net value of the 11 years old stand lies at about 9500 US$ per ha, the medium aged stand has a net value of 26000 US$ per ha, and the oldest stand may reach about 316000 US$ per ha. Empirical data are considered to be indispensable for the understanding of forest dynamics and the sustainable management of depletable forest resources.

1. Objectives and research concept

In february and march 1997 a DSE (German Foundation for International Development) training course in Chiang Mai/Thailand focused on system analysis and modelling of both socio-economic and natural resources. The modelling of natural resources was for conceptional reasons restricted to the growth and yield of pure Teak (Tectona grandis L.) stands. The aim was that the participants of the training course should assess their own data in the field, and the following data processing and modelling should be done with these same data. This procedure should guarantee a close identification of all the participants with the data and the complex modelling approach.

Given the objective to design a single tree and distance dependent growth model the problem is to find suitable data for a parameterization of the model (PRETZSCH, 1998). The model to develop should be used to generalize growth dynamics that are to be identified from the data and to design a decision support system for Teak management and for biological understanding of growth dynamics as well as for teaching and educational purposes (KAHN, 1998). The decision was to simplify the data assessment and to choose a Teak plantation not far from Chiang Mai for a three day assessment that would deliver the required data. This approach was only possible because of the cooperation between the DSE (German Foundation for International Development) and the partners from Chiang Mai University (CMU), Faculty of Agriculture. The close contacts of our partner Dr. Apichart from the Department of Forest Resources (CMU) to the Thailand Royal Forest Department and to the Forest Industry Organisation were indispensable.

To get a detailed insight into growth dynamics of pure Teak stands the concept of a growth series seemed to be the most promising. This concept implies to establish experimental plots in different ages on the same site and to substitute the temporal development of tree and stand growth by a spatial arrangement of stands in different phases of development. Together with

experts from Chiang Mai University and local experts from the Mae Moh Teak plantation of the Forest Industry Organisation near Lampang in Northern Thailand three plots were chosen: one of 11 years age, a second 28 and a third about 100 years old.
The data assessments on the plots were conducted by the participants of the 1997 DSE training course in Chiang Mai. The following chapters describe the procedure of establishing the plots in the field, the data assessment and from the data analysis the most important growth and yield data from the Teak stands.

2. Establishment of experimental plots

2.1. Plot characteristics

The Mae Moh Teak plantation near Lampang in Northern Thailand was first established in about 1968 with a total area of 3,200 ha. This plantation is under supervision of the Forest Industry Organization of Thailand. The Mae Moh plantation is located about 35 km at highway no. 1 in the north of Lampang city (ROYAL FOREST DEPARTMENT, 1992). The site conditions of this area are as follows:

Rainfall	: 1,100 mm/year
Temperature	: min. 18.5°C ; max. 32.3°C
Soil	: clay , pH = 4.5 - 5.4, poor nutrient supply

Three plots in the stand ages of 11 (plot no. 1), 28 (plot no. 2) and 100 (plot no. 3) years were established. Plot no. 1 had a size of 20m*30m, and the plots no. 2 and 3 were 30m*30m large. The sizes of the plots were kept small to avoid exhausetive measurements in the context of a training course, although the stem numbers on the plots may be small and the border effects may be high. Such small plots are not recommendable for a scientific research, but for training purposes they seem to be acceptable.

The slope on all plots was low. Each tree was signed with a tree number and a line to mark the diameter at breast height ($d_{1.3}$). For this purpose a small piece of paper with a prepared tree number was fixed at the tree with ordinary glue. Every corner of each plot was temporarily marked with a bamboo pole.

2.2. Data assessment

On each plot the following tree parameters were assessed for all trees:

- tree species
- circumference at breast height (in 1.3 m of tree height)
- tree height
- crown intersection
- crown radii (north, east, south, west)
- x- and y-co-ordinates

The circumference of every tree was measured with a girth tape, for height measurements a

Blume-Leiss device was used (fig. 1). The crown intersection is the height of the base of the crown and determined as the first branch that belongs to the crown. The crown radii were measured with a measuring tape. Also the x- and y-co-ordinates were assessed using measuring tapes.

Fig. 1: Height measurement with a Blume-Leiss device on the Teak experimental plot no. 2, stand age 28 years, Maeh Moh plantation (Northern Thailand).

Additionally from about 3 trees on every plot boring cores were taken to get information about the actual growth dynamics. For this purpose a dominating, a medium layered and a suppressed tree was chosen (fig. 2).

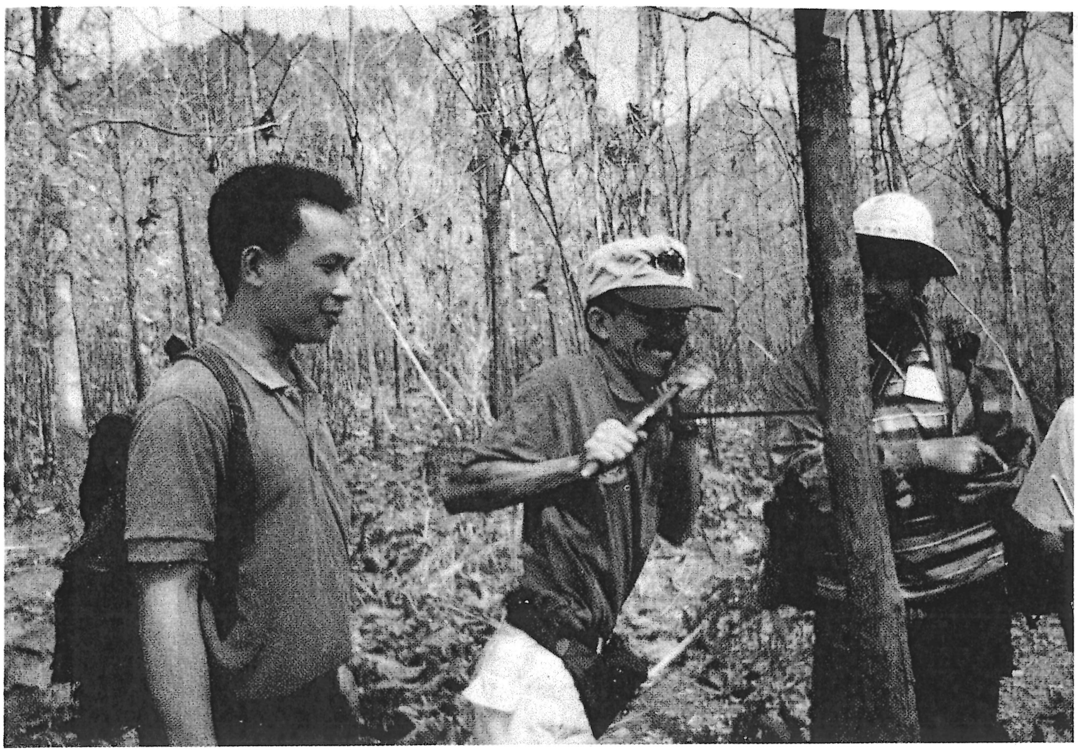


Fig. 3: Taking boring cores on the Teak experimental plot no. 1, stand age 11 years, Maeh Moh plantation (Northern Thailand).

To gain information about the stem form and to experience the practice of stem analysis one tree with a height of 12 m was felled on plot no. 2. On the tree heights of 0.15m and then every meter from 1 to 9 m height a stem disc was taken.

2.3 Data processing

The data from the assessments were processed on Win95-computers (fig. 3) and transferred into the spread sheet program MS EXCEL first, because it were only few data which can be handled with EXCEL easily. There the data were analyzed for missing values and typing and measuring errors respectively. After that the data were brought into the data base system MS ACCESS (mainly because of training purposes in the context of the training course): 3 tables were created, one with general plot data including the location of the plots as well as soil and climatic conditions. The second table included the measured tree data and the third table contained calculated data like competition indices, potential diameter and height increment data. For data analysis also the statistic program SPSS was used. Special analyses were performed with the single tree model SILVA 2 (PRETZSCH, 1992) and with the dendrochronology program WINDENDRO.

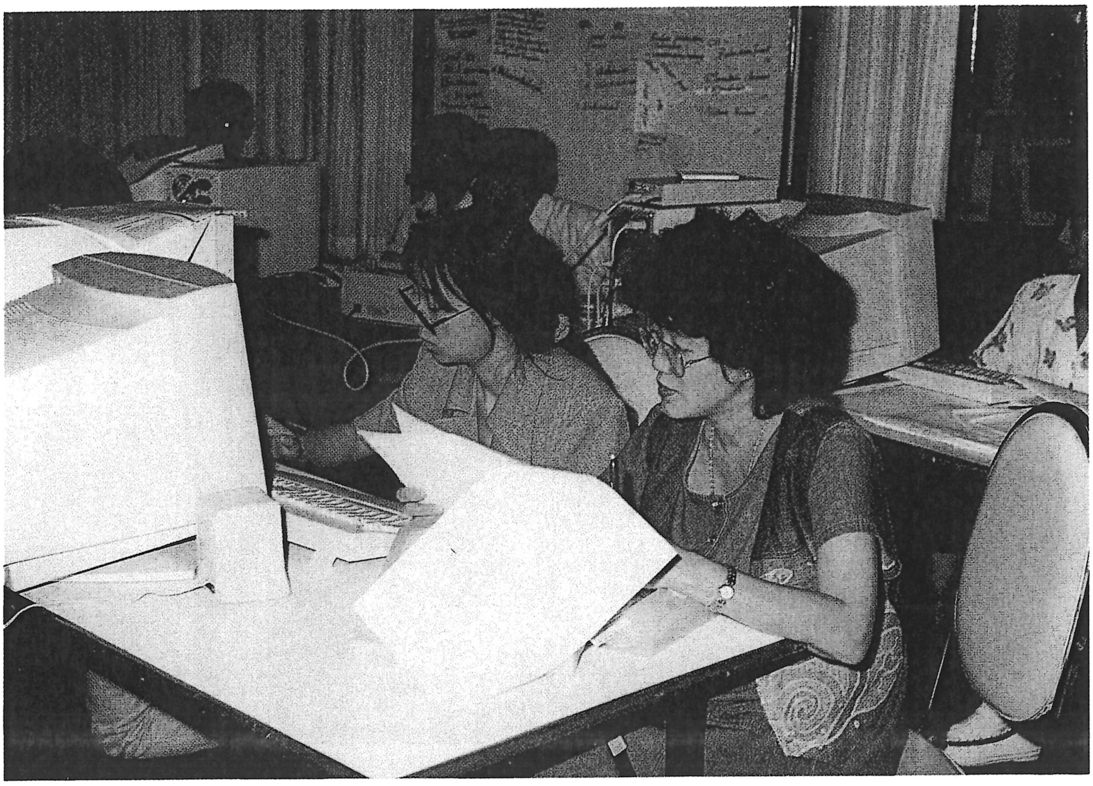


Fig. 3: Data processing on Windows 95 personal computers by the participants of the training course.

3. Analysis of growth and yield

3.1. Graphical aspect of the plots

Because for every tree the co-ordinates are known and of course diameter at breast height, tree height, crown intersection and crown radii were measured, a graphical aspect of the plots can be scetched. For this purpose the single tree model SILVA 2 was used to prepare the graphics (fig. 4).

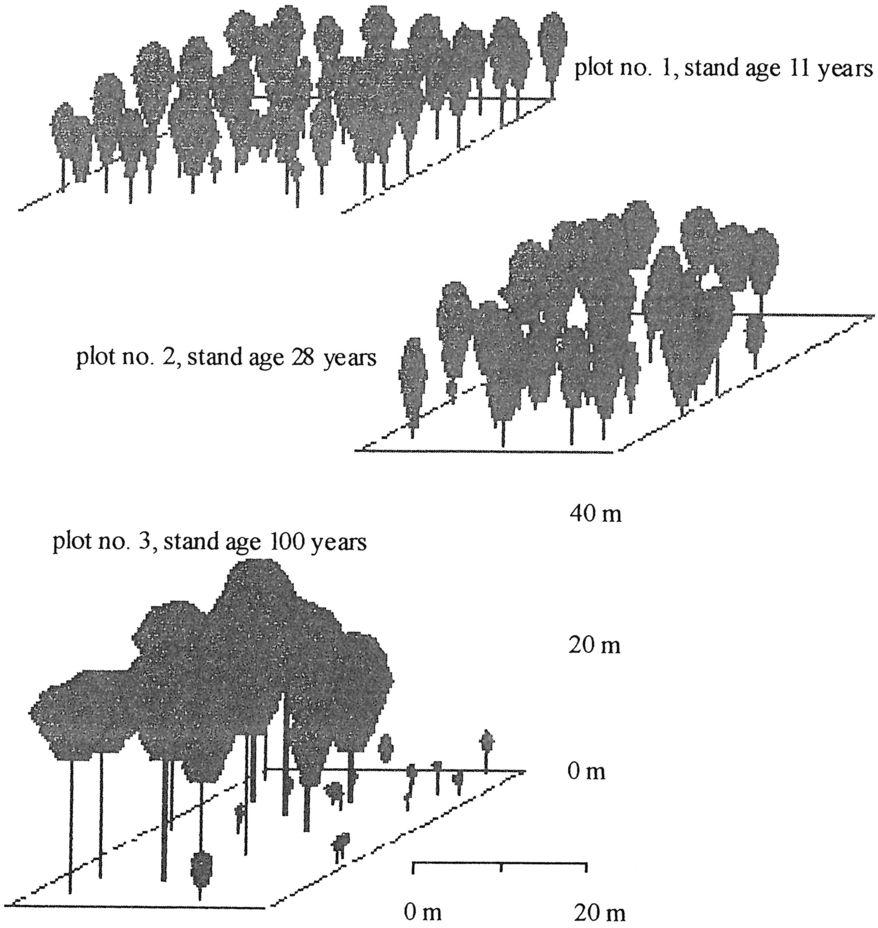


Fig. 4: Aspect of the experimental plots, pure Teak stands in Maeh Moh plantation (Northern Thailand), stand ages 11, 28 and 100 years.

3.2. Distribution of stem number over diameter at breast height

The concept of a growth series requires the substitution of a temporal development by a spatial arrangement of experimental plots. A good test to check if this substitution has been achieved well is to plot the distribution of the stem numbers over the diameter at breast height (fig. 5), calculated with the statistic program SPSS. The diameter at breast height is derived from the circumference at breast height.

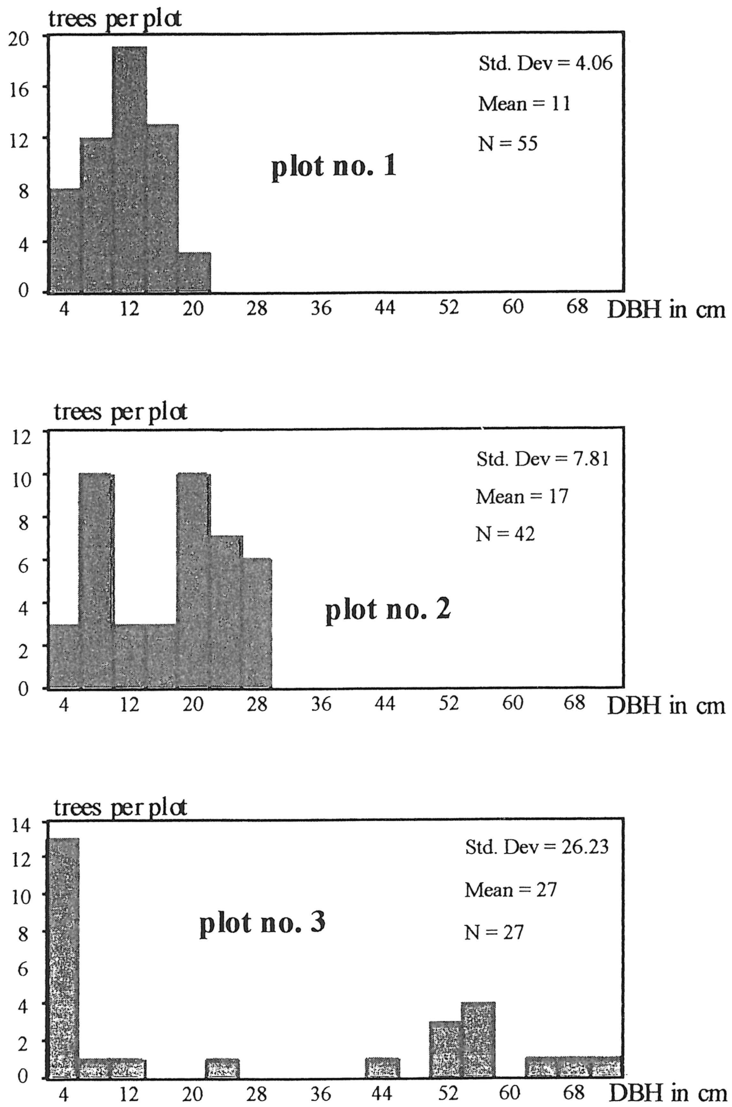


Fig. 5: Stem number over diameter at breast height (DBH in cm). Data from the Teak experimental plots in Maeh Moh Plantation.

Figure 5 reveals that there is indeed a shift of the tree number over DBH-distribution from small to large diameters. Obviously the plots no. 2 and especially no. 3 show that Teak is also able to exist in multi layered stands. On plot no. 3 the large spread in the diameters results from different ages of the trees, as could also be seen in the aspect of the stand in fig. 4, and we find natural regeneration here on this plot. On plot no. 2 the trees with the smaller diameters probably result from sproud shooting after a thinning a few years ago.

3.3. Stand height curves

Another point of view to proof the plots to represent a time series in a spatial arrangement is analyzing the height development. For this purpose the relation between tree height and tree diameter at breast height is modelled with a Michailov function as

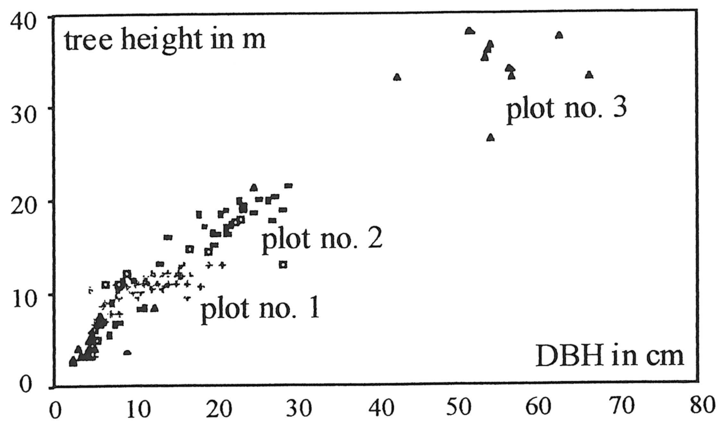
$$h = 1.3 + a_0 * e^{-a_1 / DBH}$$

with h = tree height in m, DBH = diameter at breast height in cm, a_0 and a_1 = parameters. With the statistic program SPSS the stand height curves are fitted, the results are summarized in table 1.

Table 1: Parameters of the stand height curves on the experimental plots in Maeh Moh plantation:

Plot no.	Parameter	Parameter estimate	Asymptotic standard error of the parameter	R^2	N
1	a_0	14.429169935	0.697611945	0.68328	55
	a_1	4.643993442	0.503971687		
2	a_0	24.988758483	1.220997007	0.85629	42
	a_1	9.288200455	0.818424527		
3	a_0	46.573507716	2.745138492	0.95909	27
	a_1	18.490064560	2.679302913		

The parameter estimates in table 1 underline the evidence that the parameter a_0 is the asymptotic value of the Michailov height curve, a_1 is a slope parameter. The asymptotic standard errors of the estimated parameters are relatively small, the R^2 values are quite high. Therefore the statistic results can be considered to by reliable.
Figure 6 proofs that the attempt to establish a growth series was successful. It can be seen easily that the plots approximately represent the desired temporal scale.



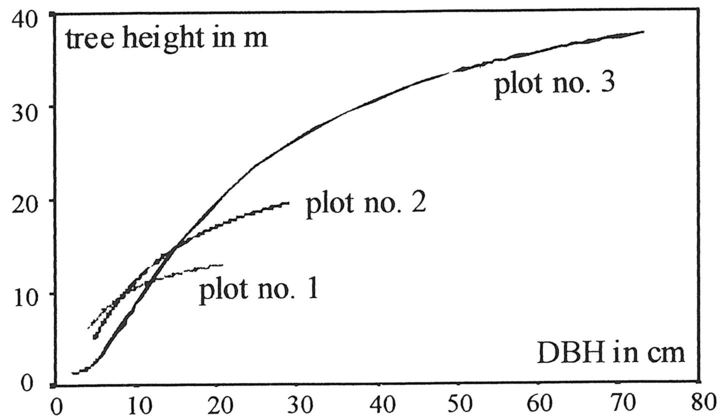


Fig. 6: Single tree heights and stand height curves underline the character of the experimental plots in the Maeh Moh Teak Plantation to represent a growth series.

3.4. Basic growth and yield characteristics

The first results from experimental plots often arise in data concerning growth and yield. These results were calculated with the growth model SILVA 2, which can be used as an analysis tool too. Most important stand characteristics are for example stem number per ha, basal area and volume per ha or mean and top height as well as mean and top diameter. The results are summarized in table 2.

Table 2: Yield data of the Teak experimental plots in Mae Moh plantation.

Variable	Dimension	Plot					
		young	medium	old	old	old	old
Area	[sqm]	600	900	900	900	900	900
Species		Teak	Teak	Teak	Teak	Teak	Sum
Age	[years]	11	28	100	25	10	
N	[trees/ha]	917	467	122	11	167	300
H100	[m]	13.2	19.3	36.2	21.3	5.5	
d100	[cm]	20.5	29.2	64.9	24.7	6.7	
hg	[m]	11	16.3	35	21.3	5.1	
dg	[cm]	11.9	18.6	57.5	24.7	5.6	
BA	[m^2/ha]	10.2	12.7	31.7	0.5	0.4	32.7
Vol	[m^3/ha]	51	106	486	6	1	493

N = stem number per ha; H100 = top height (h_{dom}); d100 = top diameter (d_{dom}); hg = mean height; dg = mean diameter; BA = basal area; Vol = stand volume.

The table shows that the old Teak stand consists of 3 different strata of trees: first there is an upper layer with trees that are about 100 years old. At second there is a stratum of very young trees that may be about 10 years old. One tree on the old plot with a DBH of 24.7 cm belongs neither to the old growth nor to the regeneration. It is estimated to be about 25 years old. The old plot reaches a total volume of 493 m^3/ha in total. The 28 year old stand has a standing volume of 106 m^3/ha, and the 11 old stand of about 51 m^3/ha.

The following figure 7 shows again impressively, how the different ages of the stands represent a temporal growth dynamic that results from the plots to be a growth series:

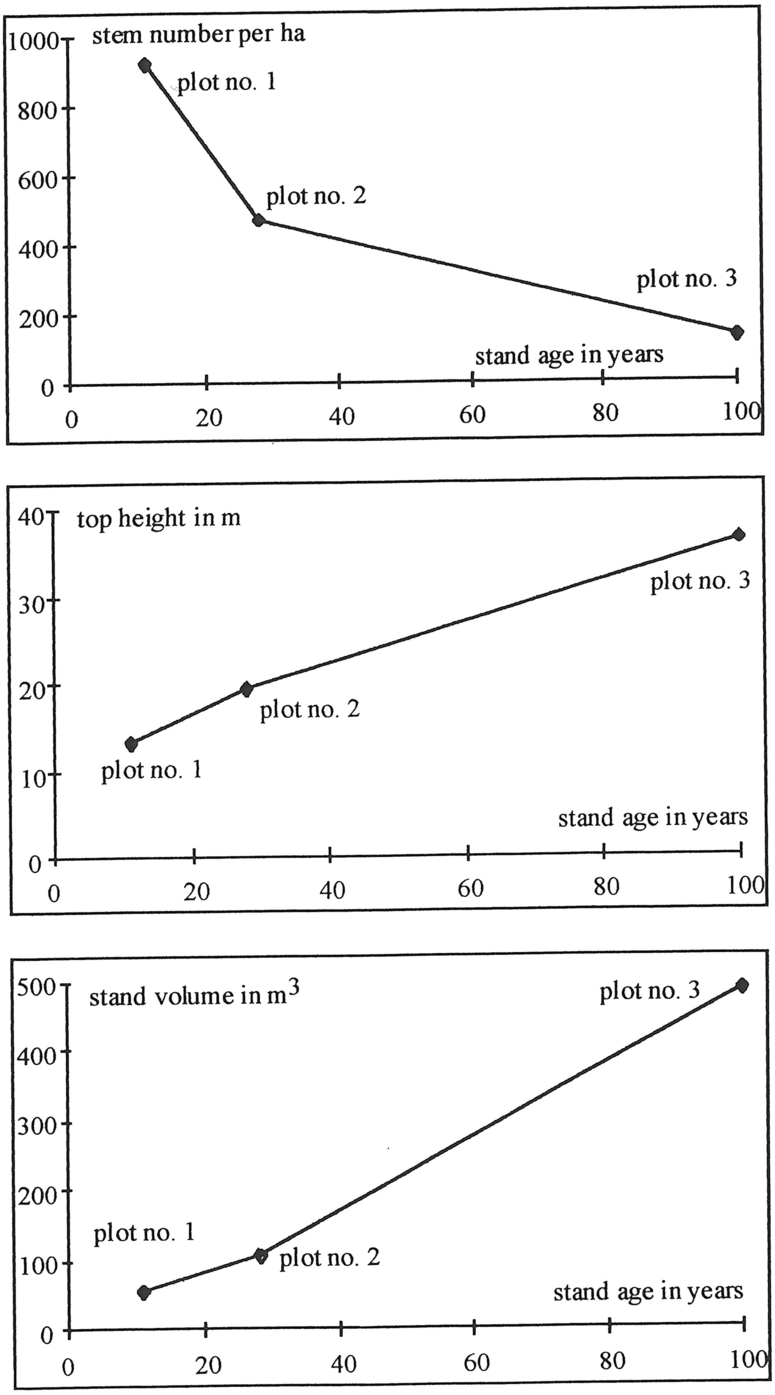


Figure 7: Stem number per ha, top height and stand volume over stand age for the Mae Moh Teak plots.

3.5. Basic economic and ecological characteristics

A different level of results from a system analysis in forest stands is reached if we switch from mere growth and yield data to ecological and economic results. They are also computed with the

analysis tool SILVA 2. The ecological results will be restricted to indicators of a horizontal aggregation and the vertical structure in the stands, indicated by a Clark and Evans index and a modified Pielou index (BIBER, 1998). The economic results show on the basis of local reliable sales prices and average harvesting costs the turnover and net value of the log wood in the Teak stands, if it is assumed that they are harvested.
The calculation of turnover, harvesting costs and net value is based on girth-dependent sales prices for the Teak timber (merchandable volume). Table 3 shows the underlying assumptions.

Table 3: Girth-dependent sales prices for Teak timber and harvesting costs.

Girth	sales price	harvesting costs	net value
□ 30 cm	188 US$/m^3	92 US$/m^3	96 US$/m^3
31cm - 50 cm	250 US$/m^3	92 US$/m^3	158 US$/m^3
51 cm - 70 cm	292 US$/m^3	92 US$/m^3	200 US$/m^3
71 cm - 90 cm	333 US$/m^3	92 US$/m^3	241 US$/m^3
> 90 cm	833 US$/m^3	92 US$/m^3	741 US$/m^3

Especially the sales prices for timber with a DBH of more than 90 cm is negotiable, but it is considered to be constant here. The harvesting costs shall also remain constant.

The results of the economic and ecological calculations are summarized in table 4.

Table 4: Data about structure and economic parameters of the Teak experimental plots in Mae Moh.

Variable	**Dimension**	**Plot**					
		young	medium	old	old	old	old
Area	[sqm]	600	900	900	900	900	900
Species		Teak	Teak	Teak	Teak	Teak	Sum
Age	[years]	12	30	100	20	10	
C&E		0.896	0.822	0.697		0.491	0.623
Pielou		1.000	1.000	-0.098		0.348	0.109
mShannon		0.851	1.076	0.633		0.327	1.082
Turnover	[US$/ha]	14928	35120	355470	226	43	355739
Cost	[US$/ha]	5410	9310	39260	79	16	39355
Net value	[US$/ha]	9517	25810	316210	147	27	316384

C&E = Clark and Evans index; Pielou = Pielou index; mShannon = modified Shannon index; Turnover = sum of sales prices of log wood; Cost = theoretical harvesting cost; Net value = Turnover - Cost.

3.6. Crown maps

As we know position (x- and y-co-ordinates) and crown radii from every tree on the experimental plots crown plots can be scetched. For this purpose we use a special version of the growth model SILVA 2. The crown plots are scteched in figure 8.

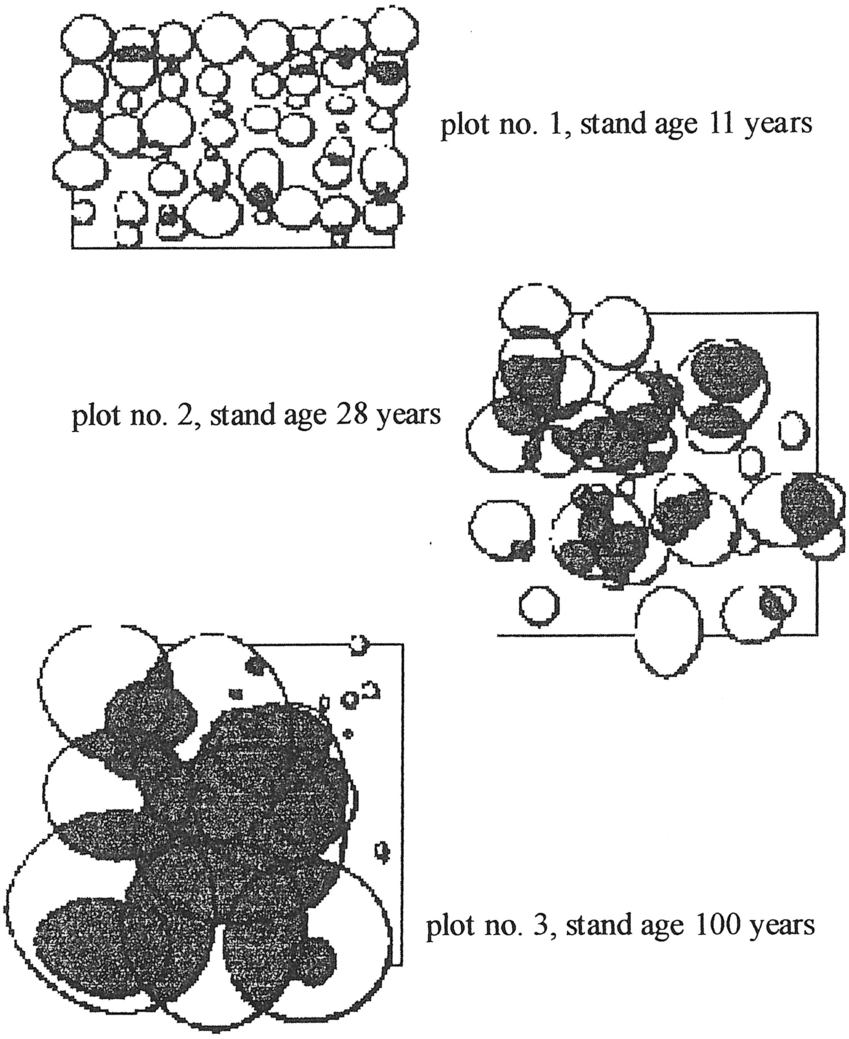


Fig. 8: Crown maps of the experimental plots, pure Teak stands in Maeh Moh plantation (Northern Thailand), stand ages 11, 28 and 100 years. Dark colours express multiply covered ground areas.

The crowns in fig. 8 are plotted using spline functions. The dark colours in the graphic express those ground areas that are multiply covered with crown projections. Plot no. 1 shows very impressively the stand characteristic of a plantation. In the 28 year old plot no. 2 the stand looses this artificial character, maybe especially because of the sproud shooting after the first thinning.

3.7. Diameter increment of single trees

The measurements on the experimental plots in Mae Moh Plantation were an ad hoc assessment, and dynamic information are difficult to achieve if there is no repeated measurement. But for growth modelling increment data on height and DBH are indispensible. Therefore from at least 3 trees on each plot boring cores were taken and analyzed. The analyses resulted in diameter increments i_{DBH}, which were related to a 1 year period. So for every boring in general more than 1 increment could be extracted. These 1 year increments were extended to 5 year increments and than regression analytic fitted by linear functions. With these linear functions of the form

$$i_{DBH} = b_0 + b_1 * DBH$$

for every tree a so called "real" diameter increment was calculated to enable the continuation of parameterizing a growth model. The parameter estimates are summarized in table 5.

Table 5: Parameters of the i_{DBH}-curves on the experimental plots in Maeh Moh plantation:

Plot no.	Parameter	Parameter estimate	standard error of the parameter	R^2	N
1	b_0	0.281979	0.537824	0.67588	10
	b_1	0.186177	0.042976		
2	b_0	0.295061	0.286620	0.85808	14
	b_1	0.092731	0.013333		
3	b_0	0.346183	0.253590	0.60307	9
	b_1	0.018170	0.005571		

The increment curves are depicted in figure 9. The curves show a typical behaviour: in the young stand the increment curve is steep and on a high level over small diameters. On the old plot the slope of the increment curve has decreased to a very low value.

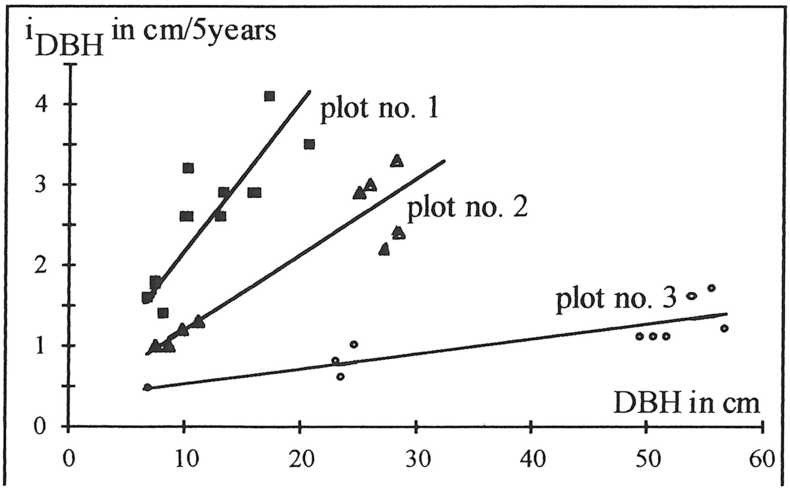


Figure 9: Diameter increment over diameter at breast height on the Mae Moh experimental plots of Teak.

3.8. Height increment of single trees

Furthermore height increments had to be generated. For this reason a height curve over DBH was calculated including all data from all plots. With this height over DBH curve for each tree a model height could be computed. After adding the generated i_{DBH} on the real DBH a new height can be calculated. This leads to the so called "real" height increment

$$ih_{real} = height(DBH+i_{DBH}) - height(DBH)$$

Although the described approach for generating height increments is quite rough it enables to continue modelling under the assumption of having somewhat real data.

3.9. Stem analysis

A stem analysis was done only for didactical reasons in the context of the mentioned training course. Stem analysis data can be used to develop stem form and stem volume functions. Figure 10 shows some results of the stem analysis of tree no. 113 from plot no. 1. This tree had a DBH of 13.1 cm and a height of 12 m.

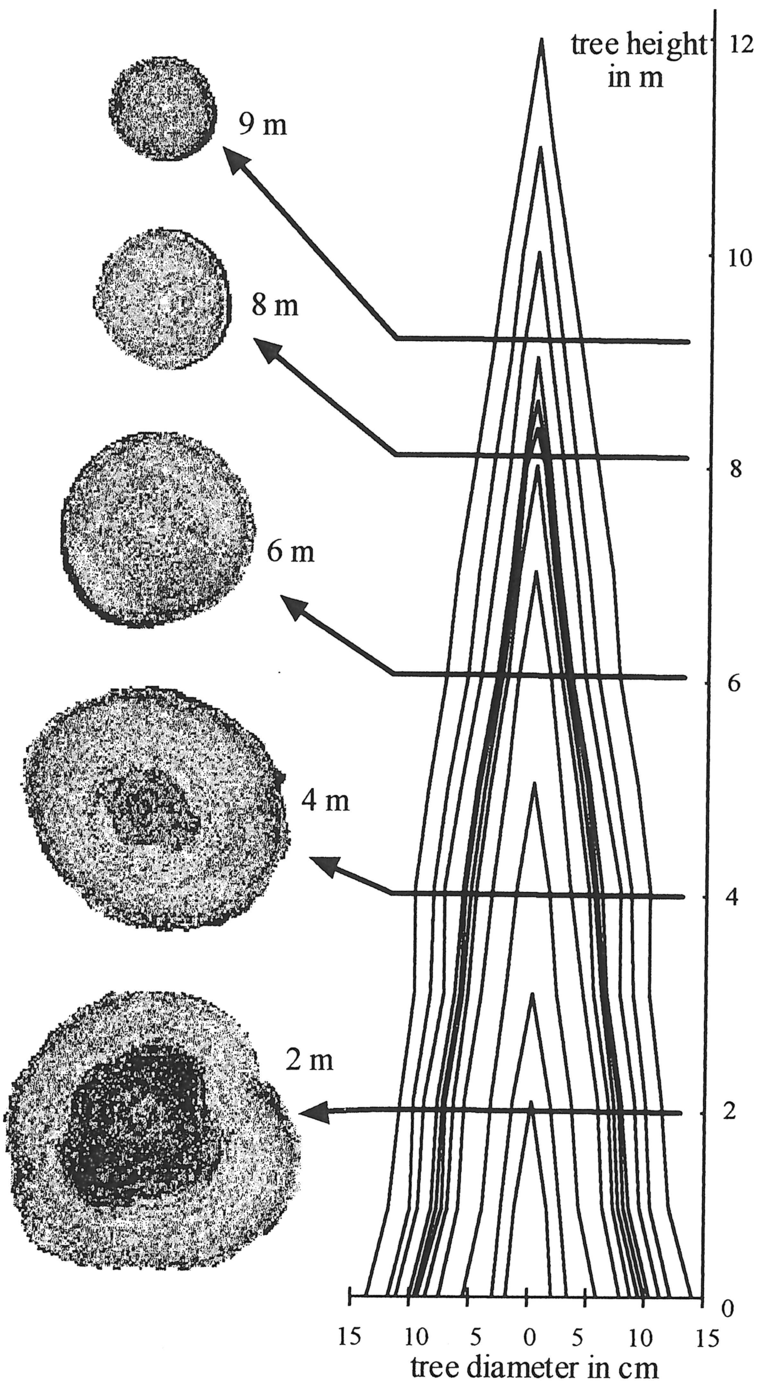


Fig. 10: Stem discs and stem shape of tree no. 113 of plot no. 1, DBH 13.1 cm height 12, Mae Moh Teak plantation.

The stem discs that were taken from tree no. 113 were specially prepared for an image scanning in the prgram WINDENDRO. The following tree analysis of every disc led to the results summarized in table 10.

Table 6: Numerical results of stem analysis of tree no. 113 from the experimental plot no. 1 in Maeh Moh plantation. DBH and tree stem volume without bark.

Age	DBH in cm	iDBH in cm	height in m	vol in dm^3	DBH form factor
1	1.40	1.40	2.0	0.29	0.9489
2	2.51	1.11	3.0	1.09	0.7370
3	4.16	1.65	5.0	4.10	0.6042
4	6.17	2.01	7.0	10.74	0.5127
5	7.01	0.84	8.0	15.93	0.5156
6	7.59	0.58	8.3	19.29	0.5113
7	7.97	0.38	8.7	21.59	0.4991
8	8.41	0.43	9.0	23.69	0.4742
9	9.47	1.06	10.0	33.33	0.4734
10	10.34	0.87	11.0	43.13	0.4671
11	11.95	1.61	12.0	62.19	0.4620

Now that for every tree age the DBH is available and the respective height, the volume of a cylinder can be calculated as

$$Vol_{DBH-cylinder} = \left({}^{DBH}\!/_{100}\right)^2 * height * {}^{\pi}\!/_{4}$$

where $Vol_{DBH\text{-}cylinder}$ is the volume in m^3 of a cylinder with the diameter DBH (here without bark). To get the real stem volume of the tree it follows with

$$Vol_{real} = Vol_{DBH-cylinder} * f_{1.3}$$

that the stem form factor $f_{1.3}$ is

$$f_{1.3} = {}^{Vol_{real}}\!/_{Vol_{DBH-cylinder}} .$$

Table 6 includes this stem form factor $f_{1.3}$ now in dependence on DBH, and the interesting relation between DBH and $f_{1.3}$ is visualized in figure 11.

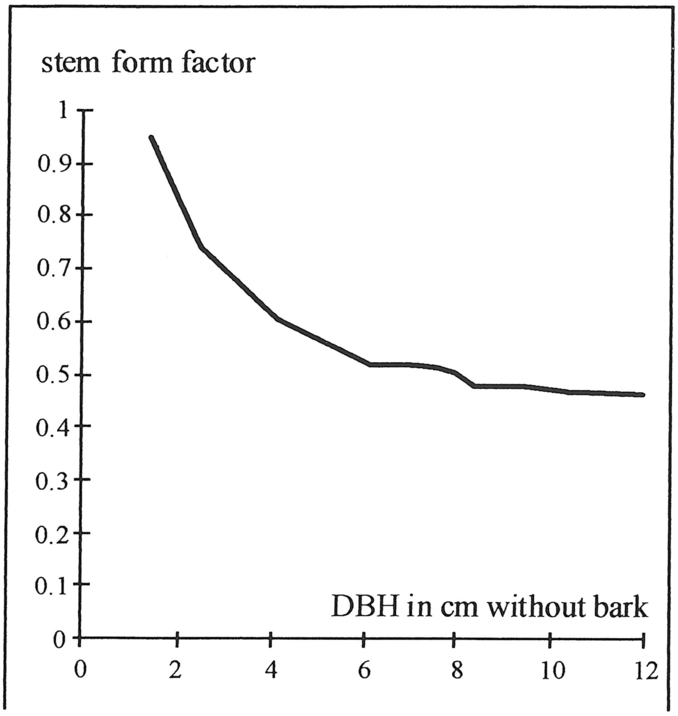


Fig. 11: Stem form factor for tree no. 113 of plot no. 1, DBH 13.1 cm height 12, Mae Moh Teak plantation.

4. Final Remarks

The objective of the establishment of experimental plots was to get empirical data for the purpose of forest growth modelling, within the restrictions of the limited time in a DSE-training course in Chiang Mai, Thailand. The availability of empirical data is indispensable for the understanding of forest dynamics. And real data are indispensable for a sustainable management of (tropical) forest resources too. The value of these data can hardly be overestimated. It is important to know that on the analysed site Teak can reach up to about 500 m^3 timber volume per ha in the age of 100 years with a basal area of approximately 32 m^2 per ha and a top height of 36 m. And it is important to know that in an age of about 28 years the respective values are 106 m^3 timber volume per ha, a basal area of about 13 m^2 per ha and a top height of 19.3 m. These values are so important because they help to define a sustainable management, where sustainability is the keyword.

In addition, if we combine the natural growth and yield data with monetary issues, the importance of forest and Teak management becomes even more evident: the youngest Teak stand, which is only 11 years old, reaches a montetary net value of about 9500 US$ per ha, the 28 years old plot has already a net value of 26000 US$ per ha, and the oldest stand may reach about 316000 US$ per ha. Even if these values are not very reliable, because of the underlying assumptions, the dependencies on overall market conditions, exchange rates or whatever, these numbers document that a sustainable forest management can contribute to the benefit of the people. Not only in an economic dimension, but at least it can.

The data that were assessed lead to the suspicion that there might be more in them than can be seen on a first glimpse. Questions that may arise are for example if we could get some information about Teak stands that are 50 or 60 years old, or how we should manage a Teak stand to optimize the benefits. An answer on these questions is to parameterize a growth and simulation model with the empirical data that were assessed exactly for this purpose (KAHN, 1998). A forest growth model is the desired extension and generalization of a limited set of data. This must be the next step.

5. Literature

BIBER, P., 1998: Numerical methods for characterizing structure and diversity applied to a natural tropical forest and an even aged Teak stand, in MIES, E. (Ed.): Natural and Socioeconomic Analysis and Modelling of Forest and Agroforestry Systems in Southeast Asia, Publication by the German Foundation for International Development, Zschortau, Germany.

KAHN, M., 1998: Modelling Teak Forest Growth and Scenario Analyses, in MIES, E. (Ed.): Natural and Socioeconomic Analysis and Modelling of Forest and Agroforestry Systems in Southeast Asia, Publication by the German Foundation for International Development, Zschortau, Germany.

PRETZSCH, H., 1992: Konzeption und Konstruktion von Wuchsmodellen für Rein- und Mischbestände, Forstliche Forschungsberichte München, Nr. 115, 358 S.

PRETZSCH, H. 1998: Models for Pure and Mixed Forests, in MIES, E. (Ed.): Natural and Socioeconomic Analysis and Modelling of Forest and Agroforestry Systems in Southeast Asia, Publication by the German Foundation for International Development, Zschortau, Germany.

ROYAL FOREST DEPARTMENT, 1992: Proceedings Teak Conference, 50th Year Anniversary of Mae Huad Teak Plantation, Ngao Lampang, Thailand, 414 p.

Appendix

Table A1: Tree data from plot no. 1, Teak stand age 11 years
DBH = diameter at breast height in cm, Height = tree height in m, CInt = crown intersection in m, CR = crown radius in m, N = North, E = East, S = south, W = West, x = x-co-ordinate in m, y = y-co-ordinate in m

Tree no	DBH	Height	CInt	CR N	CR E	CR S	CR W	x	y
101	10.3	11.2	4.5	1.0	1.0	1.1	1.5	1.0	3.2
102	9.4	11.7	3.2	1.5	0.8	1.0	1.8	4.9	0.9
103	14.0	12.3	3.7	2.0	1.0	1.0	2.3	5.0	3.1
104	12.0	12.0	3.5	1.7	0.7	1.2	1.9	9.0	1.5
105	5.9	8.6	3.1	0.8	1.2	0.7	0.9	8.9	3.3
106	20.6	13.0	2.4	3.0	2.2	2.5	2.2	12.9	3.2
107	8.1	10.4	4.1	0.9	0.8	0.9	0.6	17.8	3.0
108	15.4	12.7	3.9	2.3	2.0	2.4	2.1	21.0	3.7
109	5.0	6.1	3.5	0.9	1.0	0.4	1.3	24.9	1.0
110	11.1	11.6	3.8	1.9	2.0	1.8	1.6	24.9	3.3
111	16.8	12.0	3.9	2.0	2.0	1.8	1.4	28.9	3.3
112	5.8	7.1	3.3	0.7	0.9	0.5	1.2	28.9	4.8
113	13.1	12.0	4.3	2.3	2.6	2.2	2.3	29.1	7.2
114	11.4	11.2	3.9	1.6	1.9	2.0	1.3	24.6	7.4
115	15.6	11.9	2.4	1.6	2.7	2.5	2.5	18.0	6.8
116	6.2	9.0	3.0	0.6	1.0	1.4	1.1	17.9	4.8
117	10.2	11.2	3.4	1.5	1.7	1.8	1.8	13.2	6.9
118	5.0	3.3	1.4	0.9	0.4	0.2	0.8	13.1	5.1
119	9.7	10.1	2.9	1.8	1.2	1.7	2.0	8.8	6.1
120	4.8	4.0	1.5	0.3	0.4	3.0	0.4	8.9	9.1
121	15.1	12.0	4.4	2.4	1.8	2.8	1.9	0.9	7.3
122	19.1	13.0	3.0	1.8	2.1	1.8	2.5	1.0	11.4
123	18.0	10.8	4.8	1.4	2.5	2.8	1.5	5.1	11.1
124	16.2	11.0	3.3	2.2	1.7	2.8	3.0	9.1	11.0
125	15.8	13.2	4.4	2.1	1.4	1.4	1.4	13.3	10.9
126	4.8	6.6	2.1	0.5	0.6	0.6	0.9	13.0	8.7
127	10.0	11.0	2.5	1.4	1.1	2.2	1.4	18.1	12.0
128	15.4	11.9	3.4	1.5	1.5	2.2	1.6	21.2	11.0
129	12.2	12.2	2.6	1.2	1.2	1.6	1.4	25.2	9.0
130	7.8	10.0	3.6	0.6	0.4	0.4	0.5	25.2	11.2
131	11.2	11.4	4.1	0.8	0.6	1.6	1.5	29.3	11.5
132	9.1	10.7	3.6	1.0	0.5	1.7	1.1	25.5	13.2
133	9.0	10.8	3.3	0.7	0.6	1.5	0.7	21.4	13.7
134	7.0	7.9	3.4	1.3	0.5	0.6	0.9	13.5	13.0
135	8.1	7.8	2.5	0.8	0.6	1.2	1.7	5.5	13.3
136	13.8	10.9	2.8	2.1	2.6	2.2	1.9	1.1	15.4
137	10.2	9.5	4.0	1.5	1.4	1.0	1.6	9.1	15.3
138	6.4	7.0	2.0	1.4	1.1	1.6	1.8	13.2	15.3
139	7.6	11.0	4.5	1.4	1.2	1.4	1.4	18.2	15.2
140	11.1	11.0	5.0	1.7	1.1	1.7	1.7	21.5	15.3
141	12.5	11.0	5.0	2.0	1.5	2.2	2.3	25.6	16.4
142	11.9	12.0	4.8	2.0	2.3	2.3	2.1	29.5	15.2
143	10.6	10.0	3.4	1.7	1.5	1.6	1.6	29.6	16.9
144	4.5	10.5	3.5	0.5	0.4	0.6	0.6	25.5	17.2
145	16.3	9.5	3.8	1.2	1.1	1.3	1.0	21.5	17.2
146	5.1	7.0	2.9	0.8	0.8	0.4	0.7	9.2	17.2
147	12.7	11.2	4.0	2.2	2.3	2.4	1.9	5.7	17.0
148	14.9	11.1	4.5	2.4	2.1	2.3	2.4	1.3	19.4

149	14.9	12.0	4.9	2.1	1.6	2.3	1.7	5.7	19.0
150	12.0	10.5	3.5	2.0	2.0	1.7	1.8	9.3	19.3
151	15.3	12.0	4.5	2.4	2.3	2.5	2.5	13.9	19.4
152	14.1	11.0	4.5	2.2	2.5	2.2	1.9	18.4	19.3
153	8.0	9.5	2.0	1.7	1.3	1.6	1.2	21.6	19.5
154	13.1	10.5	4.9	2.1	1.6	2.7	2.1	25.7	19.4
155	11.5	11.0	2.5	2.7	1.8	2.2	2.7	29.7	19.8

Table A2: Data from plot no. 2, Teak stand age 28 years
DBH = diameter at breast height in cm, Height = tree height in m, CInt = crown intersection in m, CR = crown radius in m, N = North, E = East, S = south, W = West, x = x-co-ordinate in m, y = y-co-ordinate in m

Tree no	DBH	Height	CInt	CR N	CR E	CR S	CR W	x	y
201	14.0	16.1	2.0	1.9	1.8	1.6	1.8	3.8	2.7
202	29.0	21.5	4.0	3.5	5.3	2.7	3.0	15.7	1.4
203	20.5	18.5	6.1	3.4	2.5	2.5	2.9	23.6	1.7
204	16.6	14.8	3.8	1.8	1.5	1.4	1.6	26.2	2.9
205	27.0	17.8	1.8	2.7	1.3	1.4	3.4	29.8	8.3
206	7.9	11.1	2.1	1.2	1.3	1.7	1.3	23.4	8.7
207	25.3	20.1	4.1	3.1	3.6	4.2	3.5	19.5	10.0
208	18.9	14.5	2.1	2.7	3.4	4.1	2.3	13.2	8.0
209	6.4	11.0	1.6	1.3	1.2	1.1	0.8	10.8	5.3
210	8.5	11.4	3.4	2.3	1.9	1.4	1.2	11.4	9.3
211	27.2	20.3	15.4	4.1	4.0	5.0	4.3	9.9	9.1
212	17.9	18.4	7.0	1.8	1.7	1.9	1.4	7.6	7.5
213	4.8	5.0	2.6	0.7	1.1	1.3	0.8	2.7	8.2
214	21.1	19.0	4.1	2.7	3.7	3.2	2.1	0.7	10.6
215	7.1	9.0	2.1	0.9	1.1	1.0	1.0	8.0	13.0
216	5.4	5.0	2.8	1.1	1.6	1.7	1.5	9.5	12.6
217	11.1	8.4	2.8	1.8	1.7	1.5	1.8	9.0	10.1
218	7.5	6.7	1.9	0.6	1.2	1.1	0.8	12.3	13.9
219	21.4	16.3	4.0	3.2	2.3	2.2	2.9	16.7	12.3
220	6.9	5.5	1.4	1.1	1.7	2.4	2.3	16.6	10.4
221	28.4	13.0	2.8	3.6	3.2	5.2	3.6	27.9	11.5
222	21.1	17.0	8.4	3.4	3.6	2.5	2.2	29.2	12.7
223	10.7	8.3	2.7	1.5	1.4	1.2	2.1	27.6	18.7
224	7.9	6.9	2.6	1.3	1.2	1.1	1.9	23.7	15.7
225	12.9	13.1	3.8	2.9	2.0	2.7	2.7	20.3	18.9
226	6.0	6.8	2.9	0.9	1.0	1.2	1.0	14.7	16.2
227	19.7	15.3	7.4	4.1	3.3	3.3	2.8	12.5	18.1
228	21.9	17.3	5.0	3.1	2.5	4.1	2.5	10.8	17.8
229	23.3	19.0	9.8	3.7	2.5	2.7	2.7	7.7	19.2
230	18.5	17.2	6.1	1.9	2.1	3.7	2.5	6.1	17.0
231	26.5	19.9	7.1	2.5	3.1	4.5	3.8	1.6	18.3
232	22.7	20.0	7.8	3.7	3.4	2.4	3.9	2.0	22.2
233	24.7	18.7	6.7	3.6	2.6	2.3	4.1	2.6	24.7
234	23.3	19.6	3.1	3.6	3.8	3.2	1.8	5.4	24.1
235	9.8	11.5	3.7	1.9	2.0	2.3	1.6	14.2	20.0
236	9.1	12.3	3.5	1.4	1.5	1.6	1.5	15.9	22.6
237	20.0	16.4	3.4	2.2	2.7	4.3	2.9	14.3	21.6
238	28.3	18.9	8.7	4.7	4.5	4.1	4.6	20.7	23.0
239	19.4	16.6	6.7	3.1	3.7	3.5	1.4	21.7	25.4
240	5.8	6.6	1.6	1.0	1.2	1.2	1.2	14.2	24.5
241	23.0	18.0	7.5	2.9	3.4	3.7	3.2	11.5	28.2
242	22.3	17.7	7.3	3.9	1.8	2.7	3.3	3.0	29.5

Table A3: Tree data from plot no. 3, Teak stand age 100 years
DBH = diameter at breast height in cm, Height = tree height in m, CInt = crown intersection in m, CR = crown radius in m, N = North, E = East, S = south, W = West, x = x-co-ordinate in m, y = y-co-ordinate in m

Tree no.	DBH	Height	CInt	CR N	CR E	CR S	CR W	x	y
301	56.9	33.2	21.4	9.1	2.9	3.5	5.4	4.8	2.7
302	66.4	33.0	20.0	12.2	8.5	7.2	10.2	5.3	5.7
303	62.9	37.3	19.0	9.0	6.3	8.0	11.5	12.8	5.4
304	54.2	36.5	18.5	7.7	8.5	8.0	6.8	21.1	1.5
305	12.3	8.5	3.0	2.1	1.9	2.0	2.5	21.8	0.6
306	73.3	42.2	19.7	12.0	9.4	7.9	6.8	16.8	11.0
307	24.7	21.3	8.8	2.7	5.5	5.2	3.0	20.6	14.5
308	53.7	35.2	17.2	8.5	8.0	6.3	7.5	18.5	16.3
309	53.9	36.0	22.0	6.7	6.0	7.2	6.0	3.1	15.9
310	51.7	38.0	19.0	3.8	4.0	4.7	1.9	5.9	22.5
311	4.4	4.0	3.0	0.6	0.6	1.6	0.6	10.8	15.9
312	2.3	3.0	2.0	6.0	0.8	0.5	0.4	8.2	18.7
313	4.9	6.0	3.0	0.9	1.0	1.0	0.7	11.9	20.5
314	9.0	3.7	1.0	0.8	0.8	0.9	0.7	15.6	22.2
315	3.3	3.3	1.8	0.4	0.5	0.5	0.4	17.0	21.5
316	54.2	26.5	8.2	4.9	0.7	6.0	7.0	17.2	22.6
317	2.3	2.5	1.5	0.4	0.5	0.4	0.3	25.0	21.3
318	4.3	3.3	1.3	0.8	1.2	0.8	0.3	27.0	25.2
319	4.6	5.5	4.3	0.8	0.9	0.6	0.6	25.2	24.6
320	4.3	5.0	2.3	0.1	1.0	0.6	0.4	22.6	24.1
321	4.0	3.5	1.5	0.6	0.3	0.4	0.7	14.4	25.5
322	42.7	33.0	13.0	6.5	4.4	5.6	8.4	2.7	27.4
323	56.8	34.0	20.0	7.6	11.0	7.4	8.4	12.2	20.0
324	5.8	7.5	2.5	0.7	1.0	1.0	0.4	16.1	27.7
325	5.6	6.5	3.0	0.9	1.2	0.7	0.6	26.0	29.6
326	3.0	4.0	1.8	0.2	0.3	0.3	0.2	28.4	9.9
327	5.0	4.0	2.0	0.6	0.8	0.5	0.9	28.2	10.8

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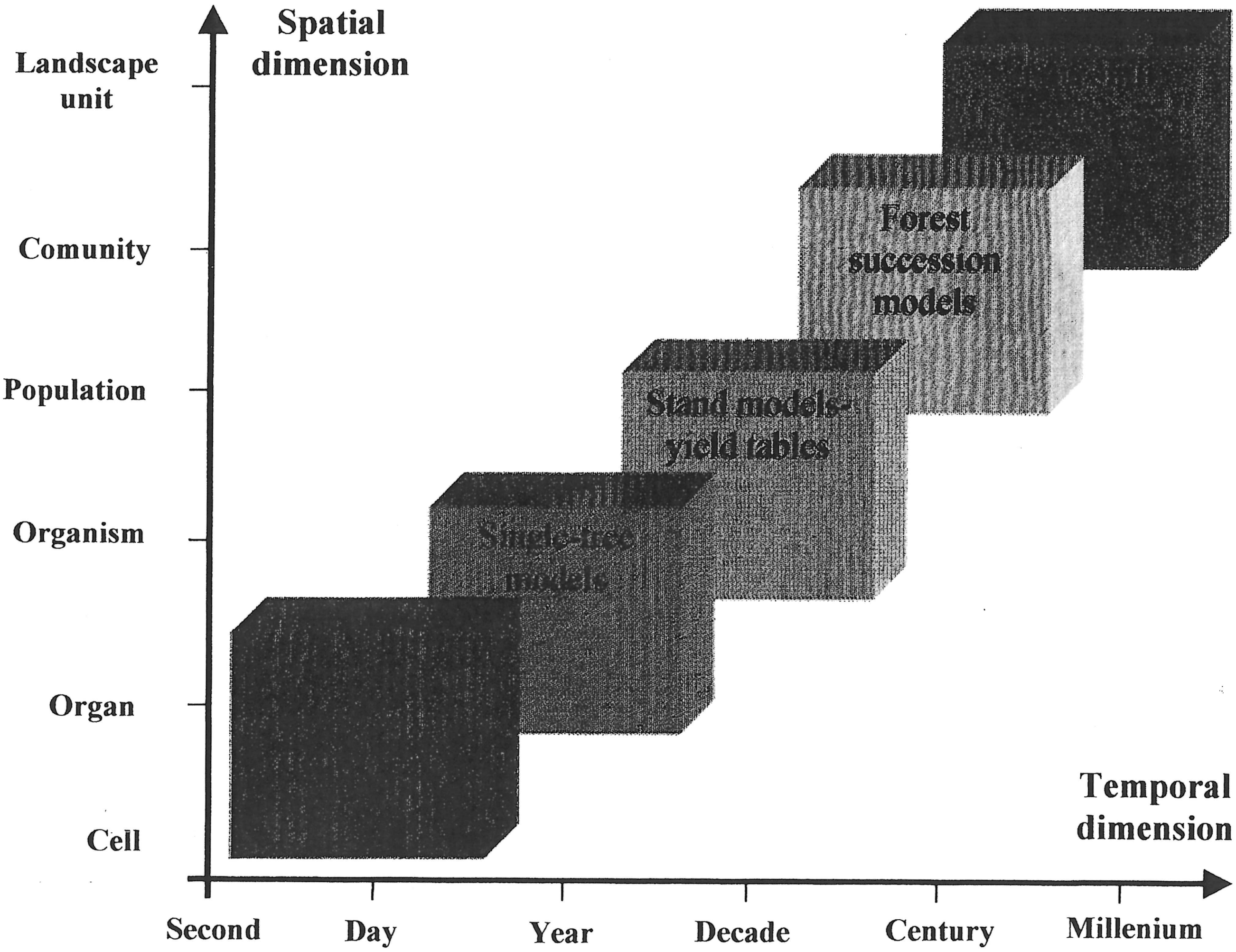

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Table of Contents