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GROWTH AND PRODUCTIVITY OF TEAK PLANTATIONS IN DACLAC

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1. INTRODUCTION

In Dac lac teak plantations were first established in the early 1950's years, some of which are of undermature age (at Eakmat there are 43-year old plantations), some others are about 20 years old. There have been many publicaions on teak, but for effective exploitation of teak plantation it is still necessary to tackle the following issues: identification of adequate silvicultural techniques, planting intensiveness, growth, sustainable management, and stable development.

In order to find out some answers to the above questions and meet the objectives of teak plantation development a research project on growth and yield prediction of teak plantations has been carried out by the University of Tay Nguyen for several last years. As a result growth and yield models have been developed and can be introduced into teak planting practice to predict growth and yield, identify suiable silvicultural measures such as initial spacing, thinning operations, final optimal density and target volume for several teak planting sites in Dac Lac. This should be considered as a step towards improving technology of planting teak for the whole region of Tay Nguyen and a basis for teak plantation management.

2. NATURAL CONDITIONS OF THE RESEARCH REGION

Climatic data and soil samples presented below were collected at five representative areas planned to be used for planting teak in Dac Lac province: Eakmat Forest Seed Enterprise, Buon gia vam Forestry Enterprise, Krong Ana, Duc lap, and Nam nung.

- Average annual rainfall: 1400-1800 mm, moisture index K = 0.5-2.0
- Average annual temperature: 22-24°C
- Topography flat or hillsides with slopes up to 12°
- Altitude: 400-600 m asl

and the soil types include:

- Red-brown ferralitic soil derived from basalt
- Yellow-red ferralitic soil derived from basalt

- Purple-brown ferralitic soil derived from basalt
- Yellow- brown ferralitic soil derived from basalt
- Yellow-red ferralitic soil derived from limestone

3. METHOD

42 Temporary standard plots sized 1000m^2 each were established in the studied plantations varied in their growth rate and age. Average trees from each plot were cut and analysed; tree height (H), diameter (D), canopy radius (Rt), Kraft grade, and quality of each plot were fully measured and assessed. The total number of analysed trees was 48.

The growth process was modelized through several perspective functions such as of Schumacher, Gompertz, Korf, etc. The dominant storey height growth curves (Ho-A (age) indicating site classes after Schumacher's function:

$$Ho = a. EXP(-b.A^{-m})$$

were divided by fixing parameter m while changing the two other, a and b.

The interrelations and laws of change of the measurement factors were imitated through mathematical models, in which empirical equations were selected and built on the basis of the tendency of relation between the dependent variate and the independent ones.

The parameters of regressive functions were estimated with the use of linear regressive method through minimum square and Marquart's unlinear regressive method through minimizing the total square of the excesses.

4. RESULTS AND DISCUSSION

Site classification

The collected data show that teak plantations established at different sites in Dac Lac significantly vary in the growth rate and yield, and for effective management and plantation yield prediction it is necessary to classify the planting sites according to their quality and identiify appropriate techniques of each of the site class. Thus, based on the variation of the dominant storey height Hø and the applicability of the site classification concept three site classes have been distinguished after the dominant storey average growth Ho-A (age) of Schumacher's equation:

$$Ho = ai. EXP(-bi.A^{-0.790}) \quad (1)$$

where ai and bi are parameters which change according to the site classes (Table 1).

Table 1. Values of the parameters ai and bi of equation(1)

Site classi	I	Class limit	II	Class limit	III
ai	34.3046	31.297	28.586	25.905	23.338
bi	4.669	4.782	4.979	5.176	5.528

The values of Ho of each site class after plantation ages are presented in Table 2.

Table 2. Values Ho of the site classes after plantation ages

Age, year	Ho, m				
	Site class I	Class limit	Site class II	Class limit	Site class III
4	7.1	6.3	5.4	4.6	3.7
6	11.0	9.8	8.5	7.4	6.1
8	13.8	12.4	10.9	9.5	8.0
10	16.0	14.4	12.7	11.2	9.5
12	17.7	16.0	14.2	12.5	10.7
14	19.1	17.3	15.4	13.6	11.7
16	20.2	18.3	16.4	14.5	12.6
18	21.2	19.2	17.2	15.3	13.3
20	22.0	20.0	17.9	15.9	13.9
22	22.7	20.6	18.5	16.5	14.4
24	23.3	21.2	19.1	17.0	14.9
26	23.9	21.7	19.6	17.5	15.3
28	24.3	22.2	20.0	17.9	15.7
30	24.8	22.6	20.4	18.2	16.0
32	25.2	23.0	20.7	18.5	16.3
34	25.5	23.3	21.0	18.8	16.6
36	25.9	23.6	21.3	19.1	16.8
38	26.2	23.9	21.6	19.3	17.1
40	26.4	24.1	21.8	19.6	17.3

Growth and yield prediction

Growth and yield predictions are needed to identify adequate silvicultural measures and forest management to ensure high econimic effciency in foretry exploitation.

Optimal density (Nopt) and density change

In even-age monospecies plantation forestry plantation density control is an important silvicultural measure to meet the management objectives, plan thinning operations, and predict density change and yield. Optimal density in this research was determined in accordance with the objectives of large-timber plantations, taking plantation age and site class as its units, on the basis of the average foliage square (Sopt) of a tree satisfying management objectives after the equations:

$$\text{Ln (Sopt)} = 0.922 + 0.754.\ \text{Ln (Ho)} \qquad (2)$$

$$\text{Nopt} = 10^4/2.514\ \text{Ho}^{0.754} \qquad (3)$$

The Site Class Table is combined to calculate corresponding Nopt and predict density change needed for each site class , including after-thinning density (i.e the optimal density) and number of trees to be thinned.

Timing thinning operations

According to the current regulation of establishment of industrial plantation the initial density of teak planting is 1700 trees/ha for site classes I and II (spacing 3 x 2 m) and 2 200 trees/ha for site class III (spacing 3 x 1.5 m). If agroforestry system is chosen then the initial density must be 800-1200 trees/ha. The first thinning should be done when the plantation reaches maximum diameter increment (referred as to Zd mzx). Our investigation has shown that teak plantations reach Zd max very early, usually at age 5-10 years depending on the site class. Timing of the first thinning, however, still depends upon whether small log is aimed at from this operation. It was found that the first thinning timed for site classes I, II and III was at age 8, 10, and 12 years, respectively.

The next thinning was determined by using the following equation:

$$\text{Ho} = 5.941\ /\ (1.647\ -\ 31.539/\ \sqrt{\text{N}}\ ) \qquad (4)$$

where N is the previous after-thinning density.

Knowing N we can estimate Ho at the moment when the next thinning should be done, then find thinning age after the Site Class Table. For teak plantations the next thinning must be carried out when the total canopy area (St) reaches 13000 m^2/ha, ie when the plantation volume growth is maximal, and it should reduce to 10000 m^2/ha. It was found that for site classes I and II the appropriate interval between two thinnings was 7 and 10 years, respectively, but for site class III the estimated Ho was beyont the age limits of the established Site Class Table and thinning interval could not be determined.

Yield Table

An Yield Table has been established for each of the three site classes in which the law of change of the measurement factors such as density N, average diameter Dg, average height Hg, total cross area $\sum G$, volume M, regular increment Zm, average increment Δ m, and portion volume increment Pm is reflected (Table 3). Based on the Site Class Table (Ho - A), law of density change and the thinning coefficient, the values of the measurement factors in the Yield Table have been calculated through the following equations:

$$Hg = -0.725 + 0.933\ Ho \quad (5)$$

$$LnG = -1.617 + 1.433\ LnHo + 0.088N/100 \quad (6)$$

$$Dg = 112.8 \sqrt{G/N} \quad (7)$$

$$LnM = 0.037 + 0.974\ LnG + 0.788\ LnHo \quad (8)$$

where Dg is in cm and G in m^2.

Practically it may not be necessary to find yield values after the Yield Table, but to determine the density before the first thinning, the site class of the plantation and the thinning coefficient, then the average growth values can be quickly predicted each time through the above equations.

Teak is a relatively fast-growing species. In Dac Lac the growth rate of teak during the first 20 years is as follows:

- Dg increment, cm/year: 0.9-1.3, the average being 1.1
- Hg increment, m/year: 0.7-1.1, average: 0.9
- Volume increment, m^3/year: 7-16, average: 11

Teak plantations with rotation 15-20 years on site lasses I - III can yield 210-130 m^3/ha log with Dg 25-18 cm and Hg 19-13 m from the final logging depending on the site class.

Table 3: Yield Table of teak plantations on site class II

	Tending part					Thinning part			Accumulative part				
A 1	N 2	Dg (cm)	Hg (m)	ΣG (m^2/ha)	M (m^3/ha)	ΣN 2	ΣG (m^2/ha)	ΣM (m^3/ha)	ΣΣG (m^2/ha)	ΣM (m^3/ha)	ZΣm (m^3/ha năm)	AΣm (m^3/ha/ năm)	PΣm (%)
4	900	8.3	4.6	4.9	19				4.9	19		4.6	
6	900	11.6	7.7	9.5	50				9.5	50	15.8	8.4	46.1
8	900	13.8	10.1	13.5	86				13.5	86	17.8	10.7	26.2
10	584	16.8	11.9	13.0	94	316	3.9	27	16.8	12.1	17.4	12.1	16.8
12	584	18.1	13.4	15.1	118				19.0	145	12.2	12.1	9.2
14	584	19.2	14.6	16.9	141				20.8	167	11.2	12.0	7.2
16	584	20.1	15.5	18.5	161				22.3	188	10.1	11.7	5.7
18	584	20.8	16.4	19.8	179				23.7	206	9.1	11.4	4.6
20	451	23.3	17.1	19.2	181	449	5.6	41	24.8	222	8.2	11.1	3.8
22	451	23.9	17.7	20.2	193				25.7	234	6.1	10.6	2.7
24	451	24.3	18.2	21.0	205				26.6	247	6.1	10.3	2.5
26	451	24.8	18.7	21.7	216				27.3	258	5.6	9.9	2.2
28	451	25.1	19.1	22.4	227				28.0	268	5.1	9.6	1.9
30	409	25.5	19.5	20.8	214	491	7.7	63	28.5	277	4.7	9.2	1.7
32	409	25.8	19.8	21.3	223				29.1	286	4.4	8.9	1.5
34	409	26.1	20.2	21.8	230				29.5	294	3.8	8.6	1.3
36	409	26.3	20.4	22.3	237				30.0	301	3.5	8.3	1.2
38	409	26.6	20.7	22.7	244				30.4	307	3.3	8.1	1.1
40	389	26.8	20.9	21.9	238	511	8.9	75	30.8	313	31	7.8	1.0

5. CONCLUSIONS AND RECOMMENDATIONS

- Teak grows straight even when planted scatteredly. It is recommended to manipulate canopy closure of plantations at age 5-8 years if the planting density was 1700-2200 tress/ha for monospecies planting, or 700-1100 trees/ha for agroforestry planting on sites classified as from I to III. So during the first 1-4 years agroforestry approach can be applied to intensify landuse, reduce tending costs and facilitate protection.
- Test on management of small-and medium-log plantations should be carried out in order to shorten rotation period and increase number of exploitation cycles, and technology of small and medium log processing should be introduced.
- As mentioned above, teak grows relatively fast, provides 7-16m^3/ha/year, its rotation could be rather short, and its timber is of high economical value. It is, therefore, recommended to elaborate a plan for expanding teak planting at a worthy scale, by the government agencies and community forestry as well. Results obtained from this case study are applicable to research as the established predicting models well correspond with the surveyed and statistically processed data. However, additional data are needed to check up the formulated Site class and Yield Tables, assess errors and consider the possibility of broadening their application.
- In order to develop teak plantation in our country it is recommended to carry out further research on provenance selection, tree improvement, improvement of silvicultural techniques, mixed planting, agroforestry models.

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