ANALYSIS OF GROWTH PLOTS DATA FOR THE STATE OF TERENGGANU

INTRODUCTION

In the species-rich tropical forests, the most appropriate form of management is to rely on natural regeneration to provide the future crop through selective felling of the mature crop. Following the Selective Management System (SMS), as practiced in Peninsular Malaysia, advanced growth of 30-45 cm diameter at breast height (dbh) is expected to produce the next harvest. Therefore it is important to note that residual stands must be adequate in quantity and of a specific quality to ensure a future yield that is both economical and sustainable in the long term.

An understanding of the distribution, regeneration status and growth potential of logged-over forests is important in ensuring the sustainable production of timber. An assessment of the residual stocking and development status of logged-over forests was carried out by examining the data obtained from growth plots that have been established in the State of Terengganu since 1992. Based on the enumeration of data obtained from these plots, the results of the analysis are discussed with particular reference to their implications on future production.

METHODOLOGY

Site description

The growth plots in the State of Terengganu were located in three (3) forest districts namely North Terengganu Forest District, West Terengganu Forest District and South Terengganu Forest District. A total of eight (8) Growth Plots of were established. These plots were established based on the following characteristic, namely; (i) located in the Permanent Reserve Forest, (ii) number of years after logging to sufficiently represent the different stages of forest development after logging and (iii) available information on Pre-Felling Inventory and Post-Felling Inventory for the purpose of stocking and species comparison. The size of each plot is one (1) hectare with 25 sub-plots of 20m x 20m and 9 sub-plots of 10m x 10m. In the 20m x 20m sub-plots all trees 10cm dbh and above were measured while in the 10m x 10m sub-plots all trees 5cm-10cm dbh were measured. (Forestry Department Peninsular Malaysia 1992). The background information of the Growth Plots in the State of Terengganu is shown in Table 1.

The first enumerations were made in 1992 and here since being re-measured seven times. The years 2004 was used as the reference year in relation to the year that the compartment was logged. The definitions of original forest in terms of good, moderate and poor were based on the Second National Forest Inventory 1981-1982. (Forestry Department Peninsular Malaysia 1987).

RESULTS AND DISCUSSION

Only trees that were alive, of good physical standing, and with complete stem and crown were considered. Trees that had fallen, or with broken tops and stumps, were not taken into consideration as they might not be able to contribute to the next harvest. All plots have been enumerated since 1992. Only the results of the last enumeration and only trees greater than 10 cm dbh and 30 cm dbh are shown (Setje-Eilers 2001).

Table 1. Information on growth plots

Location of Forest Reserve	Status of Original Forest	Years After Logging	Logging Strata
Compt. 9, Bukit Bauk	Good	52	Above 51
Compt. 22, Bukit Bauk	Good	43	41-50
Compt. 92, G.Tebu	Good	39	31-40
Compt. 8, Telemong	Poor	39	31-40
Compt. 26, Ulu Setiu	Moderate	32	31-40
Compt. 67, Ulu Besut	Moderate	30	21-30
Compt. 22, Jeranggau	Moderate	24	21-30
Compt. 6, Bukit Bauk	Moderate	21	21-30

Number of Stems Per Hectare

The results on number of stems per hectare for dipterocarps and commercial non-dipterocarps are shown in Tables 2 and 3, respectively. The dipterocarps show the highest number of stems of 54 stem/ha in the 20<30 cm diameter class and the lowest 4 stem/ha in the >60 cm diameter class. As for the commercial non-dipterocarps it showed a drastic decrease with the number of years after logging from 234 stem/ha in the 10<20 cm diameter class to 4 stems/ha in the >60 cm diameter class.

The results indicate that the bulk of stems in logged-over forests are in the diameter class of 10 to 40 cm dbh. This was due to the fact that trees >45 cm dbh would have been logged and the trees that appear in these diameter classes are ingrowth from the years after logging. It is also observed that on average all the compartments recorded a residual stand containing commercial species having size 30cm dbh and larger exceeding 32 trees/ha which is the threshold set under the Selective Management System.

Table 2. Mean no. of stems (ha^{-1}) for dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	68	94	18	30	14.4	9.6	234
Compt. 22, Bukit Bauk	144	166	43	13	8.4	5.6	380
Compt. 92, G.Tebu	11	24	19	10	10.8	7.2	82
Compt. 8, Telemong	30	31	15	6	2.4	1.6	86
Compt. 26, Ulu Setiu	2	2	4	1	0	0	9
Compt. 67, Ulu Besut	2	8	6	0	1.2	0.8	18
Compt. 22, Jeranggau	19	37	9	7	3.6	2.4	78
Compt. 6, Bukit Bauk	21	71	33	19	1.8	1.2	147
Average	37	54	18	12	6	4	129

Table 3. Mean no. of stems (ha^{-1}) for commercial non-dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	88	81	14	4	1	0	188
Compt. 22, Bukit Bauk	137	138	32	10	4	2	323
Compt. 92, G.Tebu	180	222	61	28	9	6	506
Compt. 8, Telemong	435	159	53	22	8	5	682
Compt. 26, Ulu Setiu	634	206	63	25	5	4	937
Compt. 67, Ulu Besut	166	239	56	17	10	6	494
Compt. 22, Jeranggau	120	174	48	19	8	6	375
Compt. 6, Bukit Bauk	112	243	62	10	2	2	431
Average	234	183	49	17	6	4	492

Basal Area (m^2/ha)

The results of basal area per hectare for dipterocarps, and commercial non-dipterocarps, are shown in Tables 4 and 5, respectively.

The results on basal area for dipterocarps showed a gradual increase in basal area with the number of years after logging from 0.45 m^2/ha in the 10<20 cm diameter class to 3.18 m^2/ha in the 50<60 cm diameter class. As for the commercial non-dipterocarps, it showed highest basal area of 6.58 m^2/ha in the 20<30 cm diameter class and then a gradual decrease to 1.79 m^2/ha in the >60 cm diameter class. This may due to greater competition for dipterocarps which occupy most of the upper storey.

Table 4. Basal area (m^2/ha) for dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	0.83	3.32	1.83	6.78	7.35	4.90	25.01
Compt. 22, Bukit Bauk	1.78	5.73	4.36	2.67	4.33	2.88	21.75
Compt. 92, G.Tebu	0.13	0.93	2.08	2.01	6.49	4.32	15.96
Compt. 8, Telemong	0.30	1.02	1.47	1.39	1.10	0.74	6.02
Compt. 26, Ulu Setiu	0.03	0.09	0.48	0.28	0.00	0.00	0.88
Compt. 67, Ulu Besut	0.03	0.29	0.59	0.00	0.76	0.50	2.17
Compt. 22, Jeranggau	0.27	1.29	0.82	1.39	1.70	1.14	6.61
Compt. 6, Bukit Bauk	0.26	2.68	3.55	4.05	0.56	0.37	11.47
Average	0.45	1.92	1.90	2.65	3.18	2.12	11.23

Table 5. Basal area (m^2/ha) for commercial non-dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	1.97	4.74	2.43	2.54	0.19	0.12	11.99
Compt. 22, Bukit Bauk	1.65	4.20	3.17	1.92	1.65	1.10	13.69
Compt. 92, G.Tebu	2.18	8.29	6.29	5.70	4.03	2.69	29.18
Compt. 8, Telemong	2.85	5.51	5.82	4.83	2.84	1.89	23.74
Compt. 26, Ulu Setiu	4.19	7.15	6.39	5.03	2.68	1.78	27.22
Compt. 67, Ulu Besut	2.04	8.06	5.93	3.84	5.00	3.33	28.2
Compt. 22, Jeranggau	1.59	6.04	5.17	4.22	4.21	2.80	24.03
Compt. 6, Bukit Bauk	1.44	8.65	6.21	1.99	0.86	0.57	19.72
Average	2.12	6.58	5.18	3.76	2.68	1.79	22.22

Volume (m^3/ha)

The results of the volume per hectare for dipterocarps and commercial non-dipterocarps are shown in Tables 6 and 7, respectively**.** The results on volume for dipterocarps showed that the volume increases from the lower 10<20 cm diameter class at 2.9 m^3/ha to the highest at 48.1 m^3/ha in the 50<60 cm diameter class and decreases to 32.1 m^3/ha in the >60 cm diameter class. As for the commercial non-dipterocarps, the trend is exactly the opposite i.e the highest at 66.5 m^3/ha in the 20<30 cm diameter class and decreases to 24.3 m^3/ha in the >60 cm diameter class. This may due to greater competition from dipterocarps which have grown taller and bigger in size and dominated the upper storey.

Table 6. Volume (m^3/ha) for dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	5.3	33.7	21.2	87.2	112.56	75.04	335.0
Compt. 22, Bukit Bauk	11.4	58.0	51.1	34.8	64.1	42.8	262.2
Compt. 92, G.Tebu	0.8	9.6	24.2	25.6	100.1	66.8	227.1
Compt. 8, Telemong	1.6	10.2	16.9	17.4	16.0	10.6	72.7
Compt. 26, Ulu Setiu	0.2	0.9	5.6	3.6	0.0	0.0	10.3
Compt. 67, Ulu Besut	0.2	3.0	6.7	0.0	11.1	7.4	28.4
Compt. 22, Jeranggau	1.8	13.0	9.3	17.3	25.8	17.2	84.4
Compt. 6, Bukit Bauk	1.7	27.7	41.7	50.1	7.2	4.8	133.2
Average	2.9	19.5	22.1	33.7	48.1	32.1	144.2

Table 7. Volume (m^3/ha) for commercial non-dipterocarps

Location of Forest Reserve	Diameter Class (cm) 10<20	20<30	30<40	40<50	50<60	>60	Total
Compt. 9, Bukit Bauk	12.9	47.3	24.5	28.9	2.3	1.56	117.5
Compt. 22, Bukit Bauk	10.4	41.0	32.0	22.0	22.5	15.0	142.9
Compt. 92, G.Tebu	13.8	85.5	65.5	65.7	55.4	37.0	322.9
Compt. 8, Telemong	12.6	55.9	60.3	55.6	36.3	24.2	244.9
Compt. 26, Ulu Setiu	18.2	72.3	65.9	57.5	37.3	24.9	276.1
Compt. 67, Ulu Besut	13.1	81.0	61.3	44.1	67.0	46.6	316.1
Compt. 22, Jeranggau	10.7	61.1	53.7	49.1	56.8	37.9	269.3
Compt. 6, Bukit Bauk	9.5	88.0	63.8	23.0	11.1	7.4	202.8
Average	12.7	66.5	53.4	43.2	36.1	24.3	236.6

Diameter Increment

Table 8 shows the summary of mean annual diameter increment for both dipterocarp and commercial non-dipterocarp while Table 9 and 10 show mean annual diameter increment by locations.

Table 8. Mean annual diameter increment of dipterocarps and commercial non-dipterocarps by diameter class

Species Group	Diameter Class (cm)					
	10<20	20<30	30<40	40<50	50<60	60<70
Dipterocarps	0.26	0.62	0.65	0.66	0.67	0.67
Commercial Non-Dipterocarps	0.18	0.26	0.33	0.35	0.36	0.34
Mean	0.22	0.44	0.49	0.51	0.51	0.51

Table 9. Mean annual diameter increment (cm) for dipterocarps

Location of Forest Reserve	Diameter Class (cm) and No. of Tree (n)											
	10<20	**(n)**	**20<30**	**(n)**	**30<40**	**(n)**	**40<50**	**(n)**	**50<60**	**(n)**	**60<70**	**(n)**
Compt. 9, Bukit Bauk	0.21	145	0.27	40	0.46	14	0.48	15	0.60	16	0.60	10
Compt. 22, Bukit Bauk	0.15	270	0.32	72	0.26	26	0.35	10	0.42	11	0.99	1
Compt. 92, G.Tebu	0.08	30	0.24	17	0.42	14	0.45	9	0.48	5	0.54	7
Compt. 8, Telemong	0.27	51	0.75	17	1.25	8	1.11	3	1.23	2	1.30	1
Compt. 26, Ulu Setiu	0.23	4	0.80	2	0.91	2	1.07	2	0	0	0	0
Compt. 67, Ulu Besut	0.55	14	1.40	6	0	0	0	0	0	0	0	0
Compt. 22, Jeranggau	0.37	56	0.84	11	0.85	4	0.67	4	0.67	4	0.52	1
Compt. 6, Bukit Bauk	0.24	65	0.32	39	0.41	26	0.50	15	0.64	8	0.07	2
Average	0.26	79	0.62	26	0.65	13	0.66	8	0.67	8	0.67	4

The mean annual diameter increment of dipterocarps ranges from 0.26 cm/year in the 10<20 cm diameter class to 0.67 cm/year in the 60<70 cm diameter class. This indicates that the diameter of dipterocarps increases with higher diameter class which is in accordance with the fact that dipterocarps are more dominant in terms of basal area and volume in the higher diameter class. The results of growth and yield study in Gunung Tebu Forest Reserve, Terengganu for the period 1974 – 1988 showed that the mean annual diameter increment for dipterocarps at 30cm dbh

and above is 0.56 cm/year and for non-dipterocarps at 0.37 cm/year (Yong 1998). The results of growth and yield study in Angsi Forest Reserve in Negeri Sembilan for the period 2001-2005 showed that the mean annual diameter increment for dipterocarps at 30cm dbh and above is 0.72 cm/year and for non-dipterocarps at 0.52 cm/year (Frisco *et al*. 2006).

The mean diameter increment of non-dipterocarps ranges from 0.18 cm/year in the 10<20 cm diameter class to the highest of 0.36 cm/year in the 50<60 cm diameter class (Table 10). This suggests that diameter increment of non-dipterocarps increases at a lower rate when compared to dipterocarps. As the number of years after logging increases dipterocarps will slowly dominate over the non-dipterocarps in terms of basal area and volume in the higher diameter classes.

The present cutting limits for both dipterocarps and non-dipterocarps commercial is capped at 65 cm dbh for dipterocarps and 55 cm dbh for commercial non-dipterocarps.

Table 10. Mean annual diameter increment (cm) for non-dipterocarps

Location of Forest Reserve	Diameter Class (cm) and No. of Tree (n)											
	10<20	**(n)**	**20<30**	**(n)**	**30<40**	**(n)**	**40<50**	**(n)**	**50<60**	**(n)**	**60<70**	**(n)**
Compt. 9, Bukit Bauk	0.14	288	0.28	64	0.29	21	0.25	7	0.23	6	0	0
Compt. 22, Bukit Bauk	0.10	267	0.26	61	0.27	25	0.31	10	0.35	4	0.30	2
Compt. 92, G.Tebu	0.13	342	0.20	123	0.35	56	0.67	19	0.43	12	0.24	7
Compt. 8, Telemong	0.22	226	0.27	67	0.27	40	0.52	18	0.54	15	0.43	5
Compt. 26, Ulu Setiu	0.19	307	0.28	91	0.37	42	0.36	18	0.16	10	0.50	6
Compt. 67, Ulu Besut	0.17	409	0.25	107	0.37	33	0.20	14	0.26	14	0.41	6
Compt. 22, Jeranggau	0.28	313	0.32	68	0.44	23	0.37	17	0.45	8	0.42	5
Compt. 6, Bukit Bauk	0.19	263	0.21	122	0.27	42	0.13	11	0.42	7	0.11	2
Average	0.18	302	0.26	88	0.33	35	0.35	14	0.36	10	0.34	5

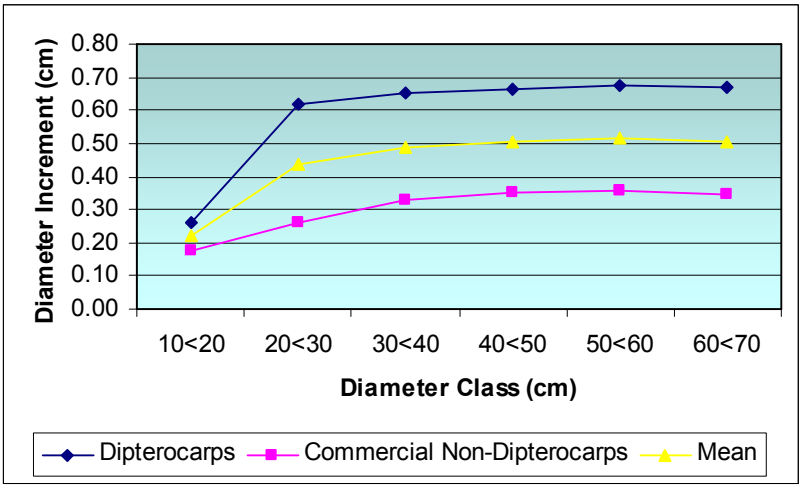

Figure 1. Mean annual diameter increment of dipterocarps and commercial non-dipterocarps by diameter class

Species Composition

Species composition of the eight growth plots in the State of Terengganu for the 10 most common species is shown in Table 11.

In term of species composition, Kelat topped the list with 22%, followed by Dipterocarps are ranked 2nd at 21%, Kapur at 11% while Medang at 7%. However, in term of stocking, basal area and volume, dipterocarps contributed 40 trees/ha or 6.37 % of trees >30cm dbh; 9.85 m^2/ha or 28.69% and 136 m^3/ha or 34.5%, respectively. This trend is very similar in all our natural or logged-over forests where dipterocarps have formed dominant residual stands over time.

Table 11. Species composition of the growth plots

Group of Species	Percentage (%)
Kelat *(Syzygium* spp.*)*	22
Dipterocarps-Meranti (*Shorea* spp.)	21
Kapur *(Drybalanops aromatica*)	11
Medang *(Cinnamomum* spp.*)*	7
Nyatoh *(Palaquium* spp.*)*	5
Keruing (*Dipterocarpus*)	4
Merawan (*Hopea spp*)	4
Bintangor (*Calophyllum spp*)	2
Kempas, Tualang (*Koompasia spp*)	2
Melunak (*Pentace spp*)	2

Mortality

The mortality rates are shown in Table 12. The overall mortality rate of the growth plots study areas in the State of Terengganu ranges from 0.12 % to 1.60% with the mean of 0.48% (>21 years after logging). In comparison, results of mortality rates from studies conducted by the Malaysia-ITTO Project at Lesong and Sungai Lalang Forest Reserves from 1988-2002 showed that the mortality rate was between 0.5 – 3.2% (5 to 8 years after logging) and 0.4- 2.1% (unlogged areas). It was observed that mortality rates are usually high immediately after logging but with time the mortality will decrease to the normal level. The results from the growth plots in Terengganu showed that the forest is getting towards the equilibrium state as it was logged much earlier compared to the ITTO study areas.

Table 12. Mortality rates (%)

Location	Mortality Rate (%)				
	10<30 (cm)	30<50 (cm)	50<70 (cm)	>=70 (cm)	Total
Compt. 9, Bukit Bauk	0.162	0.004	0.000	0.000	0.166
Compt. 22, Bukit Bauk	0.276	0.007	0.000	0.000	0.283
Compt. 92, G.Tebu	0.123	0.004	0.002	0.000	0.128
Compt. 8, Telemong	0.879	0.004	0.000	0.000	0.883
Compt. 26, Ulu Setiu	0.265	0.006	0.001	0.000	0.272
Compt. 67, Ulu Besut	1.592	0.008	0.000	0.000	1.601
Compt. 22, Jeranggau	0.272	0.000	0.000	0.000	0.272
Compt. 6, Bukit Bauk	0.220	0.006	0.001	0.000	0.227
Mean	0.474	0.005	0.001	0.000	0.479

CONCLUSION

Much more work needs to be undertaken so as to better understand the structure and regeneration status, as well as the growth and development of logged-over forests. Based on the above data analyses, the following conclusions were drawn. The stocking and basal area of all the eight growth plots in the State of Terengganu showed gradual increment over time after logging, with the dipterocarp group gaining increasing dominance with the number of years after logging.The results also showed a general trend towards the original stand composition in most of the logged-over forests. The most important factor in ensuring sustainable timber production in the future is the retention of sufficient numbers of trees of the desired species groups after logging, particularly for size classes between 30 to 45 cm dbh. In this regard, all the compartments recorded a residual stand containing commercial species of more

than 32 trees/ha having diameter size of 30 cm dbh and higher. The dipterocarp group was found to be growing faster at the higher diameter classes and thus becoming more dominant in terms of size, basal area and volume contribution towards the stand. It is suggested that the Dipterocarp Forest Growth Simulation Model (DIPSIM) be used to assist the Forestry Department in predicting the next harvest for different forest conditions and harvesting regimes by using the growth data obtained from the 96 growth plots established in Peninsular Malaysia. Basically it is an individual tree based model which allows for the simulation of annual growth in terms of stems, basal area and volume and the effect of different harvesting prescriptions to provide support for decisions in yield prediction. Finally, the monitoring of growth and development in logged-over forests is an important activity in ensuring sustainable management of forest resources. Further analysis of the growth data over longer terms is needed to indicate threshold levels for composition, removal and retention for different forest types. This will assist in fine-tuning the currently employed management practices to achieve sustainable forest management.

ACKNOWLEDGEMENTS

The authors would like to thank all the Research Assistants of the Forest Management Unit, Forestry Department Peninsular Malaysia for their assistance in the up-keep and preparation of the measurement data.

REFERENCES

Forestry Department Peninsular Malaysia. 1987. Second National Forest Inventory Peninsular Malaysia Report 1981-1982.

Forestry Department Peninsular Malaysia. 1992. Panduan Kerja Luar Penubuhan Petak Kajian bagi Daerah-daerah Hutan di Semenanjung Malaysia.

Frisco, N., Hassan-Zaki, P., Mohd Hasmadi, I., Jusoff, K. and Ismail Adnan. 2006. Lower Diameter Increment of Hill Dipterocarp Forest at Angsi Forest Reserve, Negeri Sembilan, Malaysia. *The Malaysian Forester* 69(1) : 15-25.

Setje-Eilers, U. 2001. Growth Plot Data Analysis Programme.

Yong, T. K. 1998. Forest Growth and Yield Studies in Peninsular Malaysia. *The Malaysian Forester* 61(3) : 131-176.

CONTENTS

Tables

Figure

ANALYSIS OF GROWTH PLOTS DATA FOR THE STATE OF TERENGGANU

Technical Report No. 8/2007

Prepared by:

Masran Bin Md. Salleh
Yap Yee Hwai
D.Zulkifli Bin Tukiman

Forest Management Unit
Forestry Department Peninsular Malaysia

June 2007